Question 1:

Dear Cheap Astronomy – Just how good is our planetary defence?

Planetary Defence is a genuine thing these days, where for example NASA has a Planetary Defence Coordination Office. According to the PDCO no known asteroid larger than 140 meters that has a significant chance of impacting Earth for the next 100 years. However, the key word there is 'known'. They also note that, as of December 2024, there are 36,765 known near-Earth asteroids over 1 kilometre in diameter and it's estimated there might be another 50 yet to be found.

Anything over 1 kilometre is getting into mass-extinction territory, where the Chicxcalub non-avian dinosaur ending asteroid is thought to have been about 10 kilometers in diameter. We've previously estimated that such large impacts could happen every 50 to 100 million years ago – and hence thought another might be due around now – but that modelling has since been refined and we think the frequency of these large impacts is more like every 250 to 500 million years. So there's some reason to feel a bit safer, although if we did spot one on a collision course tomorrow that would just be statistically unlikely, not impossible. All this thinking is based on averages – where we are assessing the record of known impacts on Earth and the Moon to determine expected frequencies in the future.

Anyway, we are now tracking the large majority of asteroids that could potentially wipe us out and none of them look like they are going to for the next hundred years of so. That's good, although there's still some unknowns. As the PDCO noted, it's likely there are still a small number of killer asteroids that could suddenly appear out of nowhere. This might because they have low albedos or are on unusual orbits, so we just haven't spotted them yet. And there are also comets to worry about, objects with orbits out past the frost line near Jupiter's orbit, which are hence either covered or composed of ices that begin to melt off into a tail as they approach the Sun. We know about and are tracking a lot of short period comets, but we'll still be likely surprised by some long period comets, we haven't been aware of previously. Some do have nuclei bigger than a kilometre

So, it's best to never feel completely safe. NASA's PDCO coordinates US planetary defense efforts with space agencies of other nations through the International Asteroid Warning Network , a bunch of observatories around the world and the Space Mission Planning Advisory Group, a bunch of bureaucrats, some of whom are associated with the European Space Agency. The Warning Network keeps an eye out and collects data, while the Mission Planning Group makes plans for what to do in the event of an impending impact. These plans involve international coordination to establish agreed protocols and procedures to follow in the event of observing an object on a high risk trajectory.

Assuming things get serious enough to require deflection of an object's path, there are options, at least on paper. The kinetic deflection option seems the favoured approach at the moment, perhaps partly due to the success of the DART mission in 2022, which adjusted the trajectory of the 180 m asteroid moon Dimorphus with a kinetic impact, that is by crashing into it. The mission planning group oversee regular scenario building, their latest being the subject of discussion at the annual Planetary Defence Conference. Their 2024 scenario involved discovery of an 150 m asteroid heading our way with a possible impact in 2041, which was likely to airburst above the ground over Africa resulting in casualties anywhere up to one million. The NASA/JPL Near-Earth Object Deflection App, was then used to calculate that sufficient delta V to avoid a collision with Earth could be enabled by launching a spacecraft able to deliver 600 kg to the asteroid and then impact it at about 8 km/sec. What we do if a kilometre-plus monster is heading our way is another question, but for now we have time and technological development on our side.

Question 2:

Dear Cheap Astronomy – What do you make of timescape cosmology?

Timescape cosmology is built on the idea that time runs differently in different parts of the Universe. According to general relativity, clocks will run slower in areas with high mass-energy density and gravity than clocks out in empty voids. This is undoubtedly correct given the very robust testing of general relativity that we've done in laboratories, spacecraft and through astronomical observations. So although we never have put a clock in a great void of the Universe, it's safe to say that measurements would show it running faster than a clock in the Milky Way.

How much faster and what the implications of that difference may be are the key issues here. It's been claimed the difference in the clock rate in great voids compared to the clock rate in galactic clusters could be as much as 35%, which is remarkable if not extraordinary. It may be safer just to say there will be a difference, but how big that difference is can only currently be determined from mathematical modelling, the accuracy of which depends on the data you have to model with. But for now, let's go with the possibility that it could be as much as 35%.

Now consider cumulative time over the history of the Universe. When the Universe was young and dense, clocks would have run the same everywhere, but with ongoing expansion creating a cosmic web of dense galactic clusters separated by great empty voids, clocks have been running faster across a growing proportion of the Universe, since a growing proportion of our expanding Universe over time is empty voids. From there, you have to appeal to a lot of complex mathematical modelling, out of which Timescape proponents claim that the clock rate differential is enough to explain the Type 1a supernovae data that underlies the late twentieth century conclusion that Universe's expansion is accelerating.

So, while all the data we are receiving on or near Earth does indicate the Universe's expansion is accelerating, we need to stop and consider that the data is coming to us from different relativistic frames. Imagine a relativistic thought experiment where you are in the Milky Way and your twin is in a great void. An external observer would say your twin in the void is ageing faster than you are, but neither you nor your twin would have any local perception of ageing faster or slower. Things measure differently when you make an observation from one relativistic frame into a different relativistic frame. So, if the Universe is only measurably accelerating because those measurements are relativistic rather than absolute, then Timescape proponents claim you might not need to appeal to dark energy as the driving force behind the acceleration.

Conceptually, the idea of Timescape is intriguing. At the same time, it's unlikely the Nobel prize winning calibre people behind the existing standard model of cosmology had just never thought of this angle before. The current enthusiasm for Timescape in the science blog community largely arises from a 2024 paper, so it may just be that no-one in the specialist cosmology community has had the time or inclination to find holes in the paper's findings and publish an alternate view.

There is an existing problem in current cosmology anyway, where we can't reconcile the supernova data against observations of the cosmic microwave background – where the two data sources give different expansion rates, the so-called Hubble Tension that we've covered in previous episodes. Timescape proponents are yet to show that they can explain away the cosmic microwave background evidence for accelerating expansion. So, for now it's best just to watch this space… and time.