Question 1:

Dear Cheap Astronomy – What is the latest on dark matter?

Well, there's not much new to report here. The nature and composition of dark matter remains unknown, but the likelihood that there is vast amount of non-interacting, invisible and gravity-inducingly material remains high. The compelling evidence for dark matter's existence includes the structure and dynamics of galaxies, large scale gravitational lensing and the cosmic-scale distribution of visible matter – that is, its apparent clumping into a vast web of filaments composed of galactic clusters and super clusters and also interstellar medium – which is just lots of loose dust and gas.

There is a growing view that we've now solved the missing baryon problem – which involved a mismatch between the amount of baryonic matter observed and the amount expected from the Big Bang and subsequent nucleosynthesis of hydrogen into helium and traces of beryllium and lithium in the hot and dense baby Universe. Baryonic matter is essentially anything built up from protons and neutrons – so that includes stars, planets and even black holes - although the majority of baryonic matter is hydrogen ions – that is single protons and molecular hydrogen, that is H2 – which is two protons stuck together, as well as some deuterium, a proton and a neutron stuck together. Anyhow, according to our current understanding of big bang physics, there should be about 40 per cent more baryonic matter than we've been able to observe. However, new measurements of the density of the interstellar medium, is leading us towards thinking there's a lot more interstellar medium than we were initially assuming and so it's looking likely the missing baryons are just a WHIM –warm-hot interstellar medium. Small cosmology joke there.

But anyway, that's mostly just an aside to indicate we are still finding missing stuff out there, so it's way too early to give up on dark matter. It's generally agreed that dark matter is non-baryonic, so not composed of protons and neutrons. Whatever dark matter particles are, they're invisible and transparent at apparently all electromagnetic wavelengths – which also means they neither absorb nor radiate heat. They also are weakly-interactive, so they don't readily bounce off or deflect things, all of which makes them darned difficult to detect. That could be seen as a bit of circular argument. We can't find this stuff anywhere, therefore it must have extraordinary properties that make it undetectable. But something must be exerting the substantial gravitational effects that we see – unless our understanding of how gravity works is way off. There are suggestions that the various galactic and cosmic scale gravitational effects we see are happening, not because of dark matter, but because gravity just works differently on very large scales. While possible, there's no other evidence to suggest that gravity doesn't work in the same way everywhere and on all scales – indeed it would be a huge upset to modern physics and cosmology if it turned out that both Newton's and Einstein's universal theories of gravity weren't actually universal.

And particles that are almost undetectable definitely exist. Neutrinos almost fit the dark matter frame, being invisible and weakly-interactive, but they lack enough collective mass to account for the gravitational effects described above. Also, they seem to zip around, some at close to the speed of light, while dark matter mostly just sits and gravitates.

One of the latest hypothetical particles that ‘could be dark matter’ are axions. There’s no current observational evidence for their existence, but they do fit a gap in the prevailing standard model of particle physics. A number of experiments are underway to verify the existence of axions and once we’ve identified them in a lab or in a particle collider, they should be a lot easier to identify out in the cosmos –assuming they do actually exist. Sometimes we do find hypothetical particles – the Higgs boson for example – and sometimes we don’t.

Question 2:

Dear Cheap Astronomy – Are black holes the source of dark energy?

To give you the full story, someone sent a link to an article that claims that black holes are the source of dark energy, along with their actual question which was 'this is just bollocks isn't it’? And yes, it would seem so. Firstly, to properly unravel the story, we should start by acknowledging that Cheap Astronomy thinks the whole dark energy concept is a bit meh. But leave that all to one side. It is perfectly reasonable to say that dark energy is a cosmological placeholder, where the Universe is clearly undergoing accelerating expansion and we have no idea why, so why not give the unknown cause of it a label, which we'll just call dark energy until we work out what it really is.

Anyhow the recent claim that black holes might be the source of dark energy is based on the concept of cosmological coupling. A good and valid example of cosmological coupling is the clear loss of energy over time in cosmic microwave background photons and the expansion of the Universe over time. Such a correlation does make sense. As the Universe is expanding, the wavelengths of photons do get stretched out and longer wavelengths mean less energy, In the black hole dark energy paper, the authors have presented data from distant supermassive black holes, which they suggest shows an unaccountable increase in mass over time. You might think that's enough of a headline grabber on its own, even without the dark energy stuff added on, although you might also wonder why no-one has ever noticed anything like that before. But anyway, that is the essential premise of this paper - there's been an unaccountable increase in the mass of supermassive black holes over time and we know the Universe has been expanding over time. So, therefore it's cosmological coupling. And they did find a statistically significant correlation between the black holes’ growth and the Universe's growth within some constrained parameters.

So sure, there is a strong case for cosmological coupling, it's just based on the extraordinary claim that black holes are growing in mass for reasons other than just mundane accretion of merging. But let's keep running with this for now. The authors then appeal to the Friedmann equations, which are derivations of Einstein's general field equations, aiming to demonstrate a relationship between the Universe's expansion and the mass-energy contents of the Universe. The Friedmann equations do show that the energy mass contents of the Universe seems to drive the expansion of the Universe up to a point. However, once the Universe gets big, the expansion rate should start slowing down, since its contents has been diluted. But since it didn't slow down, we've started thinking there must be some additional mass energy content being added on. - something we're currently calling dark energy and which we calculate must be about 68% of the current Universe's contents, based on this particular interpretation of the Friedmann equations.

So what the authors of this recent paper are really saying is don't worry about dark energy to explain the additional contents, we've already found it in these growing black holes. The proposed mechanism of mass increase is that the supermassive black holes have been consuming vacuum energy, which apparently also solves the problem of black holes having a singularity at their centre. So there are quite a few hypothetical angles being packaged up here. Of course the idea is that all the mass in the Universe is growing over time is what you'd call an extraordinary claim and the evidence presented for this claim in this one paper doesn't seem extraordinary or immediately compelling.

But OK, if it's really true that all the mass in the Universe was growing over time, then sure you've got yourself a possible explanation of the Universe's acceleration. However, if it isn't true that all the mass in the Universe is increasing over time then you've pretty much got - diddley squat.