Question 1:

Dear Cheap Astronomy – What are squeezars?

Squeezars are stars that orbit supermassive black holes. Essentially they are stars on a slow death spiral into the black hole and the squeezing referred to is the tidal stretch being exerted upon them as the orbit closer and closer to the black hole's event horizon. That tidal stretching heats them up, a bit like how the moon of Io, orbiting close to Jupiter is the most volcanically active body in the Solar System. So they are unusually hot and they are also unusually fast.

Much as water spiraling into a plughole speeds up as it gets caught into an increasingly tighter radius, stars around a black hole are accelerated within the black hole's steep gravity well. Achieving faster speeds means they can maintain an orbit, potentially hundreds or thousands of years, but any interactions with other orbiting bodies or even just collisions with dust grains will steadily slow them down and as they slow down they descend into a closer orbit with to the black hole. Once tidal stretching kicks, that is the pull of gravity on their near side becomes substantially greater than the pull on their far side, then they really do commence a death spiral since the extra heat generated and radiated away represents a loss of orbital momentum energy as well.

A squeezar known as S4711 orbits Sagittarius A star, the 4 million solar mass black hole at the centre of our Milky Way galaxy, at a speed of 24,000 kilometres a second – which is about 8 per cent of the speed of light – in other words, pretty-darn fast. Its current orbit is about 13 astronomical units from the event horizon, where for comparison Saturn is about 10 astronomical units from the Sun. Of course the Sun is 1.4 million kilometres in diameter while Sagittarius A star's event horizon is 24 million kilometres in diameter and it has 4 million times the mass of the Sun. Measuring the velocity of stars like S4711 is how we've been able to accurately estimate the size, mass and density of Sagittarius A star – which being a black hole is otherwise invisible.

Tracking squeezars has also allowed us to identify and quantify the mass of central super-massive black hole in other galaxies within our local group of galaxies. In galaxies further out it's no longer possible to resolve individual squeezars, but we do find that many further out galaxies have active galactic nuclei, which is a result of their central black holes sucking down much larger amounts of gas and dust, as well as stars and planets, creating huge accretion disks of hot, compressed material which radiate high energy x and gamma rays. Finding these active galactic nuclei has confirmed our modern view that most galaxies in the Universe have supermassive black holes. The fact that we see active galactic nuclei at the centre of galaxies at great distances while we most often see relatively-quiet supermassive blackholes at the centre of close galaxies, may just be because the further away we look, the further back in time we look. So galaxies in the modern universe are more likely to be mature and stable while galaxies in the earlier universe are still evolving with more free material for their central black holes to feed upon.

The original paper which proposed the name squeezars (Alexander and Morris, 2003) proposed that the stars spiraling in towards supermassive black holes should have atypical luminosities for their spectral class. It was anticipated that the tidal squeezing experienced by the stars would either make them brighter as they radiated off that extra heat, or the stars would expand due to the heating - and hence appear bigger rather than brighter. To date, we are still working at close to the limit of our observing resolution so no-one's actually confirmed whether squeezars do have atypical luminosities or not - but nonetheless the name has stuck. So if anyone starts talking about a star orbiting a supermassive black hole at a very high velocity, you can just say – oh, you mean a squeezar.

Question 2:

Dear Cheap Astronomy – Do black holes float in water?

Well, the internet says they do so it must be true. But let’s unpack this a bit. The internet also says that if you compress the Earth down to marble size it will become a black hole. This is true in a hypothetical sense, but actually compressing the Earth down to marble size is pretty much impossible. You could use some kind of gargantuan press to start the process, but once the Earth becomes denser than the material the press surfaces are made of, the press becomes useless. You can then switch to a different press made of denser material, but that’s only going to take things so much further. Probably the only way to do it is pile more mass around what was the Earth, until the self-gravity of that much more massive object is sufficient to overcome sub-nuclear degeneracy pressures in its core – so whatever you get at the end of all that probably isn’t marble sized.

But anyway, the principle is reasonable enough. If you can compress a quantity of mass to a size smaller than its corresponding Schwarzschild radius then you have yourself a black hole. We’re just making the point, that this is a big if. The usual way in which black holes are formed in the modern universe is in a very massive star which is generating fusion at its centre to push out the huge mass of the star – such that when the fusion fuel suddenly runs out, the whole star collapses inwards compressing its core into degenerate matter whose mass is more dense than it Schwarzschild radius and voila black hole.

Once you have a black hole, you’re away. Throw more mass at it and anything that descends past its event horizon is gone for good. But that mass does add to the black hole’s mass and that then also expands the radius of its event horizon. If we consider the event horizon as the surface of the black hole and the space within the event horizon to be its volume then as you keep adding more mass the volume of the black hole increases more quickly than its mass does. So, by mathematical necessity you end up with larger black holes being less dense than normal black holes. Indeed, most supermassive black holes are less dense than water, meaning they’ll float in water – and really big ones are less dense than air, meaning they could float around like balloons in our atmosphere.

But hang on, let’s remember which podcast you’re listening to here. There are so many dimensions of implausibility it’s hard to know where to start. Firstly liquid water spontaneously evaporates outside a pressured atmosphere, Secondly, if you try and drop a black hole in a giant bath, you'll find that your actually dropping the bath into the blackhole. Even if the bath is bigger, you are putting it in contact with something that warps spacetime into a steep cliff, so the near side of the bath would spaghettify and disappear across the event horizon at something approaching the speed of light.

It's also the case that the issue of density is a bit of a furphy. While we don't know what goes on in a black hole, we can be pretty confident the mass sitting within its horizon is not evenly distributed throughout its volume, it is almost certainly all squished into the centre. Indeed there is a plausible hypothesis that all matter within the black hole has been mashed down into point particle quarks which occupy no volume at all. So as you keep adding matter to it, the black hole gains mass, but the mass within has no material existence, there's just a quantity. Some people will say it has infinite density, but it's probably better to say that the whole concept of density becomes irrelevant. What matters is the effect it has on spacetime. So whether the black hole's core is close to or distant from the event horizon doesn't really matter, an event horizon is an event horizon. The only issue is that a supermassive black hole's event horizon has a much bigger surface area than a standard black holes event horizon, so it can suck down much bigger baths.

And don't even get us started on whether Saturn floats in water.