Question 1:

Dear Cheap Astronomy – What's Psyche really like?

Psyche is an asteroid in the asteroid belt and apparently a very metal rich one, which makes it a prospecting target for budding asteroid miners. Pysche is also a spacecraft, launched on 13 October 2023. We're recording this episode about one month after launch when it's already over 15 million km from Earth – and its destination? Yep, Psyche – the asteroid.

There are currently three categories of asteroids by composition. C-types, also called carbonaceous chondrites, are mostly clay with a bit of rock and are thought to be the most common asteroids out there. Then there's S-type for silicaceous asteroids. These are mostly rock with a bit of metal and then there's M-type, metallic, asteroids which are mostly metal. Although, it might be better to say about 75% of all asteroids are carbonaceous, another 17% are silacaceous and the remaining 8 per cent are anything else, where anything else includes metallic M-type asteroids. Psyche is the largest M-type asteroid we know about and it's the 13th largest of all the asteroids we know about – at least, it's the 13th largest by diameter. It's actually the tenth largest by mass – and represents about 1% of the cumulative mass of all the known asteroids, where Ceres, the largest, is about 39%.

The traditional explanation for Pysche being a big chunk of metal is that it is the remnant core of a larger protoplanet that had all its outer layers blown away in one or more collisions. This is the subject of a lot of debate though, with doubters asking why there's no sign of any nearby debris, as well as pointing to the unlikeliness of one or more collisions so effectively taking off all the crust and mantle, while still leaving an intact metal core behind.

Most M-type asteroids are classified by their relatively high albedo, that is their shinyness, but something as big as Psyche can also have its density estimated - first by measuring its size – which has been done by observing it while it occultates background stars – and then by also measuring its mass, which for Pysche can be estimated by measuring how much it gravitationally-perturbs objects that it passes by. Such measurements have landed a density estimate for Psyche of nearly 4 grams per cubic centimetre, which is fairly dense, but not dense enough for it to be solid iron, which is more like 8 grams per cubic centimetre.

With an object as big as Pysche it's also possible to distinguish a few large scale surface features. So, while Psyche does have a high overall albedo, its surface is a bit patchy, with high albedo areas, which are presumably metallic, mixed with duller areas, which may be silicon-based rock. So, one alternate suggestion to explain Psyche's make up is that there was a protoplanet that was completely obliterated in a collision after which some of the remnant shrapnel gravitationally-accreted back into an undifferentiated mix of metal and rock.

Or it could be ferrovulcanism, a proposed hypothetical feature of small planetesimals, where - after their formation and differentiation into a metallic core and a rocky crust, they still briefly retain a molten metallic core. It's proposed that the cooling and contracting outer layers could create sufficient internal pressure to force some of the molten core to squirt out through the crust, providing that crust does not exceed 50 kilometres thickness. This is why you would only

get such ferrovulcanism in planetesimals, not in actual planets. So ferrovulcanism could explain how you get an object like Psyche, that's not dense enough to be solid metal but does have metallic surface features.

Anyhow, all this should be clarified one way or another when Pysche the spacecraft arrives at Psyche the asteroid in 2029. Stay tuned.

Question 2:

Dear Cheap Astronomy – How is Mars Sample Return mission going?

Here at Cheap Astronomy we've often said that landing on Mars is one thing – getting off it again is quite another. But this is the intention of the Mars Sample Return mission – which has already commenced insofar as the Perseverance rover is currently collecting samples for it – some of which have dropped for later retrieval, while others remain stored within the rover. The current plan is for the return part of the Sample Return mission to be launched in 2027 and return samples to Earth by 2033 - although as is often the case with NASA timelines these dates look aspirational at best and recent talk of budget-cuts at NASA make those dates even less likely than they already were.

Anyway, to date the Perseverance rover has collected 10 pairs of samples from significant sites and one of each of those pairs has been dropped at location called Three Forks, with the other ten staying onboard the rover. The idea is that the Sample Retrieval Lander will land near Three Forks with the Perseverance rover having circled back to the same area. The Sample Retrieval Lander then has two options. If something's gone wrong with the rover and it can't get to the lander, the lander will have two retrieval helicopters that can pick up the already-dropped samples from the Three Forks cache site. The retrieval helicopters will be similar in design to the currently flying Mars helicopter Ingenuity – but will also have little grabby-things so they can fly the cached samples back to the lander.

However, if the rover is still working, forget all that it because it has identical pairs of the ten Three Forks samples plus a whole bunch more – which it can pass to the lander. This is all about contingency planning, you don't want to spend hundreds of billions flying the Sample Retrieval Lander to Mars only to find the rover can't deliver because it got bogged somewhere.

But anyway, if the rover does deliver, it will have twin copies of the ten Three Forks tubes, plus additional twenty eight samples it's collected from elsewhere. As of October 2023 it has collected and stored 23 of those total 38 samples. The Sample return lander is planned to land with a small Mars Ascent Vehicle (or MAV), capable of launching 12 kilograms of payload into Mars Orbit. That 12 kilograms will be at least 30 of the sample tubes filled with a mix of Mars drill cores, scooped- up regolith and some dusty atmosphere.

Perseverance landed with 43 tubes, with five being witness tubes. A witness tube is essentially a control sample- they will be flown and handled in the same way that all the other tubes are and then open and sealed again, on Mars. It's a way of testing if the real sample containers

have somehow been contaminated in the process of being launched from Earth to Mars or otherwise the whether the samples have been corrupted in the process of sample-collecting, handing and return. Only 2 of those will be returned to Earth with the other rover samples – or If it all goes pear-shaped, the 10 contingency samples dropped at Three Forks will be flown back – of which one is a witness tube.

So that's the plan, but there's still a lot of issues to work through. The proposed lander is in no way built, nor is there a clear plan for how it will land. Retro-rockets? A sky crane? Who knows? There's also issues with the Mars Ascent Vehicle. It's not considered feasible to have it blasting straight off the top of the lander – so there's thinking about first flinging it upwards off the lander with some kind of a spring system and then have its rockets will ignite while it's in midair. Nothing like this has been done before, but it could be feasible. Similarly, the plan for the MAV to then dock with the European Space Agency's Earth return orbiter in Mars orbit hasn't been done before either, although that might also be feasible.

But, if you're thinking this all sounding a bit too speculative, well you might not be the only one thinking that. As of October 2023 the budget for Mars Sample Return is on hold and its future is a little uncertain. That's not unusual in this business and it's likely a revised plan may get back on the rails after some further wrangling and possibly budget cuts. So if you're thinking space is hard, yep, and it's also slow and expensive.