Asteroids: Crash Course Astronomy #20

Crash Course: Astronomy
https://youtube.com/watch?v=auxpcdQimCs
https://nerdfighteria.info/v/auxpcdQimCs

(PBS Digital Studios intro plays)

Phil: When you look at a diagram of the solar system, you'll see a big gap between Mars and Jupiter. A few centuries ago, that gap bugged astronomers. They really wanted there to be a planet in there. On the first day of the 19th century, January 1st, 1801, they got their wish...kinda? Italian astronomer Giuseppe Piazzi found a point of light moving at just the right speed to be the desired planet, but it was just a dot, and too faint to physically be a terribly big object. He suspected it might be a comet, but follow-up observations showed it wasn't fuzzy. The object was given the name Ceres, but was it really a planet? Well...

(CrashCourse Astronomy Intro)

Hopes were high that Ceres was the wished-for planet between Mars and Jupiter. But then something rather amazing happened. A little over a year later, in 1802, another one was found. Then in 1804, astronomers spotted a third one, and a fourth in 1807. It was becoming clear that a new class of solar system object had been discovered. Given that they were all just dots in the telescopes at the time, points of light like stars, they were given the name 'asteroids', which literally means 'star-like.' By the end of the 19th century, more than 450 had been found in total. The rate of discovery has accelerated over the years, and now, today, we know of hundreds of thousands. There are probably billions, yes, billions of them, larger than a hundred meters across in the solar system, and over a million larger than 1km in size.

So what are we dealing with here? What are these asteroids? There's not really a hard-and-fast definition of what's an asteroid and what isn't, but generally speaking, it's a class of smaller bodies that are rocky or metallic that orbit the Sun out to Jupiter. Objects past Jupiter have special designations that we'll get to in the next episode. Over the centuries, we've learned a lot about them by scrutinizing them with telescopes.

Asteroids come in a few basic flavors. Most of them, about 3/4, are carbonaceous, which means they have lots of carbon in them. About 1/6 are silicaceous, heavy on the silicon-based materials, you know, rock. The rest are lumped into one catch-all category, but are dominated by metallic objects, literally loaded with iron, nickel, and other metals. So many of them orbit the sun between Mars and Jupiter that this region is now called the main belt. The main belt has structure. For example, there are very few asteroids about 425 million kilometers from the Sun. An asteroid at that distance would have an orbital period of about 4 years, a simple fraction of Jupiter's 12 year period. Any asteroid there would feel a repeated tug from Jupiter's mighty gravity, pulling it out of that orbit. The resulting gap is called the Kirkwood Gap, and there are several such asteroid deserts, all with simple multiples of Jupiter's period. In this way, the main belt is like Saturn's rings, whose gaps are carved out by the gravity of the orbiting moons.

Another way to group asteroids is by orbit. Some have similar orbits, and may have formed from a bigger parent asteroid that got disrupted by impact. These groups are called families, and there are few dozen known. For example, the Eunomia family has over 400 members, and are silicaceous rocky asteroids and probably all formed from a parent body that was about 300km across. When you watch movies, they always show spaceships dodging and swooping through asteroid belts, trying to evade the bad guys, but in reality, our asteroid belt is mostly empty space. On average, decent-sized asteroids are millions of kilometers apart, so far that if you stood on an asteroid, odds are good you wouldn't even be able to see another one with your naked eye. And despite their huge numbers, they don't add up to much. If you took all the asteroids in the main belt and lumped them together, they'd be far smaller than our own moon.

Ceres is the biggest, at about 900km across. It's round, nearly spherical due to its own gravity crushing it into a ball. A funny thing about Ceres. As we write and record this episode, it's being visited for the first time by a spacecraft named Dawn. That means everything I tell you about this asteroid is probably about to be obsolete. But, we do know a few things.

Ceres probably has a rocky core surrounded by a water-ice mantle. The amount of water in it is staggering, probably more than all the freshwater on Earth. It may even be liquid under the surface, like the oceans of Enceladus and Europa. Early images by Dawn as it approached the asteroid show its surface is heavily cratered, and some craters are very bright. They may be exposing ice under the surface, or just fresher, brighter material. There are tantalizing observations of localized water vapor on the surface, which may be from sublimation, ice turning directly into a gas due to the sun's heat, or it might indicate cryovolcanoes.

Dawn also visited Vesta, which is third largest, but second most massive asteroid known. Vesta is round-ish. What's called an oblate spheroid, flattened a bit like a ball someone's sitting on. The southern hemisphere got hammered by impacts long ago, leaving a huge basin there. Several other main belt asteroids have been visited by spacecraft, mostly via fly-bys. Lutetia, Gaspra, Steins, Mathilde. Ida is another, and was discovered to have a small moon orbiting it. In fact, a lot of asteroids have moons, or are actually binary, with two similar sized bodies in orbit around each other. Cleopatra, a weird dog-bone shaped rock has two moons.

You might think asteroids are just giant versions of rocks you might find in your garden, tough, solid, singular bodies, but it turns out that's not the case. A few years ago, scientists realized that asteroids spent billions of years whacking into one another, sometimes in high speed collisions, sometimes more slowly. Slower hits can disrupt the asteroid, crack it, but not necessarily be strong enough to actually disrupt it so that it breaks apart. Over time, enough hits like that can leave behind what's called a rubble pile, individual rocks held together by their own gravity, like a bag of gravel or a car window that's been cracked and still holds its overall shape. This became more clear when the Japanese Hayabusa spacecraft visited the asteroid Itokawa and saw what can only be described as a jumbled mess. The asteroid had no craters on it, and was littered with rubble and debris. It was also very low density, just what you'd expect for a loosely bound rock pile. It's weird to think of some asteroids as being not much more than free-floating bags of gravel, but the universe is under no obligation to adhere to our expectations. It's full of surprises, and we need to keep our minds flexible. So here's a question. Why is there even a main asteroid belt at all?

The solar system formed from a disc of material, and over time, that material started to clump into bigger and bigger pieces. As planets formed, they swept up and pulled in lots more stuff and grew large. Jupiter consumed a lot of the material around it, but not all, and left a lot of debris inside its orbit. Some of this clumped together to form middling sized objects, probably smaller than the planets we have now, but big enough to undergo differentiation. Heavy stuff like metal sank to the middle and lighter stuff formed a mantle and crust. Collisions broke almost all of them apart, and that's why we see asteroids with different compositions. Some are from the denser core, others from the lighter crust. There was probably a lot more material between Mars and Jupiter billions of years ago, but it either got eaten by Jupiter or the planet's immense gravity altered the asteroids' orbits, flinging them away. This may be why Mars is so small, too. Jupiter robbed it off all of its food as it formed.

While most asteroids live in the main belt, not all of them do. Some have orbits that cross that of Mars, taking them closer to the Sun. We call those, wait for it, Mars-crossing asteroids. Some have

orbits that take them even closer to the Sun, crossing Earth's orbit. We call those Apollo asteroids, ehhh, gotcha! They're named after the asteroid Apollo, the first of its kind to be found. Some have orbits that are almost entirely inside Earth's orbit, called Aten asteroids. Aten and Apollo asteroids can get pretty close to Earth, so we call them near-Earth asteroids. Now, while they get close to us, that doesn't mean they'll hit us, because, for example, their orbits may be tilted, so their orbits and the orbit of the Earth don't actually ever physically cross, but some do have paths that literally intersect Earth's. That doesn't mean they'll hit us every pass either, after all, you can walk across a street without getting hit by a car. The problem comes when you try to occupy the same volume of space as a car at the same time. Astronomers unsurprisingly are very concerned about asteroids that can hit us. That's why we have surveys, observatories, scanning the skies looking for them. This is a pretty important topic, and I'll go into it in more depth in a future episode.

There's another category of asteroid that exists due to a quirk of gravity. When a planet orbits a star, there are points along the planet's orbit and near it in space where the gravitational forces are in balance. If you place an object there, it tends to stay there, like an egg in a cup. These are called Lagrange points, one of them is along the same orbit as the planet, but 60 degrees ahead, another is 60 degrees behind. The first such asteroid found was orbiting 60 degrees ahead of Jupiter, and was named Achilles, after the Greek hero in the Trojan war. As more were found, the naming convention stuck. Asteroids ahead of Jupiter were named after Greek figures in the Trojan war, and those behind Jupiter were named for Trojans, and now we just call them all Trojan asteroids. Trojan asteroids have been spotted for Jupiter, Mars, Uranus, Neptune, and even Earth. Earth's was found in 2010, using observations by an orbiting observatory called WISE, which scans the skies in infrared light where asteroids glow due to their own heat. 2010-TK7, as it's called, is about 300 meters across and 800 million kilometers away, orbiting the Sun ahead of Earth.

There are also asteroids that have orbits that are very similar to Earth's, but are slightly elliptical and tilted with respect to ours. Because of this, they can stay relatively near the Earth in space, but don't really orbit us. Instead, they sometimes get closer, and sometimes recede. It's pretty weird, but a natural outcome of orbital mechanics. Some people these asteroids are moons of Earth, but it's better to say they're co-orbital with us. Only a few are known, the most famous being Cruithne, which can get as close as 12 or so million kilometers from us.

Oh, one more thing. Originally, asteroids were named after female goddesses, Ceres, Vesta, Juno, and so on. But as hundreds more were found, and then thousands, we ran out of names. Eventually, astronomers who discovered asteroids were allowed to name them, through a lengthy proposal and acceptance process, governed by the International Astronomical Union. They also get a number assigned to them as well. A lot of astronomers have asteroids named after them, including astronomers who study asteroids, like my friend Amy Mainzer, who works on the WISE mission. Hers is 234-750-Amy Mainzer, and Eleanor Helin, who discovered quite a few asteroids and comets. Hers is 3267-Glo, for her nickname. And this one? It's a 1km wide rock in the main belt and goes by the name 165347-Phil Plait. Must be a coincidence.

Today you learned that asteroids are chunks of rock, metal, or both that were once part of smallish planets, but were destroyed after collisions. Most orbit the sun between Mars and Jupiter, but some get near the Earth. The biggest, Ceres, is far smaller than the Moon, but still big enough to be round and have undergone differentiation.

CrashCourse Astronomy is produced in association with PBS Digital Studios. Head over to their channel for even more awesome videos. This episode was written by me, Phil Plait. I hosted it, too. You probably saw that. 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, and the sound designer is Michael Aranda, and the graphics team is Thought Cafe.

(Endscreen)