Question 1:

Dear Cheap Astronomy – How many near-Earth objects do we need to worry about?

As you are probably aware, the Earth's orbit is an average 1 astronomical unit away from the Sun. The definition of a near-Earth object is any solar system body whose closest approach to the Sun is 1.3 astronomical units. All that matters is that closest approach, the periapsis – so Halley's comet is a near-Earth object, even though for most of its 76 year orbit it's nowhere near Earth or Earth's orbit. Of course, most NEOs are near-Earth asteroids with relatively-circular orbits similar to Earth's. There are over 18,000 near-Earth asteroids that we know about versus just over 100 near-Earth comets.

The near-Earth asteroids we worry most about are the ones that cross the Earth's orbit. These are the Atens group (with about 1,400 known members) and the Apollo group (with about 10,000 known members.

Of course Earth's solar orbit's is pretty big, about 940 million kilometres in circumference, so the probability of the Earth and an Earth-orbit-crossing object being in the same place at the same time isn't very high, but it's not a zero probability either. So, we've assigned the term potentially-hazardous objects of PHOs to the subgroup of near-Earth objects that are over 400 metres in diameter and have the potential to come within about 20 times the distance from the Earth to the Moon during their orbit. Over 1,800 objects currently fit these criteria – which is around 11% of the total near-Earth object population.

A well-known example of a PHO is the 400 metre diametre asteroid Apophis, a member of the Atens group, which was discovered in 2004 and caused some consternation when it was determined to carry a 3% risk of hitting the Earth in 2029. Subsequent refined measurements of its orbit eliminated that risk – but still raised the possibility that its close encounter with Earth in 2029 might shift its orbit so it would then hit Earth in 2036. But yet further refinements suggested that wasn't altogether likely either, so it's now considered just another PHO – with a Torino scale measure of 0.

The Torino scale goes from 0 to 10 where 0 just means an object is either too small to make it to the ground, or it has zero current risk of hitting Earth. A score of 1 is an object of interest, but with a lot of careful wording to avoid anyone thinking there's immediate cause for concern. A score of 2-4 means a close encounter is expected – where 2 is a close encounter with something the size of the 400 metre Apophis and 4 is a close encounter with an object that's a kilometre or more in diameter. A score of 5-7 means it's time to start huddling around the TV awaiting further bulletins, where 5 means someone might die and 7 means we all might die. Then 8 to 10 means a collision is a certainty, where 8 means local destruction from direct impact or a tsunami, 9 means regional devastation and perhaps by a really devastating tsunami and 10 means it's pretty much game over for civilisation as we know it.

The Chixcalub impact which took out the dinosaurs is considered to have been a 10, while the 1908 Tunguska event is considered to have been an 8 because it caused fairly-localised damage. The 2013 Chelyabinsk meteor also caused local damage, but due to the shock wave from it exploding in mid-air, so it's still considered a zero, because it didn't reach the ground intact, even though the airburst broke windows and injured some 1500 people.

So, how many current-known NEOs have a Torino scale above zero? Well, none. So, as far as catastrophic impacts go, there's nothing at all on the horizon – although lost of little gravitational perturbations could add up to all sorts of trouble in the longer term. It is great that we know this and that we're looking out for trouble now. We really are one step ahead of the dinosaurs, even if it is just one small step.

Question 2:

Dear Cheap Astronomy – Does The Goblin change our thinking about the hypothetical Planet 9.

Well, maybe – but it doesn't change our thinking much. On the first of October 2018, the discovery of a new solar system body was announced – called 2015 TG387. The TG is just a catalogue reference, but since it was discovered just after Halloween someone decided that should stand for *The Goblin*. If you heard it was a new dwarf planet – well, no. The International Astronomical Union is in charge of dwarf planet designation and they haven't actually designated any new dwarf planets since the first batch of five was announced back in 2008. So any largish solar system bodies that we've found since just get called minor planets, although there no reason why some of those minor planets couldn't be put in the dwarf planet category. Mind you, here at Cheap Astronomy we think the dwarf planet category is a pretty arbitrary sort of category. After all, what do Ceres and Eres have in common apart from being medium-sized round things that are in belts, that were known about before 2008.

Anyhow, at just 300 kilometres diameter, The Goblin is right on the cusp of how big an icy outer solar system body should be, to be in hydrodynamic equilibrium - that is an object that's adopted a spherical shape as a result of its own self-gravity. So, if the IAU is going to designate any new dwarf planets, it will first need to work through a list of larger objects – like Sedna, for example, which has a diameter of about 1,000 kilometres in diameter. But again, there's been no new dwarf planets announced for ten years now. It makes you wonder if the IAU are just hoping everyone will quietly forget about the whole dwarf thing – which was arguably just a distraction to ease the pain of Pluto's demotion from planethood.

But anyway, there was some genuine news-worthiness to the announcement of The Goblin' s discovery. It is the latest member of a small and specific group of minor planets, which are called sednoids – because, like Sedna, their perihelion is outside the Kuiper belt, at more than 50AU from the Sun. So of course any Sednoids' aphelions, being their most distant orbital point from the Sun, is going to be way, way out. By definition, sednoids have semi-major axes of more than 150 AU – remembering that the semi-major axis is one half of the long axis of an elliptical orbit, which would be equivalent to the radius of a perfectly-circular orbit.

So, all this means that Sednoids have huge orbits and hence have huge orbital periods, with Sedna needing over 11,000 years to do just one single orbit of the Sun. And then The Goblin has the biggest period of all, with a semi major axis of 1,051 AU, which gives it an orbital period of over 34,000 years. This is the largest orbital period of anything that we currently call a minor planet. There are long-period comets that have longer periods, the longest we know about being Comet West, which is thought to have an orbital period of a quarter of a million years – although we've only actually seen it come around once and it did start breaking up on that pass, so who knows what its future is – but we are pretty sure it came from an aphelion of about 1 light year away, which is about where we consider the hypothetical Oort cloud to be.

Of course, another subtext to The Goblin announcement is that it represents another data point to support the Brown / Batygin proposal of a Uranus-sized ninth planet that is out there somewhere perturbing the orbits of many small, known bodies. At the time of the Planet 9 announcement, Cheap Astronomy was concerned that we were trying to build a robust model from a very limited set of data points, which were collected from the very edge of our current observational limits.

So, some are seeing The Goblin's discovery as increasingly the likelihood of us discovering Planet 9. But, from Cheap Astronomy's perspective, discovering The Goblin really just supports our scepticism about the strength of the existing data set since it's likely there's a whole bunch of other objects out there that we just haven't found yet, which could change everything. As usual, the best thing to do is to just wait and watch this space.