Uranus & Neptune: Crash Course Astronomy #19

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Uranus. You run us. YOU run us. You RAN us. OOO ran ose.

There are five planets in our solar system you can see without a telescope; well, six if you include the one you're sitting on. But there are two more big ones out there, orbiting the Sun out in the cold depths of the outer solar system: Uranus and Neptune. They're a lot alike in many ways, but of course they have their individual quirks.

Uranus was the first planet to be discovered, and by that I mean it wasn't known in ancient times. It took an astronomer with a telescope to find it. In 1781, William Herschel was mapping the skies through his telescope when he spotted a greenish object that was clearly a disk and not a dot, like a star. He noted its position, and moved on. But when he went to observe it again sometime later, he was astonished to discover it had moved!

It was quickly determined to be a planet, more distant from the Sun than Saturn. In true brown-nosing style, he named it Georgium Sidus, or George's star, after the reigning king George III. Yeah, happily, that name didn't stick, and keeping with the nomenclature of Roman gods, the new planet was dubbed Uranus.

Interesting tidbit: It actually is visible to the unaided eye if you have very sharp eyesight and very dark skies. It's right on the thin hairy edge of visibility. What's funny is that several people had observed it before Herschel, but none had noticed its movement. Some even catalogued it on their maps as a star!

The planet is massive—about 14.5 times the mass of Earth—but not terribly dense. This means its interior must be made of lightweight stuff. Scientific models of the planet based on physics and chemistry of the outer solar system indicate its interior is probably made up of three general layers.

There's a small rocky core, smaller than Earth, surrounded by a very thick layer of materials like water, ammonia and methane. This mantle makes up the bulk of the planet, in fact, and is dense, hot, and under a lot of pressure. In many ways, it's more like an ocean than anything else. However, somewhat confusingly I'll admit, outer solar system planetary scientists refer to water, ammonia, and methane as "ice," so even though it's not ice like we usually think of it here on Earth, we say that the mantle of Uranus is "icy." To distinguish it from the gas giants Jupiter and Saturn, Uranus is called an "ice giant."

Speaking of "ice," here's a really weird thing: Studies have shown that the pressure inside Uranus can break up methane molecules, squeezing the carbon in them so tightly that it actually forms diamonds! These would then fall down to the base of the mantle like sparkly hailstones. Except it's dark. But still, down there in the depths of Uranus there may even be an ocean of liquid diamonds, where solid ones float like, um, diamondbergs.

Not that we'll ever see that. When we observe the planet, we're only seeing the top of its atmosphere. Besides hydrogen and helium, the air there is about 2% methane. Methane is really good at absorbing red light, which means the light we see reflected from Uranus is mostly green and blue, making the planet look distinctly cyan or aquamarine. And it's pretty striking through a telescope.

But in visible light the planet looks almost featureless. It doesn't have the deep banding like Jupiter, or even the pale ones of Saturn, though when you look in the infrared some banding can be seen.

There are clouds, but again they're difficult to see in visible light. The clouds are made of methane, ammonia, and hydrogen sulfide—that last one is what makes rotten eggs smell so bad. I'd avoid breathing through your noise at Uranus.

But then, the atmosphere there is negative 220 Celsius, so that might be a better reason not to inhale.

In late 2014, a bunch of storms popped up in Uranus's atmosphere, so big and bright they were easily visible from Earth. The storms may have dredged up very reflective methane ice from lower down in the atmosphere -- and this time, I do mean icy ice -- which is why they were bright. The northern hemisphere of Uranus is approaching summertime, which may be why these storms formed.

And that brings us to the weirdest thing about this planet: It's sideways!

If you were above the Earth's north pole looking down, you'd see our planet spinning counter-clockwise, west to east. The Sun spins that way, and all the planets do as well… except Venus and Uranus. While Venus is flipped all the way over, Uranus is tilted by about 98°. That means that in the summer, its axis is pointed almost directly at the Sun, so seasons on Uranus are pretty extreme, by outer solar system standards.

Weird.

No one knows why Uranus is tipped so much. An obvious thought is that it got whacked, hard, by an impact long ago. If it were a grazing collision by a BIG object, that could have pushed hard enough on the planet to tip it over.

Unfortunately, Uranus is very far away, and has only been visited by spacecraft once—Voyager 2, in 1986—and even then it was a quick flyby. Uranus's weird tilt is just one of those many mysteries that astronomers are trying to solve with limited data.

Uranus has a magnetic field, but it's truly odd: Its axis is tipped by over 50° from the planet's spin axis, and it's way off-center; the center of the magnetosphere is about 8000 km from the planet's center. It may be that the magnetic field is generated in the icy mantle, or that the core somehow interferes with the magnetic field, throwing it off. Truthfully, no one really knows why.

Uranus has more than two dozen moons; five big ones and a bunch of dinkier ones. Cool fact: The moons are named after characters in Shakespeare plays. So we have Ariel, Umbriel, Titania, Oberon, and Miranda. Even Puck!

Of them all, I think the most interesting one is Miranda. When Voyager 2 flew past, it revealed an icy world that looks like it was put together by Dr. Frankenstein: a patchwork of jumbled terrains all crammed together, criss-crossed by canyons and grooves. It's possible a giant impact in it past actually disrupted the moon somewhat, and it settled back together into this weird mishmash.

But the reason I like it so much is a feature called Verona Rupes: It's the tallest cliff in the solar system, 5 to 10 kilometers high. If you jumped off the top, it would take you six minutes to fall to the surface! That would be a fantastic ride.

Like Jupiter and Saturn, Uranus has a ring system, too. They were discovered by accident in 1997; astronomers were observing Uranus pass directly in front of a star. They were hoping to use this to gather information about the planet's atmosphere as starlight passed through it. But they saw several dips in starlight before the main event, which they realized were from rings around the planet.

The rings are made of dark particles, probably ice and reddish

organic molecules. There are 13 rings known, most of them are very faint and narrow. They may have been created by an impact completely shattering a small moon orbiting Uranus, but as for now, the ring origins are unclear.

And then, finally, we have Neptune, the guardian of the solar system's nether regions. Neptune is an ice giant, like Uranus, and has a lot of similarities. Like its green brother, it probably has a rocky core surrounded by a thick icy mantle of water, ammonia, and methane. Above that is an atmosphere of hydrogen, helium, and methane.

But there are differences, too. Neptune is more massive than Uranus; 17 times Earth's mass, versus just 14.5 for Uranus. Neptune is slightly smaller than Uranus, which means it's a lot denser. Also, while Uranus is teal, Neptune is a deep, rich azure—I like to call it "the other blue planet", the first one being, y'know, Earth. Through a telescope, Neptune's color is quite lovely. It has roughly the same amount of red-light-absorbing methane in its atmosphere, as Uranus does. So its deeper blue hue is something of a mystery.

That may have to do with its active atmosphere. Unlike blander Uranus, Neptune has clouds of methane, ammonia, and hydrogen sulfide lying the skies at different depths, and white streaky clouds were seen during the Voyager 2 flyby in 1989. They looked whipped by wind, and for good reason: Sustained wind speeds in Neptune's atmosphere have been clocked at over 2000 kph: Faster than the speed of sound on Earth! It's thought that the low temperatures in the atmosphere reduce friction, allowing the winds to gather to such amazing speeds.

Voyager saw a huge storm marring Neptune's face, called—for some reason—the Great Dark Spot. A few years later, when Hubble was used to observe the planet, the spot was gone, but others had appeared. They're probably vortices, cyclones, which allow us to see through the upper atmosphere and peer farther into Neptune's depths.

Neptune has a magnetic field, and like Uranus, it's offset from the planet's center. Perhaps that icy mantle is at work, somehow interfering with the generation of the magnetic fields in both planets.

Neptune has rings, too, but SHOCKER, they're weird. There are three main rings; two narrow and one broad. They're clumpy, and have bright stretches that make the rings look more like incomplete arcs. It's possible those arcs are being constrained by small moonlets near the rings.

Speaking of which, Neptune has over a dozen known moons. Most are quite small, but one, Triton, is by far the largest. At 2700 kilometers across it's smaller than our own Moon, but the rest of them are really dinky. Triton orbits around Neptune backwards, retrograde. As we'll learn in a future episode, there's a repository of giant iceballs out past Neptune, so Triton was probably one of those that got too close to Neptune and was captured by its gravity.

Most of what we know about Triton came from a single flyby of Voyager 2 in 1989, and only about 40% of the surface was seen. But this quick glimpse revealed a weird little moon. The surface is covered in nitrogen ice, as well as water and carbon dioxide ice. It's really flat, and has very few craters, meaning something resurfaced it in geologically recent times. Most likely this was from cryovolcanoes, cold volcanism; that is, volcanoes where water and ammonia take the place of lava there.

Also, Triton has been seen to have active geysers of nitrogen erupting from its surface! They're probably due to warming from the Sun, and they make Triton one of the few objects in the solar system seen to be geologically active. It also has a very thin atmosphere of nitrogen, probably due to evaporation from the surface.

After all this, Neptune is special in another way, too.

Neptune is faint, and can only be seen telescopically. It was discovered in 1846, and it wasn't an accident. Over the decades, astronomers observed Uranus, and found something weird: It wasn't where it was supposed to be. Over time, its predicted position was off from where it actually was. The French mathematician Urbain Le Verrier concluded that this was due to an unseen planet, and was able to use the mathematics of orbital mechanics to predict where the new planet would be. He sent a letter with the predicted position to the Berlin Observatory. Astronomer Johann Galle read the letter, went right out and found the planet that very night. Neptune was within a degree of the predicted spot.

Amazingly, another mathematician, Englishman John Couch Adams, had also worked on the math and had made a similar prediction -- but Le Verrier beat him by two days.

Two. Days. Of such tight races are fame made in science.

Interestingly, over time, Neptune seemed to wander from its predicted position as well. A ninth massive planet was predicted, leading to a grand search that resulted in the discovery of Pluto. But Pluto was far too small to affect Neptune. When Voyager passed both Uranus and Neptune, it found the masses of the planets were different than what had been measured from Earth. When the new masses were used in the orbital equations, Uranus and Neptune were right where they were supposed to be. It helps to have the right numbers to plug into your equations.

Pluto, therefore, was found by accident. That means Neptune is the only planet in the solar system found via math.

See? Your algebra teacher was right: Someday this stuff will be important.

Today you learned that Uranus and Neptune are ice giants, with small rocky cores, thick mantles of ammonia, water, and methane, and atmospheres that make them look greenish and blue. Uranus has relatively dull weather, while Neptune has clouds and storms whipped by tremendous winds. Both have rings and moons, with Neptune's Triton probably being a captured ice ball that has active geology.

Crash Course Astronomy is produced in association with PBS Digital Studios. Head on over to their YouTube channel for even more cool 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, and our editor and script supervisor is Nicole Sweeney. The sound designer was Michael Aranda, and the graphics team is Thought Café.