The Moon: Crash Course Astronomy #12

Crash Course: Astronomy
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=====Intro (0:06)=====

The Moon is pretty hard to miss when it's up at night. It's big and bright and really, very pretty. Even cooler, it's the closest astronomical object in the universe to us, and arguably the one we know best.

(intro music)

=====The Moon's Importance (0:27)=====

I hate to break it to you, but we humans are pretty egotistical. Even though there are over 160 known moons of decent size in our solar system, we call ours The Moon with a capital M, like it's the only one, or the most important one. And I guess to us, it is the most important one. It's only the fifth largest moon in the solar system in absolute size, but compared to Earth it's pretty big, fully a quarter of the diameter of the planet. That's a way bigger ratio than for any other moon orbiting a major planet in the solar system.

=====The Moon's Size (0:54)=====

By the numbers, the Moon is about 3470 kilometers in diameter, and on average about 380,000 kilometers from Earth. That means it looks pretty big in our sky, but probably not as big as you think.

When the Moon rises, it can look huge and looming on the horizon, like you could fall into it. Ah, but that's not really the case! It's easy to show it's the same size on the horizon as it is high overhead, yet people think it looks twice as big when it's on the horizon. This is the well-known Moon Illusion, and it's due to two factors: how we perceive of the sizes of objects, and how we perceive the sky.

We don't really see the sky as a hemisphere over our heads, but more like a flattened bowl with the horizon farther away than the zenith. So when the Moon's on the horizon, our brains are convinced it's farther away. But if it's farther away, it must be physically bigger to appear that size, right? So our brain interprets the Moon's size as huge. It's an illusion, but a convincing one.

In fact, the Moon is about the same size as a small pill held up at arm's length. Our satellite is a lot smaller than you think.

=====The Moon's Structure (1:56)=====

The internal structure of the Moon is roughly similar to the Earth. It has a solid iron inner core, a liquid outer core, a thick mantle, and a crust of lighter material on top. The core is small, probably 350 kilometers in radius and still hot, though not as hot as Earth's core. The lower mantle may be a thick fluid, but unlike Earth's mantle, the upper part is solid.

=====The Moon's Surface (2:15)=====

The easiest part of the Moon to observe is its surface, so of course we know the most about that. The near side, the side we see from Earth, is divided into two distinct types of regions: highlands, which are heavily cratered; and maria, Latin for "seas", which are darker and smoother.

The craters in the highlands are from countless impacts over the eons from asteroids and comets. Rocks from these regions have been dated to be well over four billion years old, nearly as old as the Moon itself. The maria, on the other hand, don't have nearly as many craters. They're younger, but that's relative. Rocks from those areas appear to be roughly 3 to 3.5 billion years old on average. The maria are made of darker, basaltic material, which means they probably formed from lava flooding older areas.

For most of human history the far side of the Moon was hidden from us, but in 1959 the Soviet Union flew the Luna 3 space probe around the Moon, photographing the far side for the first time. Everyone expected it to look a lot like the near side, but shockingly, it's vastly different. There were almost no maria. That's weird; the near side is covered with them. And not only that, observations from subsequent lunar probes showed the crust on the lunar far side is thicker than it is on the near side as well.

=====The Mysteries of the Moon (3:23)=====

The Moon is starting to stack up mysteries. Why is it so big compared to Earth? Why are the near and far side so different? It turns out the composition of the crust has a lot of similarities to Earth, but also a lot of differences as well. Why? It turns out the answers to these questions are all related to how the Moon formed four and a half billion years ago.

=====The Moon's Formation (3:42)=====

A lot of ideas have been proposed to figure out how the Moon formed, but the best one going these days is called the Giant Impact Hypothesis. When the solar system formed, there were a lot more objects orbiting the sun than there are now. These ranged in size from grains of dust up to objects the size of planets, and that meant there were lots of collisions. No doubt the Earth suffered many such impacts, but one happened late in Earth's history, relatively speaking — roughly 15 million years after things started to settle down.

A Mars-sized planet, given the unofficial name Theia, slammed into our young planet, but it wasn't a head-on impact. It was a grazing collision. The impact was colossal, blasting a huge amount of material from both planets into space. Most of it came from the outer layers of the Earth, since the collision was a grazing one. This material rapidly coalesced into the Moon, and that explains why there's some but not total similarity in composition to Earth — it used to be part of the Earth. But some of it came from the other planet too, and we may even have some evidence of it. Some rocks from the Moon show a peculiar ratio of different kinds of oxygen atoms called isotopes. It's possible some of the more exotic isotopes of oxygen came from the other planet.

Actually this idea has been around for a long time, ever since the Apollo missions in the 1970s. There's a lot of evidence to support it too, but a new twist on it goes farther. When the Moon formed from the debris of the collision, it was close to Earth, probably 20,000 kilometers away. The collision was so violent that it completely melted the Earth, and the Moon was molten too.

Tidal forces rapidly synchronized the Moon's spin and orbital period, so that one face always pointed toward Earth. If you were on that side of the Moon, the Earth would dominate the sky, appearing 80 times larger than the Moon appears in our sky today. And the Earth was hot. It hung there like a blast furnace, and would have seriously heated the near side of the Moon. The far side would have been much cooler. The material on the near side would have vaporized, and a lot of it would have condensed on the far side. Over time, this created the thicker far side crust we see today.

Then there was another seriously terrifying event: the Late Heavy Bombardment, a period of intense collisions with comets from the outer solar system, probably triggered by the movement of outer planets. This rain of millions of comets left scars on all the inner worlds, including the Moon. That's when most of the highland

cratering occurred. Some of these collisions were massive, carving gigantic craters on the Moon. Later, lava bubbled up through cracks in the Moon's surface, flooding these craters, creating the maria we see today. Ah, but the far side's crust was thicker. Impacts there couldn't get as deep, and it was harder for lava to break through and bubble up. That explains why there are so few maria there.

This idea that the Earth cooked the Moon and formed the crustal anomaly is pretty new, and is still being argued over. There are also competing hypotheses about this as well. As we gather more evidence, we'll eventually get a better understanding of just why the Moon's crust is so weird.

=====The Moon's Many Features (6:31)=====

After all that, I have to say: it's a little unfair to divide the lunar surface today into just highlands and maria. For example, craters are pretty diverse. Some are small and simple bowl shapes. Others are huge, dozens of kilometers across and more, punctuated with a central peak, a mountain in the middle that formed as material from the gigantic impact that formed it splashed back up in the middle. Double craters are common too, probably formed when binary asteroids hit the Moon. There are also crater chains: long lines of small craters that may have formed when a nearby large impact splashed out long streamers of material. Rays are common from big craters too. These are extremely long splash marks pointing radially out from the impact, probably formed when plumes of material were ejected. Some of the brightest are from the crater Tycho, in the moon's southern hemisphere, and they stretch for 1500 kilometers. The material is a bit more reflective than the surrounding terrain, so they appear bright in contrast, and are one of the most outstanding features visible near the time of the full moon.

And there's so much more: long, sinuous rills like dry riverbeds wind their way across the surface, actually the sites of ancient lava flows. There are lava tubes as well, where the top of a lava flow cooled and formed a tunnel through which lava could flow for long distances. Sometimes the roof, as it's called, collapses and forms a skylight, and we can see into the otherwise hidden tunnel. There are also cliffs, mounds, ancient and quite dead volcanoes, even mountain chains! There's no tectonic activity on the Moon, but mountain ranges formed at the edges of giant impacts, where the huge forces unleashed pushed up the rocks at the crater rim.

And new observations show there's something else on the Moon too: water. Deep craters near the Moon's poles have floors that never see sunlight. Comet impacts can distribute water all over the Moon, but most of it is destroyed by sunlight. But it can collect in these dark craters, and studies show there could be over a billion tons of water there in the form of ice. That would be huge boon to colonization. Water is heavy and really expensive to transport from Earth. If it's already on the Moon, that makes it a lot easier to put people there.

And that's in our future, I have no doubt. We're starting to get serious about going back to the Moon. NASA has plans of returning, and other countries like China and India are looking Moon-ward as well. It's not a matter of if, but when, and it could be soon; so soon that I bet there's a really good chance the next person to step foot on the Moon is already alive. Perhaps some teenage student in some country is just now taking an interest in science, math, engineering; an interest that will one day lead to another giant leap for humanity.

=====Lesson Recap (9:05)=====

Today you learned that the capital-M Moon is a lowercase-m moon. It's big compared to Earth and is thought to have formed when a small planet impacted Earth at a grazing angle. It's heavily cratered and has huge flood plains on it called maria. There's water there too, just waiting for us to thaw it out and drink it.

=====Credits (9:23)=====

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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, edited by Nicole Sweeney, and the graphics team is Thought Cafe.

(outro music)