Jupiter's Moons: Crash Course Astronomy #17

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(0:05) As we saw in the last episode, Jupiter is by far the largest and most massive planet in the solar system. That means it has a very strong gravitational field, which also means it can hold on to a lot of moons. A lot!!

Right now as we record this episode, there are 67 that have been confirmed. And how many it really has depends on how small an object you are willing to call a "moon".

(Intro music)

(0:38) In 1610, Galileo pointed his telescope at Jupiter and witnessed a revolution. Oh, hey, literally!

He saw three little stars, lined up on either side of Jupiter, stars he could not see with his naked eye. And they moved. A week later, he saw a fourth one! And he knew he was seeing objects revolving, orbiting around Jupiter. It was proof that not everything in the solar system revolved around the Earth. That was a pretty big deal. Those four moons are now called the Galilean moons in his honor. Not bad for a week's work.

All four are really big, too. If Jupiter weren't there, drowning them out with its glare, they'd be visible to the naked eye. In that case, we might even call them planets, too.

The biggest of Jupiter's moons is Ganymede. At 5270 km across, it's the biggest moon of any planet. It's even bigger than the planet Mercury. In fact, in size, it's halfway between Mercury and Mars. Size isn't the only planet-like characteristic of Ganymede either. It's mostly rock and ice, but it probably has a liquid iron core. It even has a magnetic field, likely generated by that liquid core. The surface is similar to our own moon, in that there's very old crater terrain as well as smoother, younger areas.

Ganymede is also criss-crossed with large grooves. It's not clear, what the origin of those grooves is, but it may be related to stress and strain on the surface, caused by the tides from the other large moons as they orbit Jupiter and pass each other.

Ganymede has a surprise well below its surface, too: oceans of water. Measurements of Ganymede's magnetic field, made during multiple passes by the Galileo spacecraft in the 1990s, combined with Hubble observations of the moon, indicate Ganymede has quite a bit of salty liquid water, deep beneath its surface! As we'll see in a sec, it's not alone in that regard.

The next biggest moon is Callisto, at 4800 km in diameter. In many ways, it's similar to its big brother Ganymede, mostly rock and ice. It probably has a rocky core, then a layer of mixed rock and ice above that. The surface is mostly ice, but mixed with darker material as well. It has a magnetic field too, but it probably doesn't have a metallic core. The surface is heavily cratered, and there's no indication of any volcanoes or tectonic activity. That means the surface is very old, maybe as old as Callisto itself. It even has an atmosphere, but it's a tad thin: roughly one one-hundred-billionth the pressure of Earth's air at the surface.

Callisto orbits Jupiter farthest out of the four biggies, almost 2 million kilometers away. That's too far to gravitationally interact with the other three. When I talk about the moons affecting each other, it's really the other three interacting.

Next up is Io, it's only a little bit bigger than our own moon and orbits Jupiter so tightly, it only takes about a day and a half to go around the planet. When the Voyager I space probe passed Io in 1979, it revealed a surface that was really weird. It was yellow and orange and red and black, and didn't seem to have any obvious impact craters. An engineer, Linda Morabito, noticed that in one image there appeared to be what looked like another moon behind Io, partially eclipsed by it. But that was no moon! It was a volcano on Io erupting, its plume shooting up from the surface and opening up into a wide arc.

Io is the most volcanic object in the entire solar system, with over 400 active volcanoes. Quite a few of them are erupting at any given time, and images taken even a few months apart show changes in the surface due to ejected material. A lot of the erupted material is rich in sulfur, which is why the surface has all those odd colors on it.

The energy for all this activity comes from the other moons. As they pass Io in their orbits, they flex it via tides, heating its interior through friction. A lot of that sulfur ends up as a very thin atmosphere around Io, and some of those sulfur atoms are then picked up by Jupiter's powerful magnetic field as it sweeps past Io and accelerates them to very high speeds. This has created a tremendous donut-shaped radiation belt around Jupiter, like Earth's Van Allen belts, but far more powerful. The radiation there is so intense, it would kill an unprotected human in minutes. Of course, if you're floating in space near Jupiter unprotected, you might have some more immediate concerns.

Oh, one more thing: both Ganymede and Io are magnetically connected to Jupiter. Charged particles flow from those moons along the lines of magnetism to Jupiter, which then slams them down at Jupiter's poles, just like the Earth does with the particles from the solar wind. On Earth, this creates the aurorae, the Northern and Southern Lights, and it does at Jupiter, too. You can even see the ultraviolet glow where each of the moons connects to Jupiter, their magnetic footprints in the planet's atmosphere.

And now we come to Europa, the smallest, but perhaps the most exciting of all the Galilean moons. Slightly smaller than our moon, it was known for decades to be very reflective, meaning its surface was probably loaded with water ice, but even so, the Voyager observations were shocking. They showed a surface completely lacking in craters, meaning something had resurfaced the moon, like Io or Venus.

But Europa has no volcanoes. Even more intriguing, the surface was covered in long cracks, dark streaks all over the moon, as well as complex ridges. These and other features appear to be due to material from the interior of Europa welling up and forming the new surface, kind of like the way lava does on Earth. But in this case, the material is water.

It's now thought that Europa has an entire ocean of water sealed up under a solid crust of ice several kilometers thick. Water welling up and moving under the crust causes it to shift, creating all the various surface features. The amount of water that may be locked up on Europa is staggering, easily more than all the water in all the oceans on Earth. Like Ganymede and Io, the interior of Europa is kept warm by tidal flexing from the other moons, keeping the ice melted.

Now get this: a lot of Europa's material is silicate rock, like on Earth and other terrestrial planets, located in a layer under the ocean. If this interacts with the ocean in the same way Earth's oceans interact with the sea floor, this could make the subsurface Europan water salty. In fact, those dark cracks on the surface have been found to be rich in salt and organic materials, in other words, carbon-based compounds. This is pretty exciting! We think Earth's life originated in salty ocean water. If there are carbon-based molecules actually in Europa's water, it's not too crazy to wonder if the same spark that occurred here also happened there. We think Europa has everything it needs to spawn life. We just don't have any direct

evidence of it yet.

Some people have proposed sending a space probe to Europa specifically to look for life. It would land near a crack in the ice where the crust is thinner and somehow penetrate it, perhaps melting its way down. Chemical sampling could then look for signs of biological activity. That's amazing to me! The idea of life in Europa, even if it's just microbial life, is taken very seriously by astrobiologists, scientists who study the possibility of life in space. It used to be science fiction. Now it's a topic of scholarly research.

Astronomers have a concept called the habitable zone, the distance a planet can be from its parent star where the temperature in the planet's surface can support liquid water. It's a fuzzy concept. Venus and Mars are both technically in the sun's habitable zone, but Venus is too hot, and Mars too cold, for liquid water. Atmospheres make a big difference. But it's still a useful concept as a rule of thumb for potential habitability.

But Europa changed that. Jupiter is way, way outside the sun's habitable zone, yet there's Europa, all wet. It's a great example that we need to let our ideas breathe a bit sometimes, let them relax and flow outside the boundaries we set for them. When we look for signs of life on planets orbiting other stars, I bet we'll have to keep our minds open to types of life we've never considered before.

Those are just the four big moons of Jupiter, each thousands of kilometers across. They probably formed along with Jupiter, coalescing from the eddies and whorls around the proto-Jupiter, as it formed billions of years ago. But the planet has dozens of other moons too. About the only thing they all have in common is that they're tidally locked to Jupiter. They all rotate once for every time they go around the planet. Jupiter's tides are hundreds of times stronger than Earth's, so no surprise there.

The next biggest moon after the big four is way smaller. Named Amalthea, it's an irregular lump about 250 kilometers across at its longest dimension. It was discovered in 1892, and it's red, probably polluted by sulfur from Io. It orbits just over 100,000 kilometers from Jupiter's cloud tops. If you stood on Amalthea's surface, Jupiter would fill half the sky.

The moons get smaller and more irregularly shaped from there, with Himalia and Thebe and Elara and Pasiphae, down to Hegemone and Kale and Kallichore, which are no bigger than hills. Many of irregular, distant moons of Jupiter orbit the planet backwards relative to the others, in what are called retrograde orbits. They may be captured asteroids from the nearby asteroid belt.

Many of the moons have orbital characteristics that are very similar too, which may indicate that they were once a single object that broke up. Several such families of moons orbit Jupiter. The smallest moons we've seen are roughly a kilometer across. If they were sitting on Earth, they might be hard to pedal up on a bicycle, but orbiting Jupiter, they hardly rate as more than debris. There are probably thousands of moons the size of houses circling the planet. And who knows, maybe millions the size of tennis balls.

Should we even call those moons? Ehh, maybe. But I don't really worry about that kind of thing. The important thing to remember is that these are worlds, big and small, each fascinating, rich, and diverse. And there's still a lot more left to explore about them.

Today you learned that Jupiter has lots of moons, and four big ones. They're mostly rock and ice, though Ganymede, the biggest, may have an iron core. Io is riddled with volcanoes, and Europa has an under-surface ocean that is the object of intense study for scientists looking for life in space. Io, Europa, and Ganymede are close enough to interact gravitationally, providing a source of heat for their interiors. There are lots and lots of littler moons, but at the moment, we really don't know much about them. Someday!

Crash Course Astronomy is produced in association with PBS Digital Studios, and you can head over to their channel and find even more awesome videos. This episode was written by me, Phil Plait. The script was edited by Blake De Pastino, and our consultant is Dr. Michelle Thaller. It was directed by Nicholas Jenkins, edited by Nicole Sweeney, and the graphics team is Thought Cafe.