Question 1:

Dear Cheap Astronomy – What's all the fuss about Venus.

In June 2021, NASA announced two new Venus missions, Veritas (Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy) which is expected to happen in 2028 and DAVINCI+ (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging, Plus) which is expected in 2029 or 2030. There's also a recently confirmed ESA mission EnVision, planned for the early 2030s. The launch dates are all a bit speculative at this point as none of these spacecraft have been built yet.

DAVINCI+ includes an orbiter and a lander that will bring back direct images from the surface, which we haven't seen since the Soviet Venera 13 lander in 1981. Like all the Soviet landers, it not expected the DAVINCI+ lander will last more than about twenty minutes under the gruelling surface conditions, but that's long enough to get some good shots. Apart from that headline grabber, the primary science goals of DAVINCI+ are to investigate Venus's atmosphere. The lander will analyse the atmosphere on its way down to the surface, while the orbiter scans the atmosphere from above.

Veritas, although also an orbiter, will mostly investigate Venus' geology, using radar and near-infrared emission detectors to map the surface. This global mapping will be an update and enhancement to the radar mapping the Magellan mission undertook between 1989 and 1994. It's expected that VERITAS will enhance our understanding of vulcanology and other geological processes on Venus, as well as look for evidence of past water on the planet and maybe even find traces of current water vapour. These objectives seem optimistic if current thinking, that the planet is regularly resurfaced by molten volcanic outputs is true, but properly investigating such possibilities can't hurt. The mission will also try to confirm whether or not Venus has plate tectonics. The mission may just confirm that Venus doesn't have plate tectonics – but there's no harm looking and it's not like we are never wrong in our assumptions. And either way, the investigation may help us better understand how and why plate tectonics work on Earth. Since the only other rocky planets we know much about are Earth and Mars – and Mars is pretty much inactive geologically, Venus is a good place to look for useful insights into how planets, including Earth, work.

And why the suddenly flurry of Venus missions? Well, no-one's saying it's because of the recent announcement of phosphine in Venus' atmosphere, perhaps because the finding remains hotly disputed, as does the suggestion that any phosphine that is there may be a by-product of Venusian life. There is a real risk that this whole line of thinking could collapse well before the mission's launch, so it makes sense not to make it a key goal of any mission. Nonetheless, it is likely that NASA and ESA will gather more data on the presence of phosphine in the atmosphere and its possible origins. Other reasons why it's worth studying Venus include a growing interest in better understanding its extreme greenhouse atmosphere, since we are in the process of growing our own one on a small scale here on Earth. And who knows, we may well find some other weird thing that no-one was ever expecting to find – which is part of the point of exploration.

These new Venus missions have actually been in the pipeline for years, for example there had been a DAVINCI mission idea around for years, which then got revised and enhanced into DAVINCI+ which then waited in the queue for a few more years. There is always a queue of possible mission projects with only one or two generally getting funding committed in each budget cycle. So, maybe the phosphine thing pushed these planned missions up the queue a bit or maybe their time had just come. In NASA's case, it has been hitting Mars pretty hard, while leaving Venus to be further explored by other agencies like JAXA and the ESA. With lots of countries now with Mars orbiters and with China now having a rover on the surface, maybe NASA was thinking it's time to do something a bit different.

Question 2:

Dear Cheap Astronomy – Can our Mars-bound astronauts survive years of exposure to space radiation

Well yes, they can potentially, but solutions are yet to be agreed upon, let alone implemented. A radiation shielding solution for a Mars-bound spacecraft, is either going to add a lot of mass if it's physical shield or draw a lot of power and still add some mass if it's a magnetic shield. You also need solutions for extra vehicular activities, that is space suit shielding. Various potential solutions are found in academic journals and white papers and various options are being tested in laboratories, including on board the International Space Station. This is all good stuff, but we still haven't really decided what option we'll use for the long journey to Mars, which will supposedly happen in the 2030s.

When people talk about space radiation they generally don't mean electromagnetic radiation, although x and gamma rays radiating from the Sun are also harmful forms of radiation. What they do mean is cosmic rays, which are either high energy protons or more complex nuclei which have been stripped of the electrons they would normally carry as a cooler stable atom. Within the solar system you get cosmic rays coming out from the Sun, as solar wind and you get galactic cosmic rays coming in from outside. While the cosmic rays from the Sun are high energy, galactic cosmic rays are really high energy, mostly flung out from supernovae bursts, which then travel for many light years at close to the speed of light until they reach us.

A unmodified spacecraft hull is generally sufficient to protect astronauts from routine levels of solar wind particles, as well as the x and gamma rays emanating for the Sun. However, should there a big solar flare that hurls out a denser burst of particles at higher speed you're in trouble. A cosmic ray particle with enough energy can penetrate and ionize atoms in the ship's hull which then creates a burst of secondary radiation, essentially subatomic shrapnel, which proceeds inwards towards the astronauts. Galactic cosmic rays are more likely to cause this kind of damage as they move at much higher speed than solar wind particles and while galactic cosmic rays are mostly protons they also include heavier ionized nuclei, anything up to uranium. A heavier nucleus than a proton moving at high speed will have more kinetic energy than a proton moving at the same speed.

The damage caused by cosmic rays is analogous to the various forms of radiation exposure we are familiar with on Earth, where the damage caused may involve DNA damage leading to cancer or more direct and immediate tissue damage.

The exposure risk starts mounting when you leave the Earth's atmosphere at 100 kilometres altitude, since even air molecules create a small degree of shielding. Once you are above the Earth’s magnetosphere you are in what is essentially interplanetary space, where there is a dynamic balance between the outgoing cosmic rays of the solar wind and the incoming galactic cosmic rays. This balance changes with the solar cycle – at solar maxima there is greater output of solar wind which reduces how many of the more harmful galactic cosmic ray particles can get through. So there’s an argument that it might be safer flying to Mars during a solar maxima, although during a solar maxima you are also going to get more solar flares and coronal mass ejections. While these particles may be less harmful than the galactic ones, after a big solar flare there will be a whole lot more of them coming at you.

What safest of all though, is to fly with adequate shielding. While something like lead might be great, it’s darn heavy, so water or high density plastics are more realistic options. A nanotube-based material called hydrogenated boron nitride is apparently great for incorporating to a spacecraft hull lining and it could be woven into garments both to wear on board and under a space suit. It will not only stop protons, but the boron is apparently ideal at stopping neutrons which are part of that secondary subatomic shrapnel radiation that happens when a cosmic ray particle first collides with your hull or your space suit. So, there are potential solutions, but implementing them is still a way off.