Question 1:

Dear Cheap Astronomy – Is there anything new on Planet 9?

Well, not really and there is some growing skepticism about whether it's really there. Nonetheless, its original proponents, Mike Brown and Konstantin Batygin, still stick to their guns on the matter, though both agree Planet 9's existence must be considered speculative until it is actually observed. Mike Brown discovered Eris in the inner Kuiper Belt which was probably the key factor in Pluto being downgraded from a planet – hence the title of his book How I killed Pluto and why it had it coming. Konstantin Batygin seems to have been good at math and has done a lot of modelling of orbits and stellar systems and wrote a paper on how stellar disk evolution can be modelled using Schrödinger's wave equation – which could be the subject of a future podcast episode if we can ever get our heads around it.

Anyhow, Brown and Batygin proposed that an observed clustering of orbits of a number of distant Kuiper Belt objects, called ETNO's extreme trans-Neptunian objects, seemed to point a larger body that must have gravitationally herded them into such a cluster. Brown and Batygin then mathematically modelled what kind of mass and orbit that larger body would have to be - and concluded that you'd need an object of around ten Earth masses following its own elliptical orbit that took it around the Sun once every 9,000 years or so. The existence of such a body it did seem to fit well with a lot of known features of the solar system. So, being an intriguing idea that fit and couldn't readily be refuted, Planet 9 settled into the public consciousness as a real possibility.

It's highly unlikely that a planet the size of Planet 9 could form as far out from the Sun as it is – the further out from the Sun you go, the less material is available to accrete together into something as big as a planet. Instead, Brown and Batygin proposed that Planet 9 must have formed somewhere within the current range of the known planets and then been ejected outwards via gravitational perturbations arising from jostling amongst the other planets. This requires some fine tuning whereby a planet was pushed well out of its previous orbit, but not pushed quite hard enough to eject it altogether. This is entirely possible, but it's also fair to say it's a bit unlikely.

However, where most of the growing doubt arises is in regards to the allegedly anomalous cluster of ETNO orbits. Firstly, the cluster can only be considered as unusual as the rest of the Kuiper Belt is not unusual – and we don't have a comprehensive data set on the entirety of the Kuiper Belt. If it turns out there's other unusual clustering we haven't spotted yet are we going to then start hypothesizing there's a Planet 10 – or might we instead acknowledge that our understanding of the Kuiper Belt is a bit naïve and incomplete, noting that much of it still lies beyond our observational range.

It is also likely the ETNO cluster is a result of observational bias, since those ETNO objects have been detected because they are in the perihelions of their orbits – that is, the parts of their orbits where they are close to the Sun and hence observable. There could be a whole bunch of other objects in elliptical orbits that are currently invisible and that we may not observe for hundreds or thousands of years to come, because they are in the aphelion parts of their orbits.

And of course, there are new surveys being undertaken all the time, which are not only not finding Planet 9 but are also not finding any new evidence of its supposed perturbing effects. Nonetheless, it could still be out there. Let's just say there's a growing number of professional astronomers who aren't holding their breath waiting for that to happen.

Question 2:

Dear Cheap Astronomy – Is Nemesis really out there?

Continuing the theme of hypothetical solar system bodies, Nemesis was proposed to be a small, dim and hence difficult to spot companion star of the Sun. Its existence was proposed in 1984 on the basis of a perceived 27 million year cycle in mass extinction events, where anything cyclical gets people thinking about orbits – and with a 27-million-year periodicity, you need a pretty big orbit. Nemesis proponents suggested it and the Sun orbited a common centre of mass and were separated by an average distance of 1.5 light years.

Since then, the various parts of this proposal have been the subject of much debate and also skepticism. For a start there's the premise that the Sun, like most other stars, should have a companion star. We've previously stated in the podcast that there are a lot more stars in binary or other multiple stellar systems than there are single stars. This remains the favoured view for bright stars, where somewhere round a half of bright star stellar systems are solitary stars, but that means the other half of all systems have multiple stars and therefore most bright stars have companions. However, more recent detailed surveys of the harder to spot red dwarves, have found nearly 75% of those are solitary and since red dwarves are about 75% of all stars in the Milky Way and probably the Universe you can't then say that most stars have companions, although it still seems to be the case that most Sun-like stars have companions.

So, after all that we can still say it's possible the Sun could have a companion star, but there's no immediate reason to think that it should or that it does. The claimed periodicity of mass extinction events is also a bit dubious. There are five big agreed-upon mass extinction events over the course of life on Earth and not all of them were asteroid related. The 27-million-year periodicity claim is a popular topic of popular science writers, but it's not obviously a widely held view. Essentially there is a claimed pattern in the fossil record of substantial change every 27.5 million years, but they're not really mass extinctions which are defined as times when you lose 75% of all species within a 2-million-year time period. Indeed, the paper by Rampino, Caldiera and Zhu claims there's a 27-million-year periodicity in geological events, only some of which are extinction events, others are sudden widespread vulcanism, sea level changes and plate shifting. This periodicity could still point to some space-related event – but it seems the mass extinction line has been a little exaggerated in the popular science articles. There are also other options to Nemesis, for example it's been suggested that the alleged 27.5 million cycle may coincide with the solar system periodically passing through the main plane of the Milky Way, where that movement through a greater concentration of stars could perturb the Oort cloud and

send lots of asteroids into the inner solar system. So, in a nutshell, while there may be something periodic going on that has been captured in Earth's geological record, it's certainly not clinching evidence of the existence of Nemesis.

Indeed, critics of the Nemesis hypothesis argue that if Nemesis is there and periodically tossing asteroids our way, it should itself be subject to perturbations from other passing stars, which could potentially knock it out of its tenuous orbit with the Sun or otherwise at least cause some variation in its periodic effects. Moreover, to have such a predictable effect on Earth it must presumably send a huge flood of objects towards the inner Solar System every 27.5 million years, since Earth isn't that big a target but it gets hit every time. And so to have such a substantial effect, surely Nemesis itself must be pretty substantial. But, here we are well into the twenty first century where we do have the technology to detect even a small brown dwarf that's just 1.5 light years away and nup. There's maybe a very faint chance we might have missed it but this is definitely not one to hold your breath for.