Question 1:

Dear Cheap Astronomy – How unique is the Universe?

So, could there be a parallel Universe with a podcast called Expensive Astronomy, who's goatee-bearing host had to shut down the Expensive Astronomy Patreon page because it had become a major drain on the world's economy? Well, sure, anything's possible.

But actually no – anything isn't possible, something's are and something's aren't. The idea that you have a goatee-bearing doppelganger in an alternative universe not only lacks imagination, but is physically implausible on a number of fronts. Such a level of congruence requires that there was either a recent historical point from which the time lines of both Universe's bifurcated or there's some kind of link that maintains an ongoing congruence between the two Universes.

If you and your evil twin exist in both Universes, then somehow your disassociated parents got together in both Universes and their respective parents also got together - and so on. Given our Universe is billion of light years in expanse and we that are constantly scanning it for any kind of signals that are in any way out of the ordinary it doesn't really seem plausible that a whole alternate Universe could be anywhere nearby and hence it doesn't seem plausible there's any kind of information exchange between here and there. At least within our Universe, information can only move as fast as the speed of light, so any information is going to take an awful long time just to get to the edge of ours.

You could entertain the notion that a parallel Universe might exist within hidden dimensions that somehow run in parallel with the dimensions of our Universe, but again if such a proximal universe is so dimensionally disconnected from us to be both invisible and undetectable then any information transfer between the two also seems implausible. While a closely-aligned parallel Universe may be easily imaginable, that does not make it any more physically-plausible. It mostly just indicates a failure of imagination.

If you do want to seriously contemplate what an alternate Universe's might be like then first consider whether it will even have hydrogen, let alone more complex fusion products like carbon and oxygen. As we've previously discussed on Cheap Astronomy, the key thing that may define our Universe from any other potential Universe is the fine structure constant, alpha, which quantifies the gap between the spectral lines of hydrogen. Remember a hydrogen ion is just one proton and a hydrogen atom is one proton plus one electron. The emission lines of hydrogen are a fundamental representation of how fundamental matter (hydrogen) and fundamental energy (light) interact. Being a constant, there is only one setting for alpha across our whole Universe. Perhaps we'll one day figure out that it is the only setting possible in any Universe. But in the meantime, here at Cheap Astronomy we like to entertain the notion that different Universe's might have different settings for alpha because in those Universe's matter will be based on something other than hydrogen and ligh, which is the way that information and energy are communicated across a vacuum, might still be light but have a totally different maximum speed and it might interact with its alternate Universe's matter in totally different ways to how it does here.

So, leaving science fiction to one side, if there are alternatives Universe they will be utterly disconnected from our Universe – both by time and by space and there won't be any magic gateways that allow people to pass between them – and if they were such gateways and you passed between one you'd just die because there wouldn't be hydrogen so there wouldn't be oxygen and who knows how space and time might interact in that Universe to accommodate your physical form. So, as well as dying your lifeless body might become spaghettified or compactified, or a bit of both.

So the idea that there's an alternate Universe where you did actually go to the high school prom with that person that you didn't actually go to the high school prom with, is not plausible. It didn't happen and it'll never happen anywhere else in the multiverse – and you'll never build a time machine that can get you back there either. It was a moment that came and it went and now it's done and it's gone. Just suck it up and move on.

Question 2:

Dear Cheap Astronomy – How close is fusion energy?

Well, a lot of people are saying 2050 – but that with that sort of timeline, you might just as well say no time soon. Fusion clearly is achievable, after all the Sun and other stars do it all the time. But stars do it through their own gravity forcing nuclei together until they have no option but to fuse. That process can't be readily reproduced on Earth, since we don't especially want our planet collapsed down to the densities requires for stellar fusion to take place. So, we look to other methods to force nuclei together, the current favoured approaches involving magnets or lasers.

To create fusion you have to bring two nuclei into close proximity with each other. The first hurdle is that most room temperature nuclei form atoms, where positive charged nuclei are surrounded by negatively charged electrons. To get around that, you can heat those atoms up into a plasma state where the electrons and the nuclei are no longer associated, they just bounce around independently within the broiling plasma. The next hurdle is that the positively-charged nuclei still repel each other, so all that bouncing around isn't about particles coming into contact with each other, they're just coming close until their like charges repel. To get particles to contact and fuse you need to confine the plasma into a smaller volume so as to bring the particles close and you need to keep it hot so the particles move fast and collide hard.

But within a box, particles will also be colliding with the sides of the box, which heats up the box and also cools down the particles, since the transfer of their kinetic energy is what is heating up the box. Once the particles in the box start cooling and slowing, the probability of fusion diminishes so you have to add more energy to try and get things back into a fusion-friendly state.

This is balancing act of fusion generators. We've built literally hundreds of them over many decades and they have all generated fusion. What we are yet to achieve is a point where you can get more energy out of the fusion reactions than you put in to make those reactions happen. What we'd really like to achieve is a sustained chain reaction. After all, while fusion requires energy, it also creates energy, so surely if you can just get it started, its own energy production should then be able to drive more and more fusion. The challenges to making that happen are keeping the fuel contained so that the density stays high, keeping it hot so that fusion probability is high and all the while adding more fuel to keep it all going.

We are getting around the problem of energy loss through heat conduction using Tokamaks, which are large helical chambers with electromagnets arranged to direct plasma flow around in circles, so the particles are more likely to collide with each other than with the walls of the confinement space. For that same reason, you get more efficiency by increasing the volume of the confinement space, which means we're now building very big Tokamaks that need lots and lots of energy input.

There is another problem where whenever you fuse one proton and one electron you get a neutron, which being neutrally-charged is no longer steerable by magnets and so just flies off – removing fuel and energy from the reaction space as well as becoming a source of damaging radiation. Part of the economics of fusion reactors is the lifetime of the reactors themselves, which will be big, expensive and technically intricate and will have to contain million degree fusion reactions, as well as high energy neutron radiation. So, even if we do gain a modest net production of energy, if we have to keep shutting them down for ongoing maintenance we may still not realise an overall benefit versus cost. So, it is all pretty tricky finding the right balance, but we really do think we're getting closer to a working solution – if the year 2050 sounds closer.

Of course, there are compelling reasons why we should be building lots of nuclear fission reactors now, to reduce our dependence on carbon fuels. But, fission reactors are big and expensive and not at all popular. It may be the same story for the first generation of fusion reactors – which will be very big and very expensive and it's unlikely anyone is going to want one in their own backyard. As always, it's not just about the technology, it's also about people.