**Question 1:**

*Dear Cheap Astronomy – How are asteroids organized?*

The large majority of asteroids in the solar system are in the asteroid belt between mars and Jupiter. There are maybe 1-2 million that are more than a kilometre in diameter and millions more that are smaller than that. Nonetheless there's a huge amount of space between mars and Jupiter so it's nothing like that bit in the Empire strikes back. If you stood one asteroid is unlikely you'd be able to see another one and the odds of successfully navigating it are about one to one.

Inwards from there is one known asteroid orbiting within Venus' orbit and 22 within Earth's orbit. Then there's some with a perihelion (that is the point of their orbit closest to the Sun) that's with Mercury's orbit – called Mercury crossers – and there's Venus crossers – which include all the Mercury crossers as well as more with perihelions that are within Venus orbit, but not Mercury orbit. And then, following the same logic, you have Earth-crossers. These and some close-by Mars crossers all fit in the general category of near-Earth asteroids of which there are just over 2,400 – also including some Earth trojans which follow Earth's orbit at the Sun-Earth L4 and L5 Lagrange points.

Out beyond the asteroid belt are more still mostly within the orbit of Jupiter – and beyond that you get objects that are more ice than rock – so arguably comets rather than asteroids, although they won't develop tails unless their orbit takes them closer to the Sun. Further out you are getting incoming objects from the Kuiper belt and perhaps the Oort cloud and we're less likely to call these objects asteroids - Kuiper Belt Objects is the general term used.

Anyway, all the asteroid groupings we've mentioned are mostly afterthoughts to the asteroid belt objects. Here The large majority are in the asteroid belt, where inner, middle and outer main belt asteroids are positioned by the influence of Jupiter, which creates the Kirkwood gaps between those belts.

Within the asteroid belt are asteroid families mostly clusters of asteroids with similar compositions, which are likely the products earlier collisions between predecessor asteroids. There's 20-30 known named asteroid families and probably the same number yet unnamed. One of the biggest asteroid families of the inner asteroid belt is the Flora family, comprising Flora at over 140 km in diameter, which is thought to be a 60% remnant of a predecessor, with other smaller members of the family being smaller fragments of it. One of those is 965 Gaspra which is about 18 kilometres in diameter and we know what it looks like up close, since the Galileo spacecraft flew by it in 1991. Much of the population of meteorites that land on Earth is thought to originate from the region of the inner belt that the Flora family is in and there's some thinking that debris from the impact that created the Flora family has made its way to Earth in the form of L-chondrite meteorites. There's some thinking is code for 'someone published a paper on int, but it hasn't been widely embraced to date.

There's also thinking that the Flora impact was fairly recent say in the last half billion years, on the basis that Gaspra seemed only lightly cratered. This has prompted a suggestion it might be

the origin of the dinosaur- ending Chicxulub impact on Earth 65 million years ago – and yes OK, all the dinosaurs apart from the birds. This one of a number of hypotheses going around on the origin of the Chicxulub impactor and it's no more or less in favour than the others really. Everyone is pretty settled that the Chicxulub impactor was an asteroid, based on the high Iridium and also Ruthenium associated with both the impact debris spread around Earth, as well as drill cores from the crater itself – and most of that evidence points to the Chicxulub impactor being a carbonaceous chondrite meteor.

**Question 2:**

*Dear Cheap Astronomy – Are primordial black holes dark matter candidates?*

Well yes, though they aren't only candidates around. To recap, a primordial black hole is a hypothetical object which originated in very primordial times – probably within the first second of the Universe. It is somewhat puzzling that when the Big Bang brought lots of mass-generating particles into existence within a very small volume and at an extremely high density, it didn't form a black hole then and there – which would have then been the end of the story. But not only did things with mass suddenly come to be, they were all flung outwards as well – though primarily moving within rapidly expanding spacetime rather than actually being flung. And so here we are.

But within that initial sub-second inflation of the very early universe, it is proposed that there might have been a few ripples and glitches that did result in a few massive particles being sufficiently clumped together to form black holes, but after the first second everything expanded too much for that to remain possible. Potentially these primordial blackholes ranged from the very small to the very large. However, really small ones would have all evaporated through Hawking radiation over the subsequent 14 billion years. So, if there are still primordial black holes around now, there's probably none smaller than tennis ball size, with the mass of a largish asteroid.

There is a theory that primordial black holes were the seeds of what are now supermassive black holes found at the centre of most galaxies, but beyond those all the other black holes we can observe seem to be clearly the result of big stars collapsing under their own mass. So, if primordial black holes are actually dark matter, we need to accept there are an awful lot of tennis ball sized ones floating around undetected, remembering that there's apparently around six times as much dark matter as there is visible matter. Of course, primordial black holes could be bigger than tennis balls and hence be less numerous, but then you have to start wondering why such numerous big black holes aren't occasionally visible insofar they would block out the background star field. So if primordial black holes are a dark matter candidate, they are most-likely tennis ball sized.

A recent paper outlines how some primordial black holes might have colour charge, which is one of those quantum attributes assigned to sub-atomic particles, where colour apparently

relates to how quarks interact with the strong force and colour charge indicates an imbalance between quarks and gluons. if you really want to know. The key point is that if primordial black holes do have colour charge, then that might be detectable. This is what theoreticians do. The current standard model of the Universe says that 26% of it is dark matter, even though no-one has a clue what dark matter is. But if the theoreticians say it might have colour charge, then the boffins who look through telescopes and stuff can start looking for color charge signatures, After all, there could be a Nobel prize in it if they do find those signatures – although there may be a lot less in it if they don't find them.

The paper suggests that most primordial black holes that might possess a net colour charge were probably very small – sub-tennis-ball and hence would have mostly evaporated over the last 14 billion years. But, as is always the case in the Universe, if you look far enough away you are looking back in time, so we could still pick up evidence that they were there back then which might then indicate that a) there really are primordial black holes; and b) they are out there in sufficient quantity to account for dark matter or otherwise a fair proportion of it.

Not sure this is one to hold your breath for, but that's the nature of science, we check out all the possibilities, steadily ruling them out until we're left with one, hopefully right, possibility.