Question 1:

Dear Cheap Astronomy – *Just how useful are humans in space*

The first episode of STNG has Commander Riker proving his collar studs by re-docking the drive section with the saucer section of the Enterprise manually, where manually largely involved looking steely while delivering a few verbal commands to the bridge crew who exchanged astonished glances in between tapping their touch screens to implement those commands, which was apparently the easy part. It's unclear how a re-docking is achieved non-manually, presumably everyone goes for a coffee while it happens, but the story exemplifies the theme of this episode, if you don't have to things manually, why do you need people on a spaceship?

Just by landing robots on Mars, we've been able to take lots of photos, smell the air, feel the ground and listen to the wind blow. We've got bogged in difficult terrain, but also climbed hills to take in the view and even operated a drone. Sending people there is a lot more fraught since the mission has to be loaded down with everything you need for life support and with current propulsion technologies those people will have to be sitting in a tin can for literally years to get to Mars and back again. And with current technologies, it looks like all we can do is get people there. The only current viable plan we have to get them home again is to get them to manufacture their own rocket fuel from in situ resources.

But firstly, keeping humans alive in space requires huge technological overheads, even though they will be pretty much useless during a journey to Mars. We've been remotely piloting spacecraft to Mars for decades now. The astronaut's main purpose in being on the ship is so they can get off at the destination. Of course, given the crew will be travelling with life support they will have a lot of maintenance tasks to do and they'll have to exercise several hours a day to stay in shape – so they'll be busy, but not with piloting. They might take a more active role in the landing, but who knows really since we don't really have a solution for the landing yet.

We might fly a lander along with the astronauts or send the lander on ahead so it's waiting there in orbit when the astronauts to arrive – since the less mass they have to fly with, the faster they'll fly. Humans and their life support makes up too much mass for either a bouncy ball or a sky crane landing, so the lander will have to come down on retrorockets – which would presumably lie behind a heat shield as the lander enters the atmosphere and then the heat shield would be jettisoned well above the ground. This is the complexity of landing on Mars, it's got enough atmosphere so that you need a heat shield but not enough atmosphere that parachutes could slow you to a soft landing, they'll slow you a bit, but you need to do more to avoid a destructive hard landing on the surface.

Nonetheless, despite having no real plan, let alone hardware, the official line is still that we'll be landing on Mars sometime in the 2030s – although regular listeners will be aware that CA thinks there's a snowball's chance in a supernova of that happening. We reckon give it a few more years and everyone will be saying it will be sometime in the 2040s.

But let's just assume we do get humans on Mars someday, will it all have been worth it? There'll be no radio delay, so humans could turn over interesting rocks as soon as they spotted them and wield a rock hammer with more dexterity than a rover could. And since they will be going home again they could take lots of Mars rocks home with them. Of course that same option would exist if we ever decided to fly our robots home again, it's just that we don't.

So yes, there's definitely some gains with sending humans, but those gains come at huge cost and a risk that you don't get those people back alive – which is bad for those people as well as for the government or private enterprise responsible for sending them. Sending people might become worthwhile when it can be done faster, cheaper and safer – in the meantime let's keep sending the robots.

Question 2:

Dear Cheap Astronomy – *What is the death zone radius of a black hole merger.*

The background to this question is the gravitational wave data we've been detecting with LIGO – the Laser Interferometer Gravitational Wave Observatory. The data received can be reverse-engineered to quantify the astronomical event that caused the gravitational waves detected. So for example the first gravitational wave detection on 15 September 2014, GW150914, is thought to have arisen from the merger of two black holes, of 36 and 29 solar masses respectively, at a distance of 1.3 billion light years away, forming a 62 solar mass merged object. Since 36 and 29 actually equal 65, the remaining 3 solar masses converted into the energy of the resulting gravitational waves.

That's a fair whack of energy, but energy from a point source spreads outwards in a sphere – so the energy declines by the inverse square of the distance it covers. So how much closer do you have to be to the merger that the energy might kill you? Well, here we need to consider what harm wave energy can do. For example, on Earth if there's an explosion nearby you the shock wave could kill you, but that's a wave of energy transmitted through the atmosphere, so really you are killed by the pressure of air molecules being rapidly shifted in your direction. If the same thing happened in a vacuum and you weren't hit by any flying shrapnel, the only effect on you would be a bright flash of heat and light. With a big enough explosion, the heat and radiation might kill you, but that would be death by electromagnetic radiation, not pressure.

With gravitational waves, the energy involved is even less tangible. You are just dealing with a reverberation in spacetime, remembering that general relativity tells us that gravity is not a force it's just a change in spacetime geometry. So, the only way for a gravitational wave to transfer its energy to a material object is through distorting the spacetime that the object occupies. This could result in some energy transfer if there's stretching that produces heat, but for the most part gravitational waves pass through matter without imparting much energy at all – in which case, you should be fine. Although… the stretching could be a problem. After all the classic death by black hole scenario is where you get spaghettified.

So rather than worrying about the energy carried by a gravitational wave, we should maybe consider the amplitude of the wave – where a small amplitude wave passing through an object stretches it a bit and a big wave stretches it a lot. If gravitational amplitude defines what the death zone radius is then amplitude just declines inversely, not inversely-squarely, so if you double the distance, you halve the amplitude rather than quarter it.

This might sound a bit serious but consider that at a distance of 1.3 billion light years the amplitude of the waves arising from the GW150914 event was sufficient to stretch the 1.6 kilometre arm of LIGO by a tenth of the width of a proton. Had the event had been a billion times closer, that is 1.3 light years away then the arm would have stretched a whole 4 nanometres and the entire diameter of the Earth might stretched by a hundredth of a millimetre. From 10,000 kilometres away the stretch becomes one in a thousand, so then it would be likely to cause significant earthquakes and potential deaths on Earth. If you were floating in a space suit at that distance, you might get stretched by a whole millimetre, which you'd feel, but it probably wouldn't kill you.

However, were you 10,000 kilometres from a black hole merger you would die for other reasons. If either black hole had an accretion disk of super-heated material, the radiation would kill you from a lot further out than 10,000 kilometres. And from 10,000 kilometres it would be hard to stop yourself in-falling until gravitational tidal forces killed you by spaghettification or something just as geometrically nasty given you would be approaching two in-spiralling black holes. So, proximity to the black holes themselves will kill you long before their gravitational waves do – and if you are far enough away that those other proximity effects won't kill you, then the gravitational waves won't kill you either.