Question 1:

Dear Cheap Astronomy – What's all the current fuss about dark energy?

Some preliminary data from the Dark Energy Spectroscopic Instrument, also known as DESI has resulted in a swath of popular science articles claiming dark energy is diminishing. Well… It's worth starting by saying that many of the core project team have stressed it's just the first data release – there'll be at least four more, so everyone should probably just chill a bit until more data is available.

It's important to appreciate that no-one can actually measure dark energy, since no-one knows what it is, so what DESI and other projects actually measure is the universe's expansion rate over time. This is largely achieved by looking at the recession velocities of close galaxies which are of a fairly contemporary age and also distant galaxies, which we observe from much earlier eras of the Universe's lifetime. So a huge discovery in 1998 was that closer contemporary galaxies were moving faster than those older distant ones and hence the expansion rate of the Universe must be accelerating over time.

DESI is really a sky survey providing data to measure the recessional velocities of different galaxies and in that respect the data is apparently quite consistent with expectations predicted by our current favoured Standard Model of Cosmology – the Lambda Cold-Dark Matter model, often called Lambda CDM. What's put the cat amongst the pigeons is a paper on BAO, standing for Baryonic Acoustic Oscillations, which arose in the very early Universe when it was dense enough to relay sound and those sound waves have left an imprint on the cosmic microwave background of the subsequently expanded Universe. So BAOs offer another way to estimate the expansion rate of the universe, by looking at density distributions of galactic clusters than can be linked back to those original BAOs.

And maybe there's the rub. It's a different way of measuring the universe's expansion over time – and it's the first data that's come from DESI, so there's two reasons to wait and see – it's a different measurement procedure and it's the first data out from this new instrument. So, let's wait and see.

Some of the commentary around the DESI findings focuses on Lambda rather than dark energy, where Lambda is the cosmological constant within Einstein's general relativity field equations. It is a constant in principle but different values can be assigned to it to fit different cosmological models. The idea is that it measures the tendency of spacetime to expand, which in our current Universe is countered by matter – but primarily dark matter – hence the Lambda Cold-Dark Matter model, where lambda does the expanding, while a CDM counters that with gravity, where dark matter is about 80% of all matter and calling it cold means it's not fast-moving, like neutrinos for example. Here Lambda essentially represents spacetime's natural tendency to expand. It can be expressed in integer units of length or in energy density per unit volume – and the latter is where we can say it's interchangeable with dark energy.

It is a bit of a problem if dark energy does turn out to be diminishing. It implies spacetime is somehow running out of puff or otherwise whatever mysterious dark force is driving it to expand is fading away. Both ideas are a bit strange, notwithstanding we are talking about something that's totally mysterious anyway. So, a likely scenario is that subsequent data analyses will show it wasn't really anything and we are just left with the ongoing mystery of what dark energy actually is. Otherwise, as some excited journalists have suggested, we would have to reconsider the whole Lambda CDM model – potentially to come up with something even more bizarrely inexplicable.

Question 2:

Dear Cheap Astronomy – Why do eclipse paths run in different directions?

Yes folks, it's that rare event when we actually answer an astronomy question. So, solar eclipses. As you know, the Earth's rotation makes the Sun appear to cross the Earth's daytime sky following a line we call the ecliptic. And yep, that's no coincidence, but we'll get to that. The ecliptic is not a fixed path because of the Earth's tilted axis of rotation. So as the Earth progresses in its orbit around the Sun, from the Earth's surface at the equinoxes, the Sun appears to be overhead at the equator, but for the rest of the year it's either shifting north towards the Tropic of Cancer or south towards the Tropic of Capricorn.

And then we have to consider the Moon. It orbits the Earth once every 29.5 days. If we are watching it from the Earth's surface, when it's on the far side of the Earth, away from the Sun, we see the Moon's face fully lit by the Sun. In other words, it's a full Moon. Then nearly 15 days later, it will be on the other side of its orbit, on the side of the Earth nearer the Sun. So when we look at it from the ground, none of its face is lit. In other words, it's a new Moon.

Now you might think the Moon should orbit the Earth's equator, but actually its orbit is more in line with the Sun. That is, its orbital plane around the Earth is only about 5 degrees off the Earth's orbital plane around the Sun. So, in terms of lines in our sky, the Moon's path is only tilted 5 degrees off the Sun's path, that is, the ecliptic. So as the Moon orbits the Earth, sometimes it will be a bit north of the ecliptic, and sometimes a bit south, and two times in its orbit it will cross the ecliptic.

So, bringing all that together, you'll get a solar eclipse when there's a new Moon at the same time that the moon's path in our sky crosses the Sun's ecliptic. There's a new Moon almost every 30 days, and the moon crosses the ecliptic twice in that almost 30 days. But those different events don't coincide very often. This is mostly because the Moon's orbit precesses, so it won't cross the same points of the ecliptic each time. It shifts a bit each time. Indeed, it will take the Moon about nine years to come back to the exact same ecliptic crossing points. However, that nine years doesn't matter so much because there's yet another factor at play. The orbital position of the Earth around the Sun is always shifting a bit, which means the Sun won't be in the same place in the sky each time the Moon crosses the ecliptic. It shifts a bit too.

Nonetheless, despite all these various motions and shiftings, you do get the necessary lineup for a solar eclipse about every six months. but that includes partial and annular eclipses. A partial eclipse being when the lineup isn't exact enough for there to be a total solar eclipse visible anywhere on the Earth's surface. And an annular eclipse is when the lineup is exact enough, but the Moon is towards the apogee of its orbit. So, it's a bit farther away from the Earth, and hence smaller in the sky, and hence not quite big enough to cover the whole of the Sun's disk. A total solar eclipse is only really total from a particular vantage point on the Earth's surface. It will just be a partial eclipse when viewed from other places. Such a total solar eclipse happens once every 18 months on average. On average means it might be as little as a year or as much as three years between two total solar eclipses, but it does work out to be 18 months on average. Total solar eclipses might not seem to happen this often because some happen over oceans or the poles or over deserts and they just don't make the news.

The direction of the path of totality for different eclipses depends on the direction of the Sun's apparent motion in the sky, but also the direction from which the Moon is approaching as it passes in front of the Sun. For example, if the Sun is overhead at a high latitude and the Moon approaches it from a longitudinal orientation, the path of totality could cross over one of the poles. While if the Sun is at a lower latitude and the Moon approaches it from a more latitudinal orientation, the path of totality could cross the equator. Paths of totality generally curve diagonally to lines of latitude and longitude, due to the Earth's tilted axis of rotation. They might trend from low latitudes up towards the poles, or from high latitudes down towards the equator. The actual pattern seen is partly a consequence of the time of year and also the time of day. So, total solar eclipses are awe-inspiring lifetime events, but they are based on very predictable geometries.