Question 1:

Dear Cheap Astronomy – Why do further way galaxies moving faster mean the Universe is expanding?

It is all a lot to take in – not only is farther away stuff moving faster, also the Universe is expanding faster now than it was in the past and there's standard candles and red-shift and much room for confusion.

So let's start with Hubble. He was into Cepheid variables, which are a type of standard candle. Any variable star varies in brightness, generally appearing to pulsate. What became clear with Cepheid variables was a direct relationship between their pulse rate and their intrinsic brightness – that is how bright they really are up close. Thanks to Henrietta Swan-Leavitt for that. So, this means you can observe a Cepheid variable measure it's pulse rate and hence know how bright it would be up close. There a lot of them just within our own galaxy – so once you've observed a few you can build up a database of them. Then you can observe a Cepheid variable anywhere, determine its pulse rate and immediately know what's it's intrinsic brightness should be – so a dim one must be further away than a bright one is and by comparing with brightnesses of Cepheid variables of known distances you can calculate just how far away the new one you've observed must be.

Hubble, who had access to the world's most powerful telescope at the time, the Hooker telescope at Mt Wilson Observatory 1:47, was able to measure the pulse rate of Cepheid variables in what was then called the Andromeda nebulae to determine it was freakin' way outside the Milky Way and hence must be a galaxy in its own right. Hubble also made similar observations of other nebula/galaxies confirming that the Universe was freaking way bigger than people had been presuming previously.

Hubble also measured the redshift of these distant galaxies based on Vesto Slipher's work – who had established the relationship between redshift and the recessional velocity of different objects – that is how fast they are moving away from us. Hubble demonstrated there was a rough correlation between the distance of different galaxies and their redshift – hence establishing the principle that farther away stuff is moving from us faster than close stuff. Hubble's correlation was pretty wonky, but was later shored up by subsequent observations with better telescopes. It turned out the very distant objects motion is largely due to universal expansion, while closer objects motions are more variable due to their own motion in directions other than just straight outwards.

But anyway, the objective of this podcast is to explain why farther away stuff moving away faster than closer stuff moves away is clinching proof that the Universe must be expanding. So, imagine a set of dots set one metre apart on a straight line in a Universe that expands at one metre a minute. If you are on one dot, the next dot along will expand away from you one metre in one minute, but the next dot along after that will expand away from you that one metre plus another metre in one minute and the next dot after that will expand three metres in that same one minute. So far away things moving away faster really is clinching proof that the Universe is expanding.

The next step to concluding that the Universe's expansion rate is actually increasing arose from observations of type 1 supernovae in very distant galaxies in the late 1990s, where type 1as always explode with the same brightness and are therefore standard candles. It was found that supernovae in galaxies with very high redshifts were dimmer than they should have been if expansion had been happening at a constant rate. So, although there is a close correlation between distance (measured by the brightness of your standard candles and recessional velocity (measured by red shift) – we find that very distant objects are actually farther away than would be expected if the Universe's expansion rate had been constant and therefore we concluded the Universe's expansion rate wasn't constant but was instead increasing over time. And so, here we are.

Question 2:

Dear Cheap Astronomy – Is there such a thing as a dead planet?

To start with it's probably unreasonably biocentric to define spherical objects that orbit the Sun and have cleared their orbits, as either alive or dead. We can redefine the question in terms of being geologically-active or not, but there it gets difficult to draw a line between what's active and what isn't. For example, the Moon, which is widely regarded as geologically inactive has detectable ground tremors – some are just asteroid impacts, others just surface heating and cooling, but some are from geological activity deep below

The terminology in this area is a bit fraught. It's largely settled now that geology is a universal term to describe the structural dynamics of rocky objects. There's also a view that earthquakes should be a universal term, though it's unclear if that will stick. Ground quakes and ground tremors are Cheap Astronomy's suggestion. There's also a terminology bias towards rocky objects since no-one applies the term geology to ice and gas giants, nor are they considered alive or dead despite the ice and gas giants being vastly more dynamic than any rocky planets. A gas giantologist would probably smirk at the thought that a big chunk of rock was somehow more alive than their favoured subject matter.

Of course the elephant in the room in any discussion of the relative animation of celestial bodies is life and that includes elephants. Surely the best definition of a live planet is one that has life. And since we have only one example, we generally associate any aspects of life with that one example. So, a living planet is rocky, with a dense atmosphere and liquid water and plate tectonics and some, but not too many, volcanoes. You also need a magnetic field to divert stellar wind from your local star. So, although Venus is plenty active in a geological sense, it barely spins (where its day is longer than its year) and so its magnetic field is negligible and so its atmosphere is just the product of its own geological outgassing, principally CO_2, with all the good stuff we're so fond of on Earth – notably nitrogen and water having been blown away in the solar wind.

So, having a molten iron core might seem like geological living, but it's not necessarily a ticket to biological living. Indeed, current thinking is that molten cores are more the norm that the exception. Early thinking had it that smaller bodies like the Moon, Mercury and Mars had cooled to the point where their cores have gone solid, but in fact we are now pretty sure all of them are much like Earth in having a solid inner core, surrounded by an outer liquid core. This comes from direct measurement of ground tremors in the case of the Earth, the Moon and Mars and indirect evidence for Mercury where subtle movements in its orbit suggest its innards are sloshing around a bit.

So current thinking is that to have a powerful magnetic field you not only need a molten core and spin, but you also need convection with the fluid layer, where hot fluid rises from beneath, cools and then sinks back down again, creating a steadily circling motion. Current thinking is it's this plus the planet's spin that's gives you a strong magnetic field – so Earth has both, Venus only has the convection and Mars only has the spin. The reason why Earth and Venus have convection and also volcanoes, while Mars , Mercury and the Moon do not, is probably related to size. All these bodies have enough mass that inward compression due to gravity heats up their cores. While the central core is the hottest part, it's also the most compressed part and so remains solid, so it's only the outer core that is able to exist as a molten fluid. With Earth and Venus their hotter centres and their greater diameters may create the right conditions for steady circular convection currents.

It's apparent from Mars rock samples that Mars did have a strong magnetic field in its early years, but it went away, presumably because the core cooled beyond a point that could drive circling convection. But with all this, it's best to say it's just current thinking. Our understanding of how planetary magnetic fields are generated is still a work in progress and our determination of which planets are alive or dead is just a matter of opinion.