Question 1:

Dear Cheap Astronomy – Do all Type 1a supernovae really explode in exactly the same way?

The story goes that in a binary star system, one star may grow old first, dwindling into a compact white dwarf while the other star is still going through its red giant phase. Matter from the expanding red giant is drawn down onto the compact white dwarf. That extra mass from the adjacent star generates internal pressures and temperatures within the white dwarf that are sufficient to initiate carbon fusion within its core.

The very compact nature of white dwarfs, where a teaspoon of matter has about a metric ton of mass, means that raising the dwarf star's total mass to only 1.44 times the mass of our Sun – that is, 1.44 solar masses – is enough to initiate carbon fusion, something that usually only takes place in much more massive stars. Unfortunately, the small white dwarf is unable to contain the colossal amount of energy that is released by carbon fusion. So, within just a few seconds of carbon fusion initiation, the white dwarf blows itself to bits as a Type 1a supernova.

Of course, Type 1a supernovae are only one type of supernovae – there are also Type 1bs, Type 1cs and Type 2s. So, just how do we pick out Type 1as from all the other random supernovae that regularly flash across the Universe?

The answer is that Type 1a supernovae have an easily-recognisable pattern of spectral lines. Because they were white dwarves prior to exploding, the contents of the explosion will have almost no hydrogen or helium, but will have a very particular mix of other heavier elements.

On this basis, it's actually quite easy to identify a Type 1a – and, having identified one, you can then measure its brightness to get a relative distance estimate for it. Indeed, since Type 1a supernovae can briefly outshine the luminosity of the galaxies that contain them, you can readily get a distance estimate of different galaxies. Furthermore, you can measure the red-shift of a Type 1a's spectral lines to estimate the expansion rate of the universe at that particular distance – and, on that basis, discover that our Universe has an accelerating expansion rate.

But of course there are a few caveats. Dig into the remarkable consistency of Type 1as and you do find some underlying noise. For example, we know that Type 1as in spiral galaxies are generally brighter than Type 1as in elliptical galaxies. There is also uncertainty about how Type 1as form. While the classic binary star formation model is plausible, it's never been observed – nor have we ever found the smoking remains of a second donor star after a Type 1a supernovae has detonated. We now think that many supernovae Type 1as result from two white dwarves merging and exploding when their combined mass exceeds 1.44 solar masses. But, this is a bit troublesome, since the combined mass of the two stars could exceed 1.44 solar masses by quite a margin, meaning that the resulting supernova could be brighter by quite a margin.

In fact, our modern view of Type 1a supernovae is that none of them can be assumed to explode in exactly the same way. They do all have very similar spectral lines and they do all have somewhat similar light curves. Making them into standard candles involves a statistical adjustment that normalises Type 1a data to an arbitrary standard, which represents our best estimate of how bright they would have been be if they did all explode in exactly the same way – even though they probably don't.

So, it's these statistically-adjusted figures that are our real distance markers. We regularly recalibrate these estimates as new data and new explosions become available to us – and we regularly double-check all these assumptions against other distance measures that have nothing to do with type 1a supernovae – Cepheid variables, galactic red-shift measures and so on. To date everything seems to match up pretty well and it looks as though the Universe really is expanding faster and faster – even though Type 1a supernovae might not explode in exactly the same way.

Question 2:

Dear Cheap Astronomy – what's the deal with dwarf spheroidal galaxies?

Right now, dwarf spheroidal galaxies are kind of a big deal. The mere mention of dwarf spheroidal galaxies can create a sudden hush in a crowded room and turn a polite conversation into a heated debate.

We have known about dwarf spheroidals for a long time. They contain mostly old stars with little free gas or new star formation. This makes them faint and difficult to observe and for these reasons we used to think that they weren't all that interesting and that there weren't all that many of them out there.

All this changed when some recent high-tech sky surveys began finding a lot more of them. Varying numbers of dwarf spheroidals have now been found loosely bound to all the nearby large galaxies, which comprise what we call the Local Group.

Indeed, although most are too small and too far away to be observed directly, we now think that one or more dwarf spheroidals are associated with all the large galaxies in the Universe. If we are right about this, then dwarf spheroidals are actually the most common type of galaxy in the Universe.

But that's not all. As well as this sudden realisation of their ubiquity, we have also realised that dwarf spheroidals have a surprising tenacity. Despite orbiting, or at least closely associating with, much larger galaxies, the ones that we can see seem to have little difficulty in staying spheroidal, despite the powerful gravitational stretching that must be acting on them.

Since dwarf spheroidals have generally less than a billion stars, and no other visible matter to speak of, they shouldn't really be able to generate enough gravity to stay spheroidal under such conditions.

Of course the answer to this seeming-conundrum is dark matter, which if you do the math, appears to be present in high concentrations in dwarf spheroidal galaxies. This makes dwarf spheroidals quite unlike their smaller cousins, globular clusters, which maintain their spheroidal geometry just by virtue of being composed of lots of closely-packed stars. If you do the math on globular clusters, you find that they need hardly any dark matter.

So, to answer your question, the deal with dwarf spheroidal galaxies is that we have just now realised how surprisingly common they are and we have just now realised that they are compact and readily-observable dark matter laboratories, which may offer our best chance yet to figure out just what the heck dark matter is.

It may be that dwarf spheroidal galaxies represent one of those, huh? that’s funny… moments that have preceded many of the major scientific discoveries in human history. But for now, it’s still just a case of… maybe.