Introduction to the Solar System: Crash Course Astronomy #9

Crash Course: Astronomy
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The Solar System is the name we give to our local cosmic backyard. A better way to think of it is all the stuff held sway by the Sunâ€™s gravity: The Sun itself, planets, moons, asteroids, comets, dust, and very thin gas. If you took a step back â€" well, a few trillion steps back â€" and looked at it from the outside, you might define the solar system as: the Sun. Thatâ€™s because the Sun comprises more than 98% of the mass of the entire solar system. The next most massive object, Jupiter, is only 1/10th the diameter and less than 1% the mass of the Sun. But thatâ€™s a little unfair. Our solar system is a pretty amazing place, and you can figure out a lot of whatâ€™s going on in it just by looking at it. For thousands of years we had to explore the solar system stuck on this spinning, revolving ball â€" the Earth. The problem was, for a long time we didnâ€™t know it was a spinning, revolving ball. Well, the ancient Greeks knew it was a ball â€" they had even measured its size to a fair degree of accuracy â€" but most thought it was motionless. When a few folks pointed out that this might not be the case â€" like the ancient Greek astronomer Aristarchus of Samos â€" they got ignored. The idea that the sky spins around the Earth seems obvious when you look up, and when great minds like those of the astronomer Ptolemy and philosopher Aristotle supported that idea, well, people like Aristarchus got left behind. The basic thinking was that the Moon, Sun, and stars were affixed to crystal spheres that spun around the Earth at different rates. While it kinda sorta worked to predict the motions of objects in the sky, in detail it was really unwieldy, and failed to accurately predict how the planets should move. Still, Ptolemyâ€™s idea of a geocentric Universe stuck around for well over a thousand years. It was the year 1543 when Nicolaus Copernicus finally published his work proposing a Sun-centered model, much like the one Aristarchus had dreamed up 2000 years previously. Unfortunately, Copernicusâ€™s model was also pretty top-heavy, and had a hard time predicting planetary motions. The last nail in geocentrismâ€™s coffin came a few years later, when astronomer Johannes Kepler made a brilliant mental leap: Based on observations by his mentor Tycho Brahe, Kepler realized the planets moved around the Sun in ellipses, not circles as Copernicus had assumed. This fixed everything, including those aggravating planetary motions. It still took a while, but heliocentrism won the day. And the night, too. This paved the way for Newton to apply physics and his newly-created math of calculus to determine how gravity worked, which in turn led to our modern understanding of how the solar system truly operates. The Sun, being the most massive object in the solar system by far, has the strongest gravity, and it basically runs the solar system. In fact, the term â€œsolarâ€• comes from the word â€œsol,â€• for Sun. We named the whole shebang after the Sun, so there you go. The planets are smaller, but still pretty huge compared to us tiny humans. At the big end we have giant Jupiter, 11 times wider than the Earth and a thousand times its volume. At the smaller end, we haveâ€¦wellâ€¦there is no actual smaller â€œendâ€•. We just kinda draw a line and say, â€œPlanets are bigger than this.â€• Thatâ€™s a bit unsatisfactory, Iâ€™ll admit, but it does bring up an interesting point. Iâ€™ve been using the term â€œplanet,â€• but I havenâ€™t defined it. Thatâ€™s no accident: I donâ€™t think you can. A lot of people have tried, but definitions have always come up short. You might say something is a planet if itâ€™s big enough to be round, but a lot of moons are round, and so are some asteroids. Maybe a planet has to have moons. Nope; Mercury and Venus donâ€™t, and many asteroids do. Planets are big, right? Well, yeah. But Jupiterâ€™s moon Ganymede is bigger than Mercury. Should Mercury be stripped of its planetary status? I could go on, but no matter what definition you come up with, you find there are lots of exceptions. Thatâ€™s a pretty strong indication that trying to make a rigid definition is a mistake; itâ€™ll get you into more trouble than itâ€™ll help. â€œPlanetâ€• canâ€™t be defined; itâ€™s a concept, like continent. We donâ€™t have a definition for continent, and people donâ€™t seem to mind. Australia is a continent, but Greenland isnâ€™t. OK by me. So thatâ€™s what I tell people if they ask me if Pluto is a planet. I say, â€œTell me what a planet is first, and then we can discuss Pluto.â€• Pluto is what it is: A fascinating and intriguing world, one of thousands, perhaps millions more orbiting the Sun out past Neptune. I think that makes it cool enough. All the orbits of the planets lie in a relatively flat disk. That is, they arenâ€™t buzzing around the Sun in all directions like bees around a hive; the orbit of Mercury, for example, lies in pretty much the same plane as that of Jupiter. Thatâ€™s actually pretty interesting. Whenever you see a trend in a bunch of objects, nature is trying to tell you something. In fact, there are other trends that are pretty obvious when you take a step back and look at the whole solar system. For example, the inner planets â€" Mercury, Venus, Earth, and Mars â€" are all relatively small and rocky. The next four â€" Jupiter, Saturn, Uranus, and Neptune â€" are much larger, and have tremendously thick atmospheres. In between Mars and Jupiter is the asteroid belt, comprised of billions of rocks. There are lots more asteroids scattered around the solar system, but most are in the main belt. Then, out beyond the orbit of Neptune is a collection of rocky ice balls, called Kuiper Belt Objects. The biggest are over a thousand miles across, but most are far smaller. They tend to follow the plane of the planets too. But if you go even farther out, starting tens of billions of kilometers from the Sun, that disk of Kuiper Belt Objects merges into a vast spherical cloud of these ice balls called the Oort Cloud. They donâ€™t follow the plane of the inner solar system, but orbit every which way. So what do all these facts tell us about the solar system? We think theyâ€™re showing us hints of how the solar system formed. 4.6 billion years or so ago, a cloud floated in space. It was in balance: its gravity trying to collapse it was counteracted by the meager internal heat that buoyed it up. But then something happened: Perhaps the shockwave from a nearby exploding star slammed into it, or maybe another cloud lumbered by and rammed it. Either way, the cloud got compressed, upsetting the balance, and gravity took over. It started to collapse. As it did, angular momentum became important. Thatâ€™s a lot like regular momentum, when an object in motion tends to stay in motion. But in this case itâ€™s a momentum of spin, which depends on the objectâ€™s size and how rapidly itâ€™s rotating. Decrease the size, and the rotation rate goes up. The usual analogy is an ice skater starting a spin, then drawing their arms in. Their spin is amplified hugely. The same thing happened in the cloud. Any small amount of spin it had got ramped up as it collapsed. It flattened into a disk, much like spinning raw pizza dough in the air will flatten it out. As it collapsed, material fell to the center, getting very dense and hot. Farther out in the disk, where it was cooler, material started to clump together as little grains of dust and other matter randomly bumped into other little bits. As these clumps grew, their gravity increased, and eventually started drawing more material in. These little blobs are called planetesimals â€" wee baby planets. As they grew, so did the center of the disk. The object forming there was a protostar â€" or, spoiler alert, the protosun. Eventually its center got so hot that hydrogen fused into helium, with makes a lot of energy. A lot of energy. A star was born. The new Sun blasted out fierce light and heat that, over millions of years, blew away the leftover disk material that hadnâ€™t yet been assimilated into planets. The solar system was born. Closer to the Sun it was warmer. Hydrogen and helium are very light gases, and the warm baby planets there couldnâ€™t hold on to them. Farther out, there was more material in the disk, and the planets were bigger. Since it was cooler, too, they could hold on to those lighter gases, and their atmospheres grew tremendously, eventually outmassing the solid material in their cores. They became gas giants. There was also a lot of water out there, far from the Sun, in the form of ice. Smaller icy objects formed past Neptune, but space was too big and random encounters too rare. They didnâ€™t get very big, maybe a few hundred kilometers across. A lot of them â€" billions, perhaps trillions of them â€" got too close to the big planets, and were flung hither and yon. Closer in, material between Mars and Jupiter couldnâ€™t get its act together to form a planet either; Jupiterâ€™s gravity kept agitating it, and impacts between two bodies tended to break them up, not aggregate them together. And there you have it. Our solar system, formed from a disk, sculpted by gravity. Echoes

of that disk live on today, seen in the flatness of the solar system. This isnâ€™t guesswork: the math and physics bear this out. And not only that, we see it happening, now, today. When we look at gas clouds in space, we see stars forming, we see protoplanetary disks around them, we see the planets themselves getting their start. We may think of ourselves as the solar system, but weâ€™re really just a solar system. The scenario that happened here so long ago plays itself out daily in the galaxy. Weâ€™re one of billions of such systems. And remember: Every atom in your body, and everything you see around you â€" every tree, every cloud, every human, every computer, everything on Earth, even the Earth itself â€" was once part of that dense cloud. We are, quite literally, star stuff. Today you learned that the solar system is one star, many planets, a lot more asteroids, and even more icy comet-like objects. It formed from a collapsing cloud, which flattened into a disk, and thatâ€™s why the solar system is flat. Rocky planets formed closer to the Sun, and larger gas giants farther out. Icy objects formed beyond Neptune in a disk as well, and a lot of them were flung out to form a spherical shell around the Sun. We see this same thing happening out in the galaxy, too. The motions of the objects in this system caused a lot of confusion to ancient astronomers, but we eventually figured out whatâ€™s what. This episode is brought to you by Squarespace. The latest version of their platform, Squarespace Seven, has a completely redesigned interface, integrations with Getty Images and Google Apps, new templates, and a new feature called Cover Pages. Try Squarespace at Squarespace.com, and enter the code Crash Course at checkout for a special offer. Squarespace. Start Here. Go Anywhere. Crash Course Astronomy is produced in association with PBS Digital Studios. Seriously, you should go over to their channel because they have a lot more awesome videos there. 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©.