Question 1:

Dear Cheap Astronomy - How do spacecraft star trackers work?

The Rosetta spacecraft, a European Space Agency mission, launched in 2004 on a ten year voyage to study the comet 67P/Churyumov–Gerasimenko – which is a short period comet, taking nearly 6 and a half years to orbit the Sun. Rosetta went into hibernation on 8 June 2011, neither transmitting nor receiving data from Earth while on the outer leg of an elliptical solar orbit where it was very cold and there was not enough sunlight to power its solar panels. But now, it is once again coming back towards the Sun and is due to wake up, at 10am on 20 Jan 2014 after a long 31 month snooze.

Rosetta's Twitter feed has broadcast the message 'still sleeping' every few months since it first opened a Twitter account in 2012 – and after only 8 tweets it gained way more followers than Cheap Astronomy.

But what has all this got to do with star trackers? Well, when Rosetta wakes up the first thing it needs to do is to communicate with Earth, which means it's got to point its receiver at Earth. After 31 months, any orientation it had pre-hibernation has long gone and Earth will be nearly a billion kilometres distant, just one tiny point in big sphere of random radio noise. But fortunately, Rosetta has star-trackers to enable it to first find, and then phone, home.

The first thing Rosetta will do at 10am on the 20th of January, is to orientate itself so that its solar panels face the Sun. This is star-tracking in its most rudimentary sense, since the Sun will be the brightest thing in Rosetta's sky. Indeed, it will be too bright for the actual star-tracking cameras to be of any use – since, if they are pointing towards the Sun, any other stars will be lost in the Sun's glare. The spacecraft will determine that its solar panels are roughly aligned to the Sun by finding a position of optimal power output. This rough alignment will also be sufficient to ensure its star-tracking cameras are pointed away from the Sun before they get to work.

Star-tracking techniques have improved a lot over the fifty years that we've been exploring the Solar System – mainly due to improvements in camera resolution and computer-based pattern-matching. The 1970s-vintage Voyager spacecraft depended upon first finding the Sun and then the bright star Canopus, which although not as bright as Sirius, is near the Southern Celestial Pole and hence always about 90 degrees away from the Sun. Once the Voyagers established the position of the Sun, they would perform a rolling manoeuvre until Canopus appeared in their star trackers' field of view. The Voyagers could find Canopus within four hours or so of finding the Sun and this was enough to re-establish a connection with Earth.

A modern star tracker contains a star map of over 6,000 stars and can guarantee orientating the spacecraft within 60 seconds using a computer algorithm which matches candidate star patterns against whatever field of view it can observe until a known pattern of stars with the right mix of magnitudes is visible within its field of view. Rosetta will then adjust its roll and attitude, using its two main star trackers as sensory feedback, until it is correctly aligned to communicate with Earth.

That's about it really, once it's in touch with Earth again, we can start passing it new commands. Rosetta will go into orbit around comet 67P/Churyumov–Gerasimenko in May

2014 and start looking for a landing site for its 100 kg robotic lander, called Philae. In November 2014, Philae will be released and will latch onto the surface of the comet, spending at least a week analysing the regolith and radar mapping the comet's interior.

And of course, the Philae lander, although passively attached to its hibernating mother ship, also has way more Twitter followers than Cheap Astronomy does.

Question 2:

Dear Cheap Astronomy – I understand solar light sailing, but why can't you sail on the solar wind?

Solar sails are generally designed to sail on sunlight, being the energetic output of photons from the Sun. But there is also a substantial output of subatomic particles from the Sun, mainly in the form of charged electrons, protons and other ions. Surely these particles, which move pretty fast (up to 900 kilometres a second), could be something we can sail on as well?

And yes, it should be possible – although we are yet to see a proof of-concept mission that demonstrates just how possible it really is. But, even if it is possible, solar wind sailing may not offer any real advantage over solar light sailing. In light sailing, the momentum of photons is most effectively used by getting them to reflect off your sail, rather than being absorbed by your sail. A similar principle applies to solar wind particles where, being charged particles, you get the best effect by repelling them away from an electrically-charged sail. However, this is tricky, since solar wind particles are a mixture of positively-charged ions and negatively-charged electrons.

There are magnetic sails, which you can easily create by running a current through a loop of wire. It's not the loop of wire, but the magnetic field it creates that becomes your sail. A magnetic field does not have a charge, but will divert both positively and negatively charged particles in a direction perpendicular to its magnetic field lines. The effect of diverting the trajectory of all those charged particles is an accumulation of equal and opposite forces which then propels your sail forward.

There are also electric sails, which are an array of wires which do maintain a particular charge and hence only repel particles with that same charge. Since ions have a lot more mass, and hence a lot more momentum than electrons, it makes more sense to deploy a positively-charged sail to repel the ions. You actually create a positively-charged electric sail by constantly unloading electrons from your spacecraft via an electron gun or a radioactive beta emitter (like strontium 90).

The advantage of magnetic or electric sails is that you can create huge 'virtual' sails from very low mass wires, while solar light sailing requires a 'real' sail made of a solid, opaque material which hence represents a lot more mass.

However, the electric current that maintains your magnetic sail or the electron emitter that maintains your electric sail both need energy to run them. Gaining that energy may require solar panels or radioactive material which represent extra mass for your spacecraft. It also puts more reliance on technical systems that would end the mission if they failed.

So, coming back to our earlier point, while solar wind sailing is possible, it may not offer any real advantages over solar light sailing, which requires no additional energy input and is technically simpler to manage. Here at Cheap Astronomy we try not to bore our listeners with audio math – which is yet to become a popular medium. So let’s just say it works out that, per unit area, the pressure exerted by the momentum of solar photons is several thousand times that of solar wind particles.

In light sailing, you really do just sail on sunlight and that sunlight represents a more powerful motive force than the solar wind does. What we really need, to understand all this better, is a proof-of-concept mission that will effectively demonstrate whether the solar wind really can float your boat.