

Question 1:

Dear Cheap Astronomy – How often does the solar system capture or eject objects.

The first evidence that stellar systems might eject things were observations of rogue planets knocked out of their systems due to gravitational interactions and now populating interstellar space. For every rogue planet knocked out its system there are likely thousands of smaller objects also knocked out that are just too small for us to observe. We call this rogue population interstellar objects.

Since the Solar system is constantly on the move circling the galaxy, there's a reasonable likelihood that it will intersect the paths of interstellar objects. There's a very small likelihood of intersecting a rogue planet, but thousands of times more likelihood of intersecting smaller interstellar objects. So there's always been a general assumption that the solar system is regularly visited by interstellar objects.

The first clear evidence of this was Oumuamua, first detected in 2017 – an interstellar asteroid which had already come in and curved around the Sun – so we only noticed it when it was on its way out again. Its velocity gave it away as an interstellar object – it was moving so fast that it was clearly going to achieve escape velocity from the Sun and tracking its trajectory back we're confident it must have come from outside the Solar System initially. Oumuamua was our first observed interstellar asteroid and we've since had an interstellar comet called Borisov, which was observed just passing through in 2019. We've also had an alleged interstellar meteor known as the Manus Island fireball which crashed to Earth in 2014, subsequent analysis suggesting a high likelihood it has also been moving too fast to have been in a bound orbit around the Sun.

So this is the extent of our understanding right now. We've long thought the solar system was visited by ISOs and just within the last decade we've started spotting them. Our observations are just based on velocities though. It's possible, if not likely, that the solar system has captured some interstellar objects that have come screaming in but then been slowed through gravitational interactions with solar system objects so that they ended up adopting a solar orbit of their own. However, it's unclear whether we could distinguish a long captured interstellar object from a native solar system object – what we need to do is actually observe such a capture event or otherwise get some up-close data on ISOs that pass through so we can start identifying any distinguishing characteristics they may have – and then go look for those distinguishing characteristics on objects that are now captured in solar orbit. It would be like finding a needle in a haystack, but we might get lucky.

There is also the matter of things being ejected from the Solar System and becoming interstellar objects. Here we've made observations of comets heading outwards at Solar System escape velocities and tracking their trajectories back it seems likely they were accelerated up to escape velocity after passing close to a giant planet. The first was Comet C/1980 E1 (Bowell), thought to have interacted with Jupiter in 1980 and this year we observed that comet A117uUD appeared to have been accelerated out after a interacting with Saturn.

Journalists are want to use words like flung or hurled as though these objects got loaded up in a cannon and then shot out, but in reality both were long period comets that already had orbital velocities that were almost but not quite escape velocities. Their interaction with the giant planets, where they got temporarily pulled into the planet's gravitational fields picking up some of the planets orbital velocity around the Sun before continuing on with that small addition to their own prior velocity – was just enough to give them proper escape velocities.

So, neither has really been shot out of the Solar System. Comet *Bowell* only passed Neptune's orbit in 1995 and is moving slower than *Voyager 1*'s escape velocity and *A117uUD* won't finish its curve around the Sun until next year – it got its boost from Saturn on the way in. There's almost certainly been a number of asteroids the Solar System has ejected as well, there just a lot harder to observe.

Question 2:

Dear Cheap Astronomy – What are the alternatives to CSOTM

Good question. There have been a number of attempts to create an asteroid mining industry despite the obvious lack of access or technological solutions. Such 'start ups' have been largely built on venture capital – the support of investors willing to take a gamble on investing in a venture unlikely to deliver profit in the near future. Asteroid mining was the focus of the high-profile *Deep Space Industries* launched in 2013 which developed some ideas for utilization of off-world resources, including building spacecraft and an orbiting platform for the collection and processing of off-world water for rocket fuel production, but nothing ever got off the ground and the venture, largely a think-tank, was bought out in 2019. *Planetary Resources* launched in 2012 and was bought out in 2018, it made a bigger thing of asteroid mining and established a conceptual pathway based on space telescopes, which would initially be put into Earth orbit and then later roam interplanetary space to gain close-up views of asteroids for prospecting purposes. They did get as far as launching a couple of demonstration cube-sats which successfully detected heat and water sources remotely. Nice.

A more recent and still operating high profile venture is *AstroForge*, which thinks chasing water is probably not the best plan at this point in history. After all Earth is probably the best source of pure unrefined water in the solar system and launch costs are steadily going down. You might start using off-world water when it's needed in large volumes off-world but it's probably not the best place to start building a space economy. So *Astroforge* are firmly focused on finding platinum rich metals and possibly cobalt and nickel in asteroids, running the line that there is growing demand for those rare metals, for example in battery production to support the world's movement to clean energy. Also, digging them up off world is better for Earth's ecosystem. So there's some virtue as well as profit to be made.

Their plans are also focused on prospecting but also on space-based refining. They have a technique, possibly based on vapourising platinum ore with xrays to extract the platinum, which they hoped to demonstrate on an orbiting cube-sat called Brokkr-1 in 2023, but had uncertain success due to various in-flight problems. The next step is to do an asteroid flyby with a spacecraft scheduled to launch in October 2024, called Brokkr-2. AstroForge haven't revealed which near-Earth asteroid Brokkr-2 will visit, it's been described as being in the 100 metre diameter range and Brokkr-2 will take pictures of the unknown asteroid from about a kilometre out. The lack of detail here is probably something to get used to as the private industry gets involved in space exploration. Assuming the flyby mission happens, it will take about 11 months to rendezvous with the asteroid, but it's unlikely AstroForge will release its findings. No point telling everyone you've found a gold mine before you can stake a claim and no point telling everyone you found nothing if you want investors to keep funding more prospecting.

In any case, who knows if they will be able to confirm there's either something or nothing worth mining just from surface images– they could get lucky in sighting a shiny metallic sticky-out bit, but otherwise the best plan is just to start building up a database of lots of different asteroid images so you can start identifying surface features that are common to valuable metallic ones and not common to others.

Once they have a positive ID on a valuable and minable one the plan is to return and do... something. AstroForge's somewhat mysterious platinum extraction technique apparently vaporizes asteroid material and somehow manages to separate the good stuff from the dross in microgravity. The ore presumably has to be in reasonably granular form for that to work. If you could just scoop ore up great, but otherwise Astroforge is also planning to trial a space drill on the Moon – so maybe it will all come together somehow.