Jupiter: Crash Course Astronomy #16

Crash Course: Astronomy
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As we take our grand tour of the solar system here on Crash Course Astronomy, weâ€™re going to skip over the asteroids for nowâ€"weâ€™ll get to â€˜em, I promiseâ€"and instead pay a visit to the King of the Planets, the big guy, the top dog, the big cheese, the head honcho, the one and only: Jupiter. Jupiter is the largest planet in the solar system. Itâ€™s not even close: All the other planets could fit inside it with room to spare. Itâ€™s a gas giant, which means itâ€™s gassy, and...giant. And I do mean giant. Itâ€™s 11 times wider than Earthâ€"more than a thousand Earths could fit inside it, and it has a mass over 300 times that of our planet. Despite its bulk, it rotates extremely rapidly: One day on Jupiter is a mere 10 hours long! Thatâ€™s the fastest spin of any of the planets in the solar system. Not surprisingly, a planet that big can reflect a lot of sunlight, and even though it orbits the Sun on average at a distance of about 800 million kilometers, itâ€™s one of the brightest objects in the night sky. With binoculars or a small telescope, Jupiter is a wonder. You can easily see it as a disk, and its four biggest moons are readily visibleâ€"if they werenâ€™t hidden by the planetâ€™s glare, theyâ€™d be naked eye objects. Galileo himself discovered those moons. Theyâ€™re worlds in their own right, and so weâ€™ll dive into themâ€"literallyâ€"in the next episode. When we look at Jupiter weâ€™re not seeing its surface. Weâ€™re seeing the tops of its clouds, and theyâ€™re a strange mix of permanence and change. The atmosphere of Jupiter is banded, with multiple stripes running parallel to its equator. The lighter-colored stripes are called zones, and the darker ones belts. Theyâ€™re fairly stable, though their shape and coloring change over time. Belts and zones circulate around the planet in opposite directions. They form due to convection in Jupiterâ€™s atmosphere. Upwelling air cools and forms white ammonia clouds; that creates the light colored zones. That air flows to the sides and sinks, and sunlight changes the chemistry in the clouds forming molecules that color the air yellow, red, and brown. This is what causes the darker belts. In May of 2010, one of Jupiterâ€™s biggest belts sank so deeply it disappeared from view completely, covered by other clouds! Then, a few months later, it popped back up and reappeared, none the worse for wear. This has happened several times in the past, too. I saw one of these events once through a telescope, and Jupiter looked really weird. Lopsided. Turbulence in the regions between zones and belts can create storms, gigantic vortices raging in the clouds. Dozens of them dot the face of Jupiter all the time, but there is one to rule them all: the Great Red Spot, a fittingly huge storm for a giant planet. Itâ€™s actually a colossal hurricane, several times larger than our entire planet Earth, with sustained wind speeds of 500 kph. And itâ€™s old; it was first seen in the late 17th centuryâ€"imagine a storm on Earth lasting for more than three centuries! And it may be far older; the 1600s is just when we firstâ€¦ spotted it. So, why is it so stable? It turns out that a vortex, a local spinning region in a fluid, can persist if the fluid in which itâ€™s embedded is itself rotating. Jupiterâ€™s rapid spin is what keeps the Red Spot circulating! And the redness is probably due to cyanide-like molecules that absorb blue light, letting redder light pass through. Weirdly, the Red Spot appears to be shrinking! It was substantially bigger and more elongated just a few decades ago. It changes color over time, too, having gone from deep red to salmon and then back again. No one knows why its shape, size, and color change, but given how long the Spotâ€™s been around, I doubt itâ€™s going to evaporate any time soon. Remember, weâ€™re only seeing the tops of the clouds on Jupiter. Its atmosphere is thick, several hundred kilometers deep! Like the composition of the Sun, the air on Jupiter is mostly hydrogen and helium, but itâ€™s also laced with ammonia, methane, and other poisonous gases. As you dive into Jupiterâ€™s atmosphere, the pressure increases with depth. But youâ€™ll never reach the surface; the planet doesnâ€™t really have a proper surface. The gas gets thicker and hotter, and eventually just sort of smoothly changes into a liquid over a several hundred km range below the clouds. Below that is where things get really weird. Instead of a mantle, like terrestrial planets, Jupiter has a huge region made up of liquid metallic hydrogen. We think of hydrogen as being a gas, or, if it gets really cold, a liquid. But under the ridiculous pressures generated deep inside Jupiter, hydrogen undergoes this strange transformation. Individual atoms donâ€™t hold on to their electrons, but instead share them. This means the hydrogen can conduct electricity, and has other properties more like a metal. This substance is hot, too: about 10,000Â° C, hotter than the surface of the Sun! If we could see it, it would glow tremendously bright. Finally, at its center is most likely a dense core of material, probably composed of rock and metal. We really donâ€™t know, because itâ€™s incredibly difficult to understand the physics and chemistry of material locked in at those pressures and temperatures. Whatâ€™s weirder is that weâ€™re not even sure if Jupiter has a core! If it did, itâ€™s possible it was eroded away by currents of hot metallic hydrogen early on in Jupiterâ€™s formation process. Itâ€™s also possible it never had a core in the first place. The solar system formed from a flat disk of gas and dust. The center of this disk is where the Sun was born, and itâ€™s thought that the planets formed as smaller particles of material stuck together during random collisions farther out in the disk. As they got biggerâ€"much biggerâ€"these protoplanets eventually started to grow even faster by drawing in material around them due to their gravity. Jupiter formed where the disk was thick, rich with material. Itâ€™s possible that several large protoplanets were forming, collided, and stuck together to really kickstart Jupiterâ€™s growth. If that were the case, it started out with a rocky metallic core, and once it got big enough it drew in that gas that made it the giant we see today. Another idea is that Jupiter didnâ€™t grow from the bottom up, but from the top down: The disk itself collapsed in several places to form huge, distended clumps. These then would have collided, stuck, and created the planet. If thatâ€™s the case, then Jupiter might not have a core at all. These two different mechanisms make different predictions about Jupiterâ€™s structure, and that means that, hopefully, we can eventually figure out which is correct by studying Jupiter more carefully. But at the moment we still donâ€™t know. Either way, Jupiter grew immense, and itâ€™s mostly liquid under all that atmosphere. Couple that with its rapid rotation, and you can see itâ€™s noticeably flattened! Itâ€™s wider at the equator than through the poles by about 6% due to centrifugal force. So, Jupiter is a big bruiser of a planet. But how close was it to becoming a star? Sometimes, people ask me if Jupiter is a â€œfailed starâ€•; in other words, as it formed it almost got massive enough that nuclear fusion could start in its center, turning it into a star. I see this a lot on TV shows and in articles, and it really burns me up. When a star forms, hydrogen fusion starts when the star gathers so much mass that its gravity can compress atoms together in its core hard enough to get them to fuse. This happens when a star has roughly 1/12th of the Sunâ€™s mass. In fact, the smallest stars we see do have about that mass. What about Jupiter? The mass of Jupiter is about 1/1000th the mass of the Sun, far too little to undergo fusion in its core. If you want to turn Jupiter into a star, youâ€™d have a lot of work ahead of you: Youâ€™d have to take Jupiterâ€¦ and then add about 80 more Jupiters to it! Saying Jupiter is a failed star is really unfair. Itâ€™s not a failed star. Itâ€™s a really successful planet. Even though Jupiter isnâ€™t a star, it does have another funny property: It emits more heat than it receives from the Sun. The Earth and other terrestrial, rocky planets are in a heat balance with the Sun; we emit pretty much the same amount of heat that we receive. But Jupiter is different. After it formed, it started to cool by radiating away heat from its upper atmosphere. A large fraction of the planet is gas, remember, and when you cool a gas in contracts. So the atmosphere cools and contracts, but this increases the pressure inside the planet, so it heats up! That heat works its way out of Jupiter, and gets radiated away as infrared light. In the end, the amount of heat Jupiter gives off is more than it receives from the Sun. Itâ€™s still actively cooling, 4.5 billion years after it formed! Oh and hey, remember the belts and zones, the stripes we see in Jupiterâ€™s atmosphere, and all the storms that pop up? Those are driven in large part by Jupiterâ€™s internal heat. On Earth our weather is powered by heat from the Sun, but on

Jupiter they get their energy from the planet itself! Jupiter has a very strong magnetic field, no doubt due to all of that metallic hydrogen inside it coupled with its rapid rotation. Like Earth it has aurorae at its poles as the solar wind is funneled down to the cloud tops. As weâ€™ll see next week, Jupiterâ€™s moons affect the magnetic field and aurorae on Jupiter as well. Jupiter also has a ring, though itâ€™s not nearly as grand as Saturnâ€™s. It wasnâ€™t even discovered until we sent space probes to the planet. The ring is made of dust, probably thrown into orbit around the planet due to meteorite impacts on its smaller moons. Speaking of impacts, we know that Earth gets hit by interplanetary debris all the time: Go outside for an hour and youâ€™re bound to see a few meteors. Jupiter, being larger and with more gravity, gets hit a lot more. A lot. A lot more. And sometimes it gets hellaciously whacked. In 1994, the comet Shoemaker-Levy 9 impacted Jupiter. Multiple times: Jupiterâ€™s fierce gravitational tides had ripped the comet into dozens of pieces, and each slammed into the planet one after the other with the force of millions of nuclear weapons. The scars left in the upper atmosphere from the plumes of material that exploded outward lasted for months. Several smaller impacts have been seen in Jupiterâ€™s atmosphere since then, and it may suffer an impact large enough to see from Earth every year or so. And while that sounds scary, it might actually be our savior. Thereâ€™s an idea that Jupiterâ€™s gravity tends to take comets that fall toward the inner solar system and fling them away into interstellar space. Over the eons, this has cleaned out a lot of otherwise dangerous object that could have eventually hit Earth. On the other hand, Jupiter has a tendency to warp the orbits of some other comets so that they do swing by the Earth. Itâ€™s hard to say if Jupiterâ€™s influence is a net benefit or not. But either way, itâ€™s clearly the 2 septillion ton gorilla in the solar system. Today you learned that Jupiter is really, really big. Itâ€™s the biggest planet in our solar system, a gas giant. It has a dynamic atmosphere, including belts and zones, and a gigantic red spot thatâ€™s actually a persistent hurricane. Jupiter is still warm from its formation, and has an interior thatâ€™s mostly metallic hydrogen, and it may not even have a core. It has the fastest spin of any planet, and itâ€™s not a failed star. Crash Course Astronomy is produced in association with PBS Digital Studios. Head on over to their channel to discover 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 co-directed by Nicholas Jenkins and Michael Aranda, edited by Nicole Sweeney, and the graphics team is Thought CafÃ©.