The Oort Cloud: Crash Course Astronomy #22

Crash Course: Astronomy
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Well, look where we are now. With our backs to the Sun, and the planets, asteroids, and comets behind us, we face deep space. Thereâ€™s nothing between us and the stars, so terribly terribly far away. â€¦ or is there? The empty space past Neptune isnâ€™t exactly empty. In episode 21 I mentioned that comets come in two varieties: Those with orbital periods of less than 200 years, which tend to orbit the Sun in the same plane as the planets, and those with longer periods, which have orbits tilted every which-way. This is something of a problem: Comets lose material when they get near the Sun. Over the course of millions of years these comets should evaporate! And yet here we are, 4.56 billion years after the solar systemâ€™s birth, and comets still appear in our skies. So, where are they coming from? To see, weâ€™ll have to turn the clock back a wee bit - like, 4.5 billion years. Behold, our forming solar system. Coalescing out of a flat disk of material around the Sun, the inner planets were warmer, smaller, and rocky, while the outer planets were in a region that was colder, and grew huge. Out there in the chillier part of the solar system, water came in the form of ice mixed in with dust and other stuff. These bits would collide and stick together, growing bigger. Some grew to hundreds of kilometers across. But there was a problem: those outer planets. They had a lot of gravity, and any chunk of ice getting too close would either fall into the planet and get assimilated or get kicked into a different orbit. It could then plunge in toward the Sun, or get flung out into deep space. Trillions upon trillions of such iceballs got tossed around by the planets. Even though they were small compared to the planets, they did have a little bit of mass and gravity, so every time the planet pulled hard on them, they also pulled a little bit on the planets, too. It wasnâ€™t much per chunk, but after trillions of events this adds up! A current model of what happened, called the Nice model after the city in France where it was proposed, says that the overall effect of all these encounters was that Saturn, Uranus, and Neptune slowly moved outward from the Sun, while Jupiter moved inward. Neptune would have had the biggest effect on these iceballs, because it bordered the biggest volume of space where they lived. As Neptune migrated outward, close encounters with these chunks of ice flung lots of them into crazy orbits, highly elliptical and tilted with respect to the planets. Repeated more distant encounters tended to more slowly increase the sizes of the orbits of the iceballs, too. We think that this shuffling around of the outer planets is what caused the Late Heavy Bombardment, the intense shower of objects that came screaming down from the outer solar system, scarring planets and moons, a few hundred million years after the planets themselves formed. Itâ€™s not known for sure, but all the pieces fit together really well. In the end, today,there are three rather distinct populations of these objects. One is a region shaped like a puffy disk or a doughnut, aligned with the plane of the planets. Icy objects there have stable orbits, unaffected by Neptune. We call this the Kuiper Belt, named after the Dutch astronomer Gerard Kuiper, one of many who initially speculated about the existence of this region. The Kuiper Belt starts more or less just outside Neptuneâ€™s orbit, extending from about 4.5 to 7.5 billion kilometers from the Sun. The second region is called the scattered disk. This is composed of the iceballs sent by Neptune into those weird, highly tilted orbits. This overlaps the Kuiper Belt on its inner edge, and extends out to perhaps 150 billion kilometers from the Sunâ€”thatâ€™s 25 times farther out than Neptune. Finally, outside those two zones thereâ€™s a spherical cloud of icy objects which starts roughly 300 billion kilometers outâ€” 70 times farther out than Neptune, a staggering 2000 times the distance of the Earth from the Sun. And thatâ€™s just where it starts: It extends way farther out than that, perhaps as much as a light year, 10 trillion kilometers! This is called the Oort Cloud, after astronomer Jan Oort who first proposed it. The Oort Cloud is the origin of long period comets. Since they orbit the Sun on a sphere with no preferred orientation, they come in toward the inner solar system from random directions in the sky. Many newly discovered comets fall into this category. Their orbits can be extremely long; they start their fall from so far away they swing around the Sun at nearly escape velocity, and their orbits are close to being parabolic. The scattered disk is the source of short period comets. They can still be affected by Neptune, which can alter their orbits to drop them down closer in. They can orbit the Sun on paths between Jupiter and Neptune, meaning eventually theyâ€™ll have a close encounter with Jupiter. This can send them in closer to the Sun, and they become short period comets. Tadaaa! Thatâ€™s how comets are made. So how do we know all this? Well, until 1930 it was pretty much just conjecture. But then an American astronomer, Clyde Tombaugh, discovered the first Kuiper Belt Object: Pluto. Pluto orbits the Sun on an elliptical, mildly-tilted path. Its orbit actually brings it closer to the Sun than Neptune! So how come it never collides with the larger planet? Plutoâ€™s orbit crosses Neptuneâ€™sâ€¦ more or less. Because the orbit is tilted, they never actually physically cross. When Pluto is at perihelion, closest to the Sun, itâ€™s well above the plane of the solar system, far from Neptuneâ€™s orbit. Not only that, but Pluto orbits the Sun twice for every three times Neptune does. Because of this, whenever Pluto is closest to the Sun, Neptune is always 90Â° away in its orbit. Thatâ€™s many billions of kilometers distant, way too far to affect Pluto. This is mostly coincidence. Weâ€™ve seen how orbital resonances can be forced by tides and by gravity. But in this case itâ€™s due to attrition. Once upon a time, billions of years ago, there were probably a lot of objects out by Pluto, with orbits of all different shapes and tilts. But the ones that got too close to Neptune got gravitationally tweaked into different orbits, turning them into comets or flinging them deeper into space. The only ones that could survive just happened to have orbits with that 3:2 or 2:1 resonance with Neptune, keeping them far from Neptuneâ€™s influence. Today, those are the only kinds of objects we see with orbits near Neptune. We call these objects plutinos. Theyâ€™re not really a separate class of objectâ€”theyâ€™re still Kuiper Belt objects, but a fun and interesting subset of them. Once Pluto was found, astronomers wondered if it might herald a new class of icy objects past Neptune. However, it took more than six decades to find the next one! 1992 QB1 was discovered in 1992, and that opened a sort of gold rush of Kuiper Belt discoveries. We now know of more than a thousand Kuiper Belt Objects. One, called Eris, is very close to Plutoâ€™s size and is more massive â€” itâ€™s probably rockier than icy Pluto. Pluto is an interesting object. A moon was discovered in 1978. Named Charon, itâ€™s actually about 1/8th the mass of Pluto itself! While Charon orbits Pluto, the moon has enough mass that it can be said that Pluto noticeably orbits Charon, too. In reality, both circle around their mutual center of mass, located between the two. Four more moons were discovered in Hubble images of Pluto in 2005 and 2012. There may be more. Pluto is so small and distant that we donâ€™t know much about itâ€¦ but that may be about to change. [sighs] And now I have to admit to being in a tough spot. As I record this episode of Crash Course, a space probe called New Horizons is heading toward Pluto. It will fly by the tiny world in July 2015. Thereâ€™s no doubt our view of Pluto will change: There may be more moons discovered, weâ€™ll see surface features for the first time, and much more. But right now I canâ€™t tell you about any of that because we donâ€™t know yet. So I think the best thing to do is leave little Pluto alone for now. But there is a point I want to bring up. Pluto was found in 1930, long before any other Kuiper Belt Object, because itâ€™s much brighter than any other. When it was discovered, it was thought to be about the size of Earth. But over the years better observations showed it to be far smaller than first thought; in fact itâ€™s smaller than Earthâ€™s Moon! Its surface is unusually reflective, shiny, making it look much bigger than it seems. Most other Kuiper Belt denizens are far less reflective, and so are far fainter. If Pluto is King of the Kuiper Belt Objects, it has a lot of loyal subjects. We think the Kuiper Belt may have 100,000 objects in it larger than 100 km wide. If that sounds like a lot, get this: The Oort Cloud, surrounding the solar system, may have trillions of icy bodies in it. Trillions! While we know of lots of Kuiper Belt Objects, we donâ€™t know of any Oort Cloud objects for sure. Two very interesting bodies have been

found: Sedna, and VP113. Sednaâ€™s orbit takes it an incredible 140 billion km from the Sun, while VP113 gets about half that far out. Both are on very elliptical orbits. Neither, however, gets close to Neptune, so itâ€™s not at all clear how they got where they are. They may be Oort Cloud objects that were disturbed by passing stars long ago, dropping them closer into the Sun. But no one knows. Yet. Speaking of whichâ€¦ we can calculate how many Oort Cloud objects there should be left over from the formation of the solar system, and itâ€™s about 6 billion. However, calculating how many there are using long period comet observations, you wind up getting about 400 billion. Thatâ€™s a big discrepancy! Now get this: One idea to solve this discrepancy is that the Sun has stolen comets from other stars. Seriously! Comets should form wherever stars do, and sometimes the Sun passes near other stars. When we see a long-period comet gracing our skies, could we be seeing an object from an alien solar system? Maybe. There is another explanation, but itâ€™s highly speculative. Perhaps thereâ€™s another planet in the solar system, well beyond Neptune. Itâ€™s possible. Some very preliminary studies have shown that some long-period comets arenâ€™t coming in randomly, but instead have their orbits aligned in a way you might expect if a very distant planet perturbed them. There are a handful of Kuiper Belt Objects aligned in a similar way. NASAâ€™s WISE observatory scanned the skies in infrared, and wouldâ€™ve seen anything as big as Jupiter or Saturn out to tremendous distances, so any hypothetical planet would have to be smaller. And very distant, probably tens of billions of kilometers out. Weâ€™ve seen other stars with planets this far out, so itâ€™s physically possible. But is there one really there? We canâ€™t say either way, yes or no. At least, not yet. This region of the solar system is seriously under-explored. Itâ€™s distant, difficult to reach, and above all else extremely huge and numbingly empty. You could hide a whole planet out there, and it would be pretty hard to find. The point? Thereâ€™s still lots of solar system left to explore. Weâ€™ve barely dipped our toes into these dark, frigid waters. Today you learned that past Neptune are vast reservoirs of icy bodies that can become comets if they get poked into the inner solar system. The Kuiper Belt is a donut shape aligned with the plane of the solar system; the scattered disk is more eccentric and is the source of short period comets; and the Oort Cloud which surrounds the solar system out to great distances is the source of long-period comets. These bodies all probably formed closer into the Sun, and got flung out to the solar systemâ€™s suburbs by gravitational interactions with the outer planets. Crash Course Astronomy is produced in association with PBS Digital Studios. Mosey on over to their channel because they have 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, the script supervisor and editor is Nicole Sweeney, the sound designer is Michael Aranda, and the graphics team is Thought CafÃ©.