Question 1:

Dear Cheap Astronomy – Please offer some examples of gravity-assist maneuvers.

The principle of gravity assist in pretty straightforward. Essentially your spacecraft undertakes a hyperbolic trajectory with respect to a large mass, generally a planet. Hyperbolic means it is going to go into the planets gravitational field with a trajectory and speed that ensures it will also leave the gravitational field – so essentially it dips in and out again. If it's a passive maneuver (no thrusters fired) then someone on the planet would see your spacecraft gain a little acceleration as it enters the gravitational field and then lose it again that upon exiting the gravitational field. So whatever speed you had on approaching the planet is the same speed you'll have upon leaving the planet.

So acceleration due to gravity plays no real part in a gravity assist maneuver – what matters is that during the maneuver you are interacting with a large mass that is itself moving quite fast. So essentially during the maneuver your spacecraft is grabbing on to that fast-moving object for a while and then letting go again. So from someone on the planet's perspective nothing really happens, but from an external observer's perspective the spacecraft's velocity (that is its speed and its direction) changes markedly, where it might not only be sped up but also flung in a totally different direction to where it was going before it interacted with the planet.

So for example, the Cassini mission left Earth with Earth's orbital velocity of about 30km/s, fell towards the Sun and then flew by Venus within an orbital velocity of 35 km/s – the combined effect of which gave the spacecraft a velocity of 40km/s, then it swung out and back again getting another kick from Venus and then flew by Earth to then be flung right out to Jupiter. This was climbing the Sun's gravity well so it only had 10 km/s when it arrived at Jupiter, which has an orbital velocity of a 13 km/s, so only a small speed increase but a useful trajectory change to put it on an intercept course to Saturn.

The Parker solar probe had a different problem to contend with – to get into a close solar orbit it had to slow down, which it managed by positioning itself in front of Venus on a fly by so that the approach of Venus slowed it down. This is probably best explained by the probe actually giving Venus a gravity assist – so as it streaks past Venus briefly grabs on to it and then lets go – speeding itself up by a minute fraction and consequently slowing the spacecraft down. The probe has done six Venus flybys and the 7th was on December 6 2024, which will put it on an orbit with its closest approach to the Sun due on 24 December 2024, when it will be out of contact with Earth so everyone is hanging out to here its beacon tone of 27 December which indicate it survived. It will then stay on that solar orbit for the rest of the mission, so no more Venus flybys.

Despite achieving this narrowed orbit through losing momentum energy, we know from Kepler's Laws that an object in a close orbit actually moves a lot faster than an object in a distant orbit – at least at the periapsis (closest-in part) of its orbit. So, even though the Parker probe has had to repeatedly slow itself down to achieve its close solar orbit, it will from this December 2024 orbit become the fastest ever human-made object – although it actually achieved this fastest-ever status in 2018 – it's just been breaking its own record ever since. So in 2025, it will approach 700,000 kilometres an hour or about 190 km/s or about 0.06% of the speed of light at periapsis. Not too shabby. Although even at that speed it will still take 88 days to do a full orbit of the Sun. which is actually the same orbital period as Mercury, but the Parker Probe is on a much more elliptical orbit where the apoapsis is near Venus orbit and the periapsis is Mercury never gets closer than 46 million km, while at its closest approach, the probe will be just under 7 million km for the Sun's surface.

Question 2:

Dear Cheap Astronomy – What is your response to the Fermi Paradox?

The Fermi Paradox is usually just paraphrased as Where are all the aliens? But the actual paradox involves it seeming inconceivable that we could be the only technologically based civilization around that is able to transmit messages and send spacecraft out from our planet. But at the same time, here we are looking out, and listening out, for signs of anyone else having figured out the secret of banging the rocks together. But, so far, zip.

But before we get too pessimistic, let's consider that to whatever extent we are an example of an advanced civilization, we aren't actually all that noisy. Although we have been broadcasting radio and TV signals for around 100 years now, and hence those signals have spread out for 100 light years in all directions, their signal strength has attenuated over distance by the inverse square law. It's unlikely our current technology would be able to detect our own radio transmissions from just four light years away, say from Proxima Centauri, which is the closest star to our sun. We might manage to detect our very loudest broadcasts, which to date have been in radar rather than radio, but already modern broad frequency radar is much harder to detect than the blaring narrow frequency radar we used in the 20th century. Similarly, our civilisation is becoming increasingly radio quiet as we steadily shift away from radio and TV broadcasting towards cable and fiber-based comms.

So, it seems after a few brief decades of noise, our advancing technology is making us quieter, not louder. So, a simple response to the Fermi Paradox is to assume that we are a good example of an advanced civilization and that currently we would be unable to detect ourselves from any reasonable interstellar distance. And while there could be more technologically advanced civilisations out there, being more technologically advanced doesn't necessarily make you easier to detect.

Mind you, our own technological advancement is going to make us much better listeners. The Square Kilometre Array will give us the capacity to detect signals equivalent to our post-WW2 narrowband radar from several hundred light years away. That's still only a small proportion of the whole Milky Way galaxy, but it will be a big step forward in the search for extraterrestrial intelligence, perhaps a big enough step to put the whole Fermi Paradox to bed once and for all.

As to what we should be listening out for, we can only guess at how many Earth-like planets that may harbour Earth-like civilisations are out there. To date, we've been able to identify Earth-sized planets around red dwarves, but these are not likely candidates for harbouring a complex ecosystem, let alone a technological civilisation. We don't yet have the ability to easily identify the much more likely candidates, which are Earth-sized planets around G-type stars like the Sun. It's thought that out of the several hundred billion stars in our galaxy, there are seven or eight billion G-type stars. And we could say there's up to 27 billion somewhat sun-like stars if we include the adjacent F and K types as well. On that basis, it's speculated that the Milky Way might contain some 50 million Earth analogues. And perhaps another 25 million Pandora analogues, where Pandoras are exomoons orbiting gas giants that are orbiting within their star's habitable zone.

But given everything we've covered in this podcast, perhaps the only way an interstellar conversation is ever going to start is if someone deliberately tries to get themselves noticed. Here at Cheap Astronomy, we feel confident that Earth could start broadcasting *yoohoo over here* messages without the slightest risk of any warmongering aliens warping over here at faster than the speed of light because, you know, physics.

But for anyone to actually hear us from more than 5 or 10 light years out, they would need some very sensitive equipment and they'd probably have to be in line of a beamed transmission we'd sent to have any hope of distinguishing our signals from the routine background noise of the Universe. So, for the moment, since it doesn't look like we'll be sending such a beamed transmission anytime soon, it's likely that any aliens out there are struggling with their own versions of Fermi's paradox.