Question 1:

Dear Cheap Astronomy – Is dark energy a dead duck?

For the record, here at Cheap Astronomy we've always maintained that dark energy has been taken way too seriously by science communicators. Cosmologists only every intended it to be seen as a black box stamped we don't know what this is. Here at Cheap Astronomy, we don't know what it is either, although on several occasions now we have sought to explain why it probably isn't energy.

Anyhow, an October 2016 paper in *Nature – Scientific Reports* challenges the notion that the Universe is accelerating in its expansion rate, which was first announced in the late 1990s. The authors claim that their analysis of a much larger and more current supernovae Type 1a database indicates the Universe is in fact expanding at a constant rate.

But here, it's also important to distinguish what science communicators are saying versus what the authors are saying. It's certainly not the case that these authors have analysed a new data set that no-one else has paid any attention to for the last two decades. In reality, the entire cosmology community are well aware that the supernovae type 1a dataset has expanded ten-fold since the 1990s. This is, after all, one of the hottest topics in cosmology, given that it wins people Nobel prizes.

What the authors actually did was to analyse a current supernovae type 1a data set, which everyone knows about, in a whole new way, using some different assumptions that aren't routinely applied in this context. Of course, there's absolutely nothing wrong with that and this is often the way that scientific breakthroughs happen – but once you appreciate that context it should have you reaching for your skeptical goggles before reading too much more about this topic.

In a nutshell, it's not the case that the authors use the same statistical analysis used in the 1990s on the bigger dataset that's available today. Instead they apply a different statistical analysis, known as maximum likelihood estimation and got a different result. Maximum likelihood estimation seems a valid-enough method to apply – it's essentially a Bayesian approach that asks if an initial conclusion is still upheld in the face of more current data. But, in doing so, the paper does beg the question as to whether any data trends have actually changed, or whether are we just applying different rules to its analysis.

Nonetheless, it's a good science paper in that it challenges people to reassess the evidence basis of their theories. Whether modern cosmology has been rocked to its core by this paper remains to be seen. In any situation like this, it will take years and maybe even decades for the cosmology community to digest and debate this new perspective – and all the while yet more data will be coming in. So, for an external observer, it's probably best to just wait and see.

As for dark energy – it's no more a dead or a live duck than it's ever been. Really, it was never been meant to provide a substantial explanation of the accelerating universe – it's just a place marker to indicate that there's something going on that we really don't understand. If this paper did turn out to be correct, it would be no more or less mysterious to find the Universe was expanding at a constant rate – indeed if such constancy was ever confirmed it would be quite strange, certainly as strange as acceleration, and it probably wouldn't be long before cosmologists started talking about dark stasis to try and explain it.

So, sometimes it is best to acknowledge that we just don't know everything and go out and get more data.

Question 2:

Dear Cheap Astronomy – We all know that temperature goes down to absolute zero, but is there also an upper limit to temperature?

The idea that there is an 'other end' to the Kelvin scale, where one end is absolute zero is a theoretical possibility rather than a measured phenomenon. Nonetheless, this theoretical temperature point, known as absolute hot, is mathematically-quantifiable, being 1.417×10^{32} kelvin – which is pretty darn hot. This theoretical temperature is also known as Planck's temperature and is also sometimes called absolute 1 – by postulating a magnitude scale where all possible temperatures lie between zero (that is, 0 Kelvin) and 1 (that is, 1.417×10^{32} kelvin). It's called 1 to represent unity in a quantum theory kind of way.

Theoretically, at Planck's temperature, absolute 1, all the fundamental forces achieve unity and there ceases to be any meaningful distinction between quarks (fundamental matter particles) and bosons (fundamental force particles) at this temperature. Indeed, quantum cosmology proposes that this is how things were at the start of the Big Bang.

Max Planck, generally considered the father of quantum physics, proposed fairly convincingly that nothing in the Universe can be infinitely sub-divided. So, measureable phenomena have fundamental limits, most of which can be mathematically-derived even if they can't be directly observed. For example, the hotter things are the higher the frequency of radiation they emit, and something with an absolute hot temperature of 1.417×10^{32} kelvin is thought to emit radiation with a wavelength of one Planck length, where a Planck length is the theoretically shortest possible distance that there can be.

Needless to say a Planck length is pretty darned short, about 10 to the minus 20th the width of a proton. It's perhaps not surprising to find that the hottest possible temperature is associated with radiation of the shortest possible wavelength and hence the highest possible energy level. For the most part, this just demonstrates the internal consistency of quantum physics and we are unable to measure these absolute quantities in a laboratory to confirm if any of this is really true.

The link between absolute hot and the Big Bang is also easy enough to explain, although it is also an entirely hypothetical concept. Consider that the only way to maintain absolute hot is in an isolated system that is uniformly hot – because if there's a cold spot anywhere, heat is going to dissipate towards that cold spot in accordance with the second law of thermodynamics. It's also logical to assume that electromagnetic radiation with the shortest possible wavelength can only remain that way in an isolated system that doesn't expand. Any expansion will stretch out the wavelength of that radiation and cool the system, even if the system continues to maintain a uniform temperature throughout.

All that thinking fits with the idea that the very early Universe was uniformly and absolutely hot, but then ceased to be so as soon as the Universe began to expand – and the sudden non-uniform disequilibrium of temperatures within that very early Universe was accompanied by the differentiation of its previously uniform contents into quarks and bosons and later into matter and light.

And, again stressing this is all totally theoretical and untested, there’s something fundamentally-entropic in all this. At the Planck temperature, absolute 1, absolute hot, everything is uniform – and at absolute zero, absolute cold, everything is also uniform. But, there’s a huge difference between those two conditions. If you let the clock run from Planck temperature then a Universe will expand and cool. But, if you let the clock run from absolute zero, then…. nothing happens – and nothing keeps on happening regardless of how long you run that clock.

Again, this all just theory and there’s plenty of theoreticians out there who would dispute everything that we’ve just said. But a temperature of absolute hot does seem to be a plausible possibility and it might really turn out to be 1.417 x 10^{32} kelvin.