Question 1:

Dear Cheap Astronomy – How much antimatter is there and will it eventually all go away?

Antimatter is generally found in subatomic particle form – so there's antiprotons and anti-electrons, for example, which can rarely come to together to form an antihydrogen atom. But that's about it, an anti-helium nucleus has been created in a laboratory but neither it nor any other more complex anti-nuclei have been observed in nature. Based on what we can see through telescopes, detect in cosmic rays and directly observe on Earth, we think it's unlikely that antimatter exceeds one per cent of the total matter plus antimatter contents of the Universe.

An antiparticle is essentially the same particle except with the opposite charge. So for example, an electron has a negative charge and its antiparticle, a positron has a positive charge – and if a particle and its antiparticle ever interact they annihilate each other. This is why you never find a lot of antimatter in our matter – dominated Universe – as soon as an antimatter particle meets its particle counterpart, both are gone in flash of gamma radiation.

As to whether all antimatter particles will ever be annihilated out of existence, we can provide a confident no –at least not before the heat death of the Universe. Fresh antimatter particles are being created across the Universe all the time. Many high-energy reactions and particle collisions create particle antiparticle pairs – for example in supernovae. It's thought that the polar jets that shoot out of accreting black holes and neutron stars are streams of particles and anti-particles. It's thought that such phenomena produce particle-antiparticle pairs in equal numbers, which we also see up-close in particle colliders experiments. On this basis of such findings, a largely-unfounded assumption has developed that the Big Bang should have produced particles and antiparticles in equal numbers.

We say unfounded since no-one really has a clue what happened at the Big Bang. We think that in a few fractions of an instant after the Big Bang, the initial superhot soup of fundamental particles was already matter-dominated and it never looked back from there – although even that proposed superhot soup of fundamental particles is itself just a hypothesis. We have observational evidence from the cosmic microwave background – and can wind the clock back further on theoretical grounds, but there is a point beyond where the best thing to do is shrug. So, in saying that the matter-antimatter imbalance is a great unsolved problem of physics, we might just as well say that what happened immediately after the Big Bang is a great unsolved problem of physics – which of course, it is.

The matter-anti-matter imbalance in our Universe could just be coin-toss thing. Once fundamental matter particles gained the slightest of edges, that's it really. It's speculated that the initial matter dominance may have only been one extra per five billion – but that means five billion matter particles annihilate when they contact five million antiparticles and only the one extra matter particle remains – scale that up to the billions of trillions and you get a matter-dominated universe. Some speculate that it could just as well have gone the other way and we'd instead live in a Universe where the little things that whiz around atomic nuclei were positrons. However, others suggest that there is some special feature of matter that means it will always be dominant. Apparently, there is some hint of what could be evidence of this arising from few particle accelerator experiments, but that conclusion is still hotly-debated. So again, at this point in history, the best thing to do is shrug – or go off and do a PhD in quantum mechanics, so that you can at least give a highly-educated shrug.

Question 2:

Dear Cheap Astronomy – How fast could we get to Alpha C with current technologies?

If we calculate the trip duration based on speeds achievable with current technology, a mission to Alpha Centauri, the nearest star system to ours, would take over 6,000 years. But even that is wildly optimistic when you consider the mass you need to accelerate to those speeds. If you want to fly humans there, you would the need to fly with not only sufficient fuel and propellant but also sufficient life support, including thousands of years' worth of food and water, and all the various services needed to maintain a generational starship, like maternity units and schools and also some quiet rooms where all the old people would be 'retired', since their precious bodily fluids would need to be recycled and whatever remains would need to be composted to support the greenhouses and algal ponds. If we make the more realistic assumption that you would fly a robotic mission, you'd still need a fly a small nuclear reactor to maintain electrical power while you are between stars and you'll need a whole lot of spare parts, but this option is a tiny bit more plausible.

Fortunately, we don't need to look far beyond current technologies to get to Alpha Centuari in a lot less than 6,000 years. Higher specific impulse nuclear thermal propulsion engines have at least been ground-tested, where a nuclear fission reactor provides a heat source through which you funnel hydrogen gas, thereby heating and expanding the gas so it blasts out at very high speed from a rocket nozzle. But when we say 'a lot faster' we're just saying nuclear thermal propulsion might get you to Alpha Centauri in 1,000 rather than 6,000 years. So again, forget about flying people, the best you can do is fly robots, which may just mean the spacecraft itself along with a few detachable probes that can explore the system and its exoplanets in more detail.

But even with a one thousand year mission, by the time it gets there it may be sending back data which will seem like bronze age technology to its recipients. Who knows how far our remote sensing technologies might advance in the next one thousand years, we might have kilometres-wide space telescopes mapping out the continents on exoplanet Proxima Centauri b and be collecting detailed spectroscopic analyses of both its atmosphere and surface rocks, assuming spectroscopy won't have become a laughably-primitive technology by then.

A better approach might be to load up the spacecraft with lots of raw materials and 3d printers, so its technology can evolve in synch with Earth-bound technology. The first 900 years might just involve upgrading the 3d printers into better 3d printers or even full-on replicators, so the last hundred years could be spent actually building equipment for the mission. But right now, like today now, it's unlikely we would take the risk that the current generation of 3d printers plus further intellectual input from Earth would be a sufficient foundation for an evolving-technology mission. And by the time you did develop the proper basis for an evolving technology mission, who knows what other sorts of technology you might also have developed to either shorten the mission or to make it unnecessary.

So, perhaps the only justifiable option for a mission to Alpha Centauri is one where we can achieve velocities of at least 10 per cent the speed of light, so we might get there in under 50 years. That may mean you're still arriving with what everyone will consider old technology, but at least in won't be bronze age technology. There is a very faint chance that this podcast and a whole bunch of other genuine experts have got it wrong and somehow we will be able to travel nearly as fast as light and get there in under 5 years, but it's pretty hard to see how that can be feasible without some stupendous and currently unimaginable fuel source, plus some very robust collision shielding for when you hit dust grains while travelling at hundreds of thousands of kilometres per second. Breakthrough star shot proposes a laser sail propelled nanoprobe, accelerated up to 25 per cent the speed of light by a kilometre wide array of lasers. It can't manoeuvre at all so would need to stay on a perfectly straight line and not collide with any dust grains for 4.3 light years. It will then manage a couple of quick photos as it screams through the system at 25 per cent the speed of light since it can't slow down either. As for faster than light travel, nah… not even worth entertaining the idea.