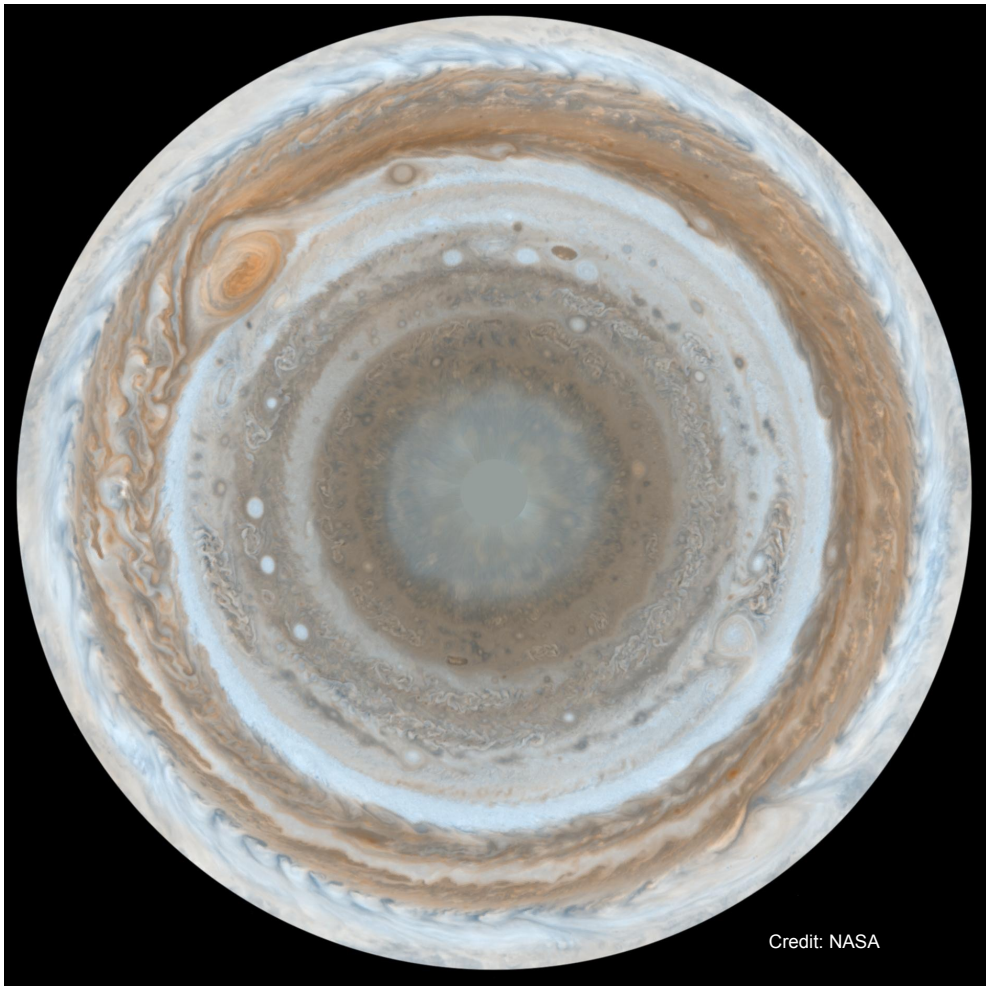
Is it a fact, or have I dreamt it - that, by means of electricity, the world of matter will become a great nerve, vibrating thousands of miles in a breathless point of time?

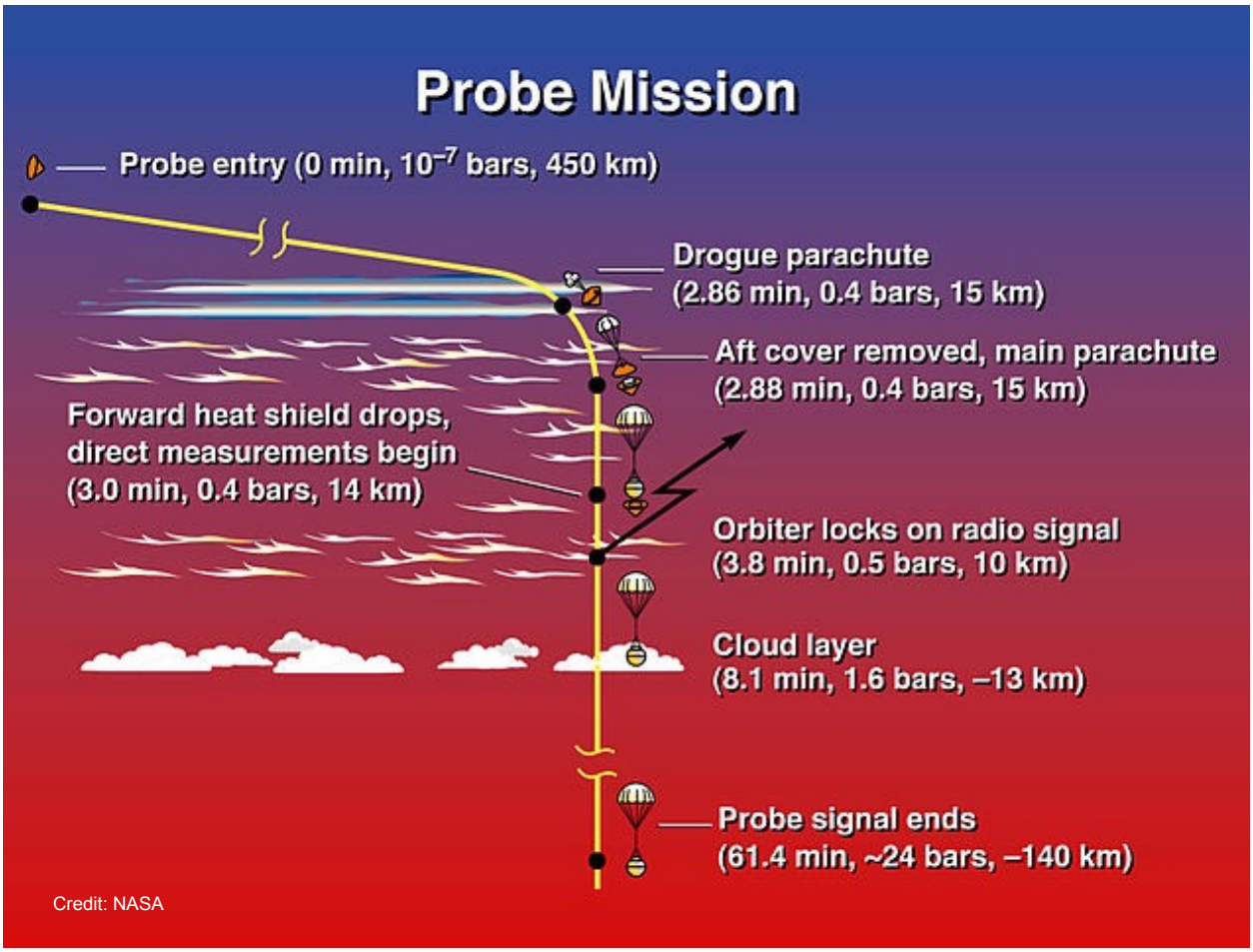
Nathaniel Hawthorne (the internet)

Our Outer Family Portrait

Hi AST 111. In this module we're going to survey the outer planets, or the Jovian planets, and as they're called. And then we'll start looking for commonalities and differences among the various planets in the solar system.



So Jupiter. In order to reach Jupiter, we have to travel about twice as far as it took to get to Mars. As we go farther out in the solar system, the planets get farther and farther and farther apart. It gets harder and harder to reach them. Jupiter is a big gas giant. It has some 300 times the mass and 1000 times the volume of Earth. Its most famous feature - a long lived storm called the Great Red Spot and visible in the image above - is large enough to swallow several Earths. It's a large, relatively stable storm. It wasn't always there. It won't always be there. But in the last couple centuries, it's been a stable storm.



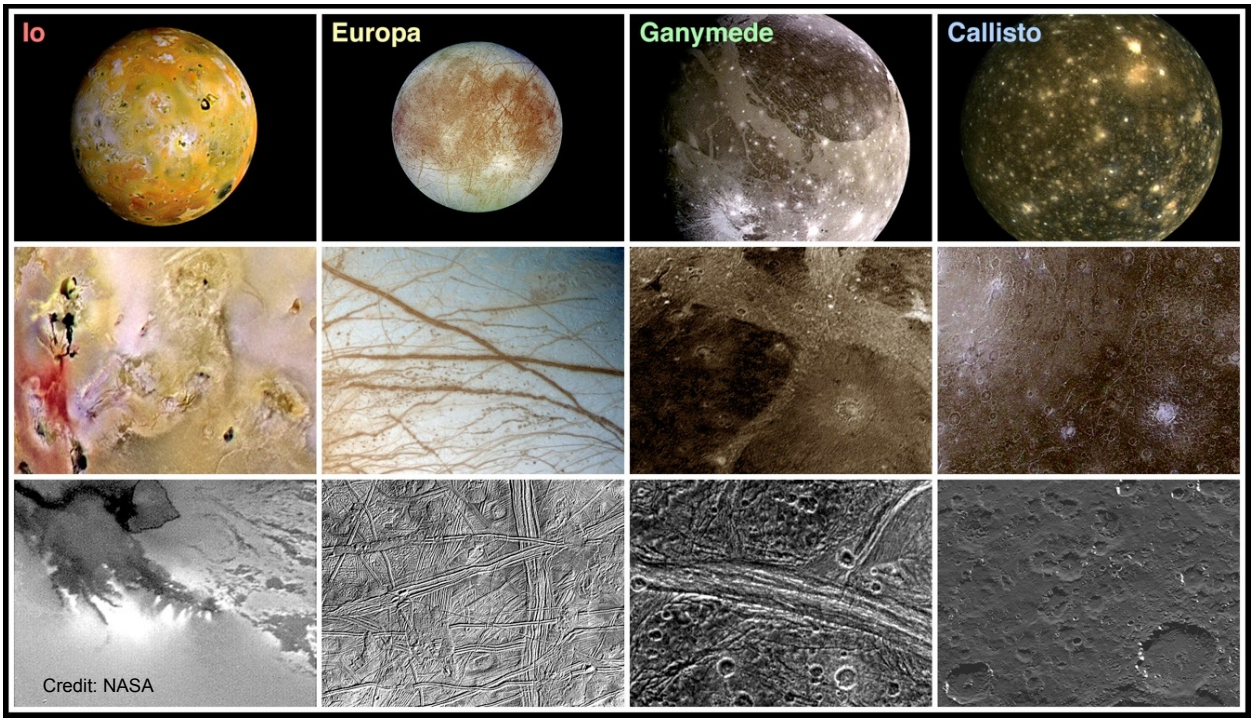
Despite its distance we have put at least three missions in orbit around Jupiter and done various flyby missions. Jupiter is made mainly of hydrogen and helium, just like the Sun. Jupiter has no solid surface. If we plunged into Jupiter, the pressure would crush us long before we reached the solid core.But we have dropped a probe inside Jupiter's and watched it descend as the image above shows. We temperature and pressure and composition until the probe got crushed by Jupiter's gravity.

Jupiter has about a dozen moons. And a thin set of rings. In fact, all the outer planets have rings, not just Saturn. Jupiter has them, Uranus has them, Neptune has them. They're not as prominent as Saturn's, but they all definitely have rings.

The four big moons of Jupiter were discovered by Galileo, so they are usually collectively called the Galilean satellites. Io, Europa, Ganymede, and Callisto. They are basically planets in their own right.

Io, shown in the images below is the most volcanically active body in the solar system. Kind of looks like a pizza. It shoots sulfur out of its many and frequent volcanoes. Although it's a relatively small body, it gets heated up so much that it has much vulcanism. Because its so close to Jupiter and has an elliptical orbit when Io is further away, it relaxes. When it gets close,

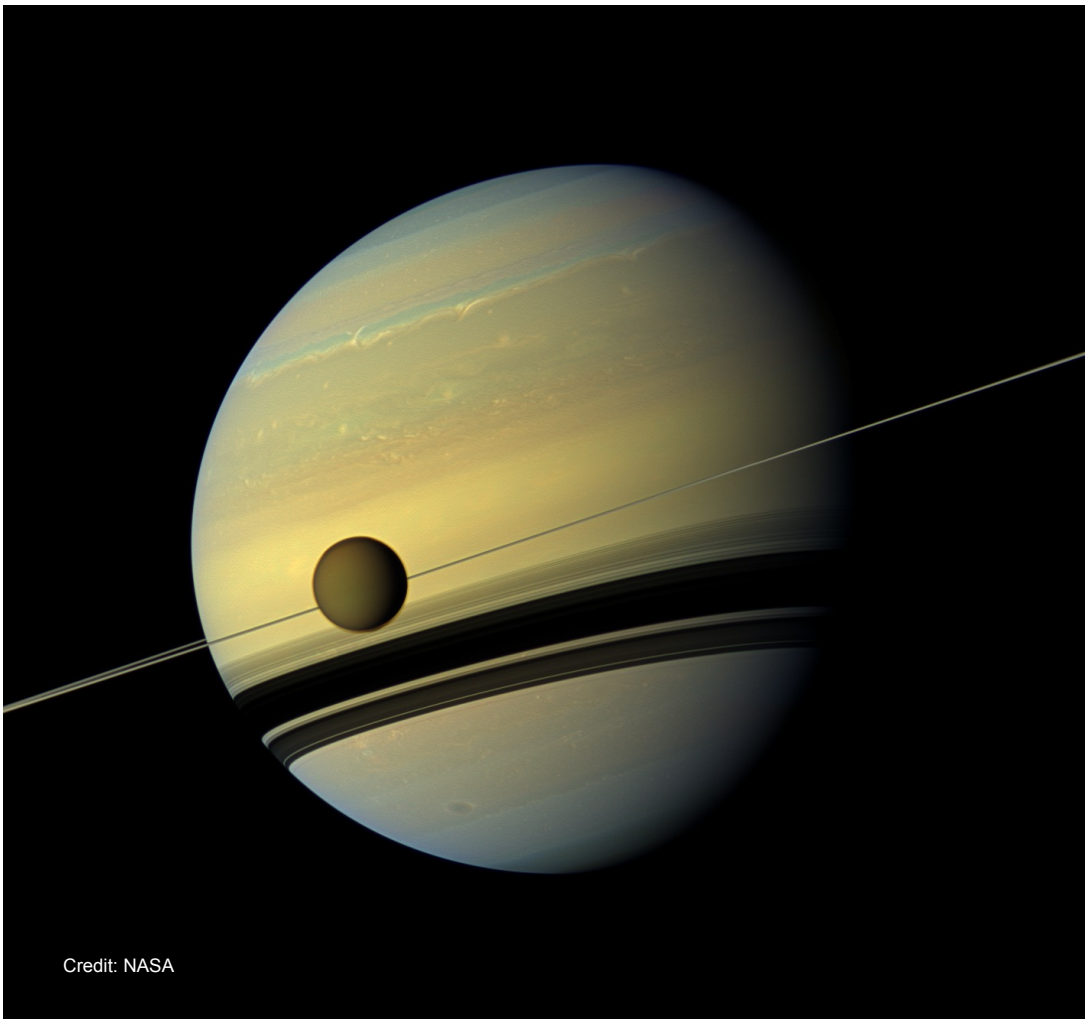
Io gets squeezed. This constant cycle of squeezing, relaxing, squeezing, relaxing heats up its interior a lot. And so it has volcanoes of sulfur spewing out all the time onto the surface.



Europa has an icy crust that may hide an ocean of liquid water. The water is liquid for the same reason Io is so geologically active, a continual cycle of flexing from tides generates heat. But because Europa is further away its not as extreme as for Io. Naturally this makes it a target in the search for life within our solar system. We are going to Europa in circa 2020! A probe will try to burrow itself down through the ice, probably through heat as opposed to drilling, to try and that subsurface liquid water.

Ganymede is also believed to harbor a subsurface ocean but probably has a much thicker ice crust since its further from Jupiter and the heating from tides smaller.

Callisto is mysterious; why it is so dark colored and yet where there are impact craters, there's this white stuff beneath it.



Ok, Saturn. Saturn is also made out of hydrogen and helium. Its a tad smaller than Jupiter but has about 1/3 the mass. So Saturn is fluffy enough that its density is less than one gram per cubic centimeter, the density of water. If you had a big bathtub, Saturn would float!

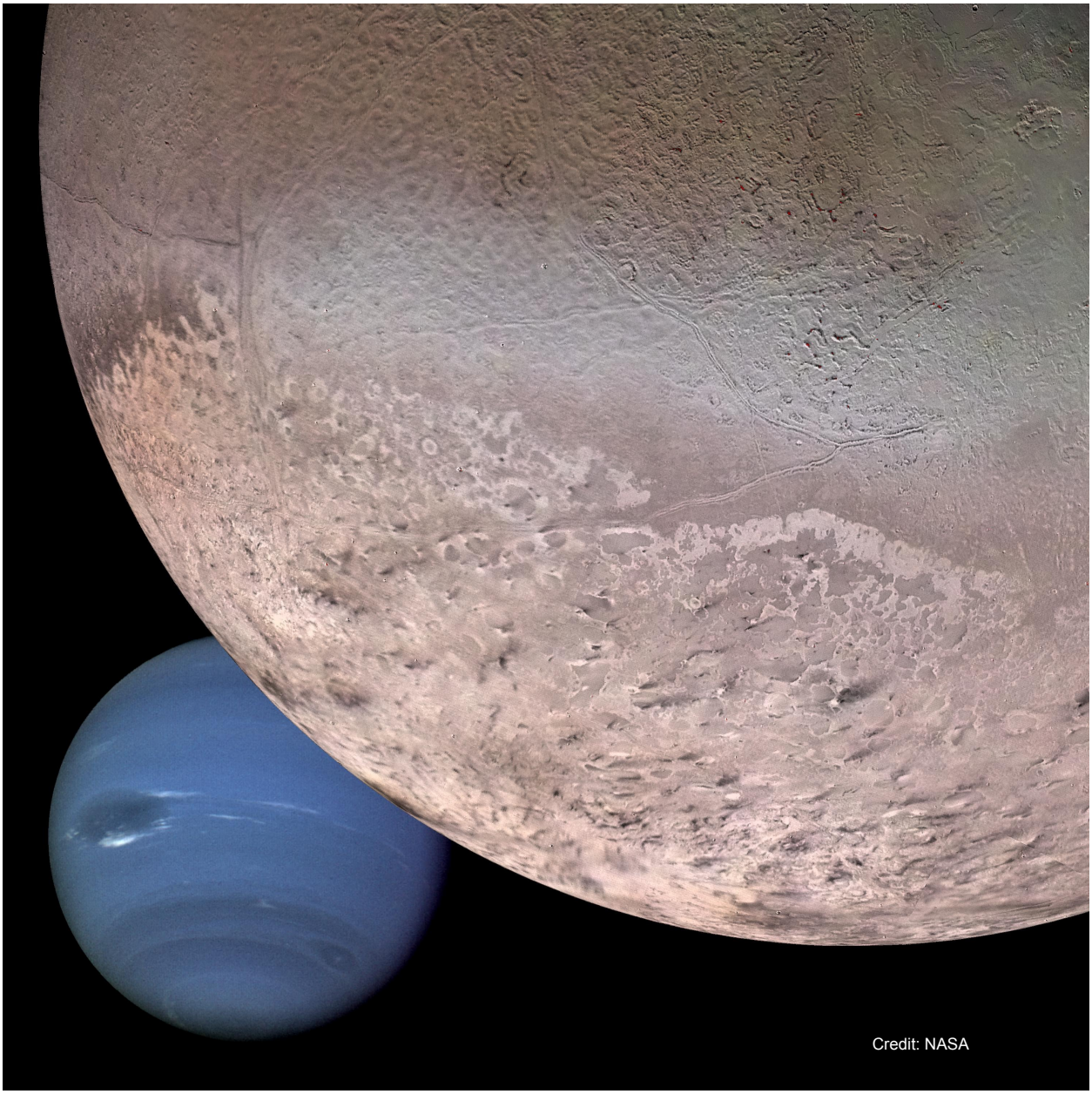
Saturn's rings are not solid. They're made out of countless chunks of rock and ice from little grains to boulders. When we say dust grains, we means particles size like what you find like in smoke - on the order of about a few microns, a few times 10^{-6} meters. By boulders we mean up to about the size of city blocks. Regardless of size, each is orbiting Saturn like a tiny moon. Saturn’s rings, as suggested by the image above, are incredibly thin relative to their size.

Saturn also has an interesting moon — Titan. We've actually landed a probe onTitan - the only other moon in the solar system besides our Moon that we’ve landed upon.What makes Titan intriguing is that it has a solid surface and it a whole lot of liquid hydrocarbons - compounds like ethane, methanes - in the form of lakes on the surface. In crude terms, it's the gasoline planet! The hydrocarbons could potentially be used as a fuel source, sort of a gas station, on trips to the outer solar system!

It's looong journey to out to Uranus - twice as far from the Sun as Saturn. Uranus is much smaller than Jupiter, but much larger than Earth. It also has, as you can see in the image below, has a ring system. It's darker than Saturn's, but a very prominent one, nonetheless. Like all of the outer planets, it's composed primarily of hydrogen and helium. But it's cold enough now, you can start making hydrogen compounds, stuff like ammonia and methane and water. It's tthe methane that gives Uranus it's pale blue-green color. More than two dozen moons that orbit Uranus.

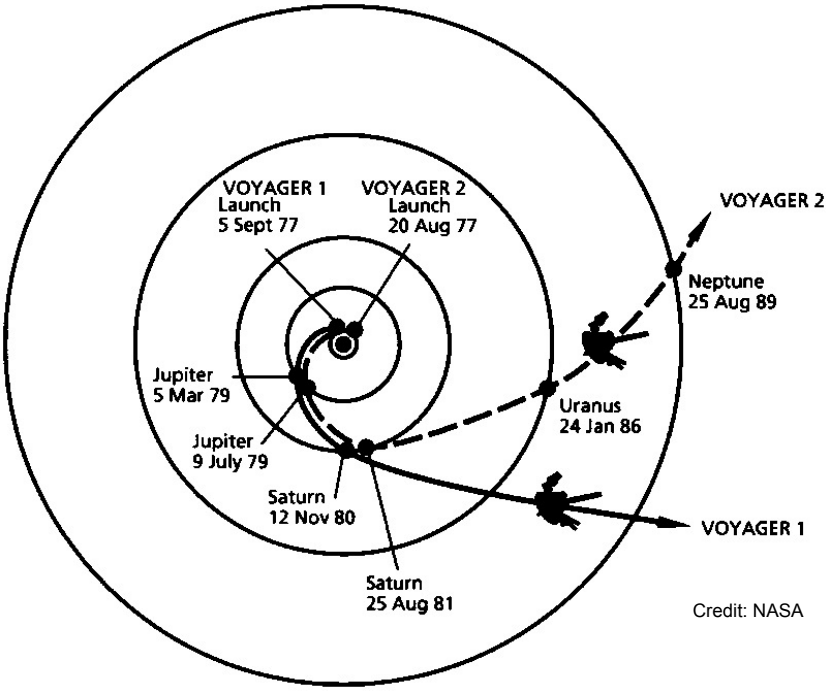
An amazing thing about Uranus, is that its tipped on its side. Most of the planets have their rotation axis pointed north, general perpendicular to their orbit. But Uranus. rotation axis is clode to its orbital plane, almost 90 degrees away from north. This is probably from a cataclysmic collision that tipped Uranus all the way over on its side.

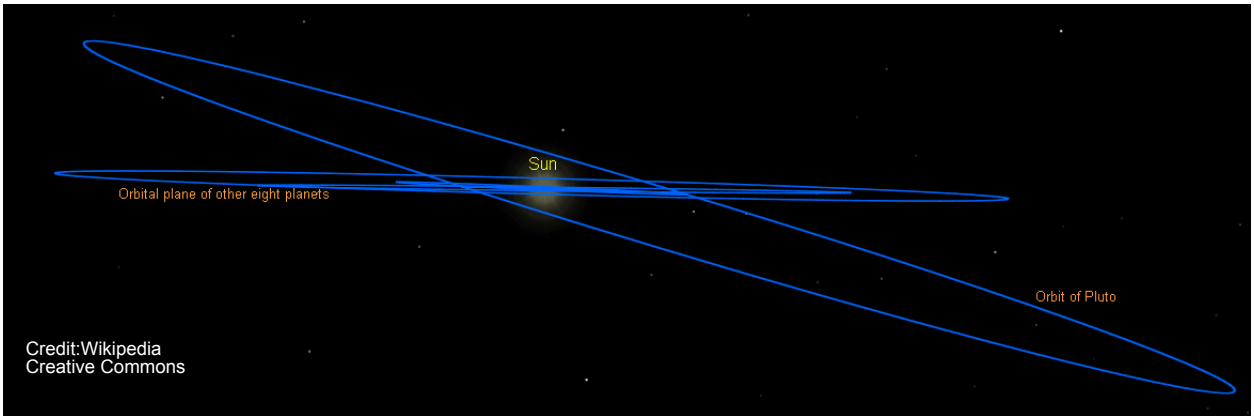
I like moon called Puck too.



Neptune looks like a twin of Uranus, although it is more strikingly blue even though the planets share similar compositions. It has a deeper darker blue because of the lower temperature and the amount of methane. Neptune's largest feature is its dark ring system. It also has a recurring large-scale storms in ints atmosphere, kinda like Jupiter’s except its called he Great Dark Spot.

Neptune has a fun moon - Triton. It's larger than Pluto, and it's perhaps one of the most geologically fascinating moons in the solar system. Although it's very cold out there, it has very active very geology. There are ice geysers shooting out methane plumes! This makes it a potentially interesting object for life in the solar system. Life ’s “rate” is going to be a lot slower out there because it's colder. There is a lot of interest in visiting Triton in the future.



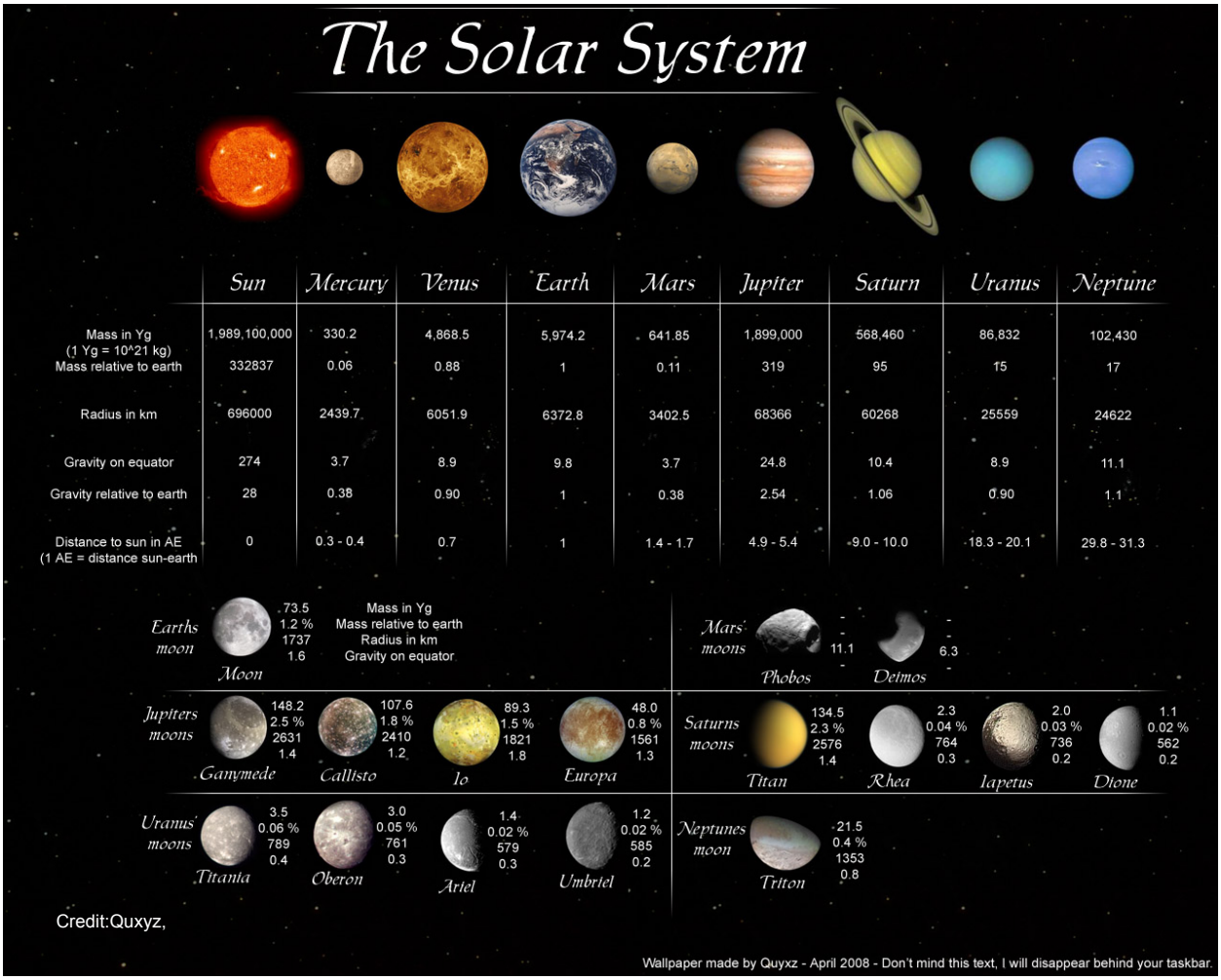


Most of what we know about Uranus and Neptune came from the Voyager II mission, launched in the 1970s, which flew past all four of our gas giant planets before heading out of the solar system. Its trajectory is shown in the image above. These days the Voyager I and Voyager II missions have now left influence of the Sun. They're enter interstellar space, out for a journey amongst the stars. These are the furthest manmade objects from Earth.

And finally good old Pluto. At its distance from the Sun, Pluto is cold and dark, the Sun being a little brighter light among the stars. We've known for years that Pluto is very different from the first eight planets. It's much smaller. It's much less massive. Its got a much more eccentric orbit that is significantly inclined to the ecliptic plane as shown by the image above.Its composition is also a lot different. It's mainly ice and dust. It's quite different from the other outer planets but very similar to that of many known comets.

Pluto, spectacularly imaged above in 2015 by the New Horizons mission, is a cute reddish orb with a wild active ice geology. But it is not a planet.

An object is defined to be a “planet” if it 1) is in orbit around the Sun; 2) has sufficient mass to become nearly spherical; 3) has cleared its orbital neighborhood. The third criteria is where Pluto falls down. There are about half a dozen or so other objects that are Pluto’s size or larger that are found orbiting at about the same distance. So Pluto hasn't completely cleared out its neighborhood. So we call Pluto a dwarf planet. But that's fine because Pluto was always kind of the odd ball out. Now Pluto has found a home with other family members!



Having completed our whirlwind tour of the solar system we can begin to compare the properties of the planets, asteroids, and comets in our solar system come of which are given in the image above. What patterns are there and how to we explain those patterns?

See you soon! Bye Bye.