Question 1:

Dear Cheap Astronomy – So the water came from asteroids now?

Yes, or at least that's some latest thinking. As we we've discussed previously on Cheap Astronomy, most astronomers think that all the water on Earth must have come from falling comets whereas most geologists – those people who are always looking down rather than up think the water was already contained within the primordial matter than accreted together to form the Earth. But, in the astronomy community there has been a shift away from comets being the water source, because for the few instances where it's been possible to sample cometary water we've found it having quite different hydrogen to deuterium ratios to the water on Earth. So, we're now thinking the water must have come from asteroids, because it has to come from somewhere, unless you go with the 'water was always here' theory.

The reason why the astronomy community is not keen on the 'water was always here' theory is also about hydrogen to deuterium ratios. Theoretical modelling of the early Solar System imagines the planets forming in the solar nebula surrounding the protostar that became the Sun. As the Sun began to radiate, its solar wind would have pushed out more light hydrogen than heavy deuterium, remembering that deuterium is a hydrogen ion (that is, one proton) plus one neutron. So, the close-in regions, where the rocky planets are, would have had a relatively low hydrogen to deuterium ratio, while the outer regions would have a relatively high hydrogen to deuterium ratio, since most of hydrogen from the inner solar system got pushed out there. However, what we actually find on Earth is a relatively high hydrogen to deuterium ratio, leading to the thinking that the Earth's hydrogen and hence its water must have come back from those outer solar system regions –first we thought by comets now we think by asteroids, perhaps during the late heavy bombardment when a shift in Jupiter's orbit sent a rain of asteroids our way.

But now there's some new thinking. Here at Cheap Astronomy we do try and remind people that the latest announcements about anything are generally just some latest thinking and you shouldn't assume we've really nailed something just because someone put out a press release. But anyway, in April 2019 someone from the astronomy community put out a press release about new findings which support the 'water was always here' theory.

Firstly, consider there is a problem with measuring the deuterium ratio of Earth's water today when we are really trying to estimate what it was like 4 billion years ago. That's a long time over which you would have seen some evaporative and hydrolysis loss to space, as well as life on Earth processing both water and hydrogen through photosynthesis and other metabolic pathways. So, measuring the deuterium ratio in the Earth's water today doesn't necessarily tell you about what the deuterium ratio was 4 billion years ago.

Some researchers have tried to isolate a sample of genuinely primordial water – or at least primordial hydrogen from deep mantle rock that's been brought to the surface by volcanoes around Iceland, where it's said that mountains stand with pride. The researchers' claims that particular rock samples are primordial do depend on several disputed assumptions, but if they're right the hydrogen deuterium ratio found in that primordial rock is about what you'd expect in the early solar nebula around where the Earth formed. So, this supports the view that the water was here when the Earth first formed and not delivered later on.

Broadly the thinking is that by the time the proto-Earth had become massive enough to start heating up and going molten, it was also massive enough to start generating a substantial gravitational field. So, while any primordial water would evaporate out of that molten rock, it then just rises, cools and precipitates back down again because of the gravity field. If the water is superheated it might hydrolyse into hydrogen and oxygen, but our magnetic field protects most of those ions being blown away by the solar wind. Mars and Venus might also have started with equivalent water contents to the early Earth, but their respective lack of a magnetic field meant their primordial water and its ionic constituents, that's hydrogen and oxygen ions were mostly lost to space.

So, is that the end of the story of where all the water came from – nah.

Question 2:

Dear Cheap Astronomy – What are the Voyagers learning about interstellar space

It was announced in August 2012 that Voyager 1 over into interstellar space, although no-one was able to confirm that until an announcement in 2014. It was announced in December 2018 that Voyager 2 has crossed over, apparently on the 5th of November 2018. It didn't take so long to realise that Voyager 2 had crossed over partly because people had a better understanding of what to look for but mostly because Voyager 2's Plasma Science Experiment was still working. Using the plasma experiment instrumentation, Voyager 2 was able to detect a sudden drop in the speed of solar wind particles coupled with an increase in the speed of galactic cosmic rays within its immediate environs.

We worked out that Voyager 1 entered interstellar space in 2012 using its Plasma Wave Experiment which monitors for changes in a plasma's electrical field, using what basically amounts to a radio antenna. While Voyager 1 was still in the heliosphere, it was possible to detect plasma waves arising from coronal mass ejections, which put an extra kick into the solar wind. So with the combination of knowing the velocity of Voyager 1, and the expected decline in the standard solar wind background and the expected pulse from the coronal mass ejection, we were able to work out when Voyager 1 crossed into interstellar space by calculating expected and actual plasma density changes over time. With Voyager 2 and its functioning Plasma Science Experiment, we just saw when it crossed over.

But anyway, what do we know now about interstellar space thanks to the Voyagers? Well, current science is mostly about the Voyagers just confirming what we'd already suspected, but let's talk that through. Firstly, remember that space is mostly vacuum, so when we talk about plasma densities we are talking in very diffuse terms. So, as was expected, Voyager 1 found that the plasma density of interstellar space was higher than it was in the heliopause, where the heliopause is the very outer parts of the heliosphere where the solar wind's outward push finally peters out. Of course, the plasma density of the inner solar system is much higher than it is in interstellar space, since you are that much closer to a star – although it's worth remembering you'd still die just as quickly if you stepped out of an airlock in either environment.

But anyway, consider that around every star you can expect an expanding sphere of plasma formed by each star's stellar wind. As that sphere expands outwards its plasma density declines. So, there is a point where the density of the plasma is so thin it can no longer push out against the interstellar medium. This is mostly an magnetic field effect, as the density of the outward flow of charged particles declines, the field strength they can generate declines until that field strength is overwhelmed by the field strength of the charged particles in the interstellar medium.

But that solar wind doesn't then fall back towards the star. Like probably most stars, the Sun has a proper motion of its own, so it is essentially pushing through the interstellar medium as it orbits the Milky Way galaxy. So, the outer most solar wind particles in the Sun's heliosheath are mostly blown backwards as the Sun progresses forward. So, while stellar wind particles can leave the environs of a star, it's mostly in the form of a trail of particles left behind in the star's wake.

But such small star trails make a very minor contribution to the plasma of the interstellar medium. Most of the plasma of the interstellar medium arises from really big stars that exploded at the end of their relatively short lives and after 14 billion years of that they have heavily seeded the interstellar medium. This is partly about seeding the interstellar medium with all the interesting elements formed by stellar fusion and by the supernova explosions themselves, by far the most common output of a supernova explosion is simple ionized hydrogen – that is, charged protons and electrons. The known Universe is mostly hydrogen, or more accurately its mostly single protons and electrons – although of course we think most of the Universe's matter content is dark matter, we just don't know what the heck that is yet.