Mercury: Crash Course Astronomy #13

Crash Course: Astronomy
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Mercury is the closest planet to the Sun. As you might expect, that makes it pretty hot. But also, it's pretty cool.

There are seven naked-eye solar system objects in the sky: Mercury, Venus, Mars, Jupiter, Saturn, the Sun, and the Moon. Seven. Each of them was associated with a god in ancient times. Mercury was the Roman messenger of the gods, fleet of foot—literally, he had wings on his shoes—and a rapid traveler.

To anyone who's seen Mercury in the sky, this affiliation with the swift god is no surprise. Mercury the planet moves pretty quickly, visibly changing its position relative to the background stars even after a single night.

Despite its speed, the planet never gets very far from the Sun. At best, it can reach a separation of about 28°. That's about three times the apparent size of your fist held at arm's length.

In 1639 the Italian astronomer Giovanni Zupi used a telescope to observe Mercury, and he discovered it undergoes a complete cycle of phases over time, just like the Moon does. The only way that can happen is if Mercury orbits the Sun, and not the Earth — another check mark in the column for heliocentrism, which was starting to look better and better all the time.

And of course that's the way things really are. Mercury is the innermost of the planets in the solar system. It orbits the Sun at an average distance of about 58 million kilometers, roughly a third the distance of the Earth from the Sun. That's why we never see it stray far from the Sun. From our viewpoint, its smaller orbit keeps it huddled closer to our star.

That's why we see it move so rapidly, too; it's closer to the Sun, so the gravity it feels from the Sun is stronger, and therefore its orbital velocity is faster than Earth's. It orbits the Sun once every 88 days.

And that's also why we see undergo phases. When it's between us and the Sun we're looking at its dark side, and when it's on the other side of the Sun we're looking at its fully illuminated half. In between it goes through the same phases as the Moon: crescent, half full, gibbous, and so on.

Not that this is such an easy observation to make. Because it never gets far from the Sun, it's always low to the horizon after sunset or before sunrise. When we observe it we're looking through all the muck and turbulence in our air, so it's usually pretty fuzzy. Making matters worse, it's a dinky planet, only about 4900 kilometers in diameter, about a third the Earth's width.

One upside to all this is that because it's close to the Sun, it's illuminated fiercely, and can be pretty bright even near the horizon. If you ever get a chance to see it, you really should. It's pretty cool.

Mercury's orbit is weird. It has the most elliptical orbit of any planet, ranging from 46 to nearly 70 million kilometers from the Sun. When it's closest to the Sun it receives more than twice as much light and heat as when it's furthest!

Mercury is too small and difficult to observe to see surface features on it, which for a long time made it impossible to figure out how long its day is. Astronomers assumed that the tides from the Sun had locked Mercury's spin so that its day was equal to its year, just like our Moon spins once for every time it goes around the Earth. However, in 1965, astronomers used Doppler radar to observe Mercury and directly measure its spin and they got a surprise: Its day was only 59 Earth days long, not 88.

But that's a significant number as well. To be more exact, the actual length of Mercury's year is 87.97 days, and the actual length of its day is 58.65 Earth days. If you divide those two numbers, you see their ratio is almost exactly 2/3!

It turns out there's more than one way to tidally lock the rotation of a planet to its orbit. Remember earlier, when I said Mercury's orbit is highly elliptical? The tides from the Sun are far stronger on Mercury when it's at perihelion, the closest point in its orbit to the Sun, than when it's at aphelion, the farthest point in its orbit. After Mercury first formed, tides from the Sun slowed its rotation just like the Earth's tides on the Moon slowed the Moon down as well.

But at some point, Mercury's spin slowed to where it was 2/3 of its orbital period. So, at one perihelion pass, one side of Mercury faces the Sun. Then, 88 or so days later, it approaches perihelion again. But it's spun 1.5 times, and this means the exact opposite side of Mercury faces the Sun at this closest approach. 88 days later, Mercury has spun 1.5 times again, and the whole thing repeats.

It turns out that's a perfectly legitimate stable configuration, just like the one-to-one spin/orbit setup. The way the physics works out, tides like simple multiples. Once the day became 2/3 the period of the year, forced by Mercury's elliptical orbit, the tides stopped slowing it, and things have been that way ever since.

Mercury's elliptical orbit, together with the 2:3 spin to orbit ratio, make for a very, very weird day on Mercury. If you stay in one spot, it takes the Sun two Mercury years, 176 days, for the Sun to go around the sky once! That's because if you're on the side of Mercury facing the Sun at one perihelion, the other side will face it one year later. It'll only be after the second year ends that you're facing the Sun again.

But it gets weirder. Mercury's spin is constant; it doesn't speed up or slow down. However, its motion around the Sun is faster at perihelion than aphelion. At aphelion, Mercury's spin is a bit faster than its orbital speed, so the Sun moves rapidly westward across the sky. But at perihelion Mercury's motion around the Sun actually more than compensates for its spin, so the Sun appears to stop in the sky and actually move backwards for a few days! Then, as Mercury pulls away from the Sun, its orbital velocity slows down, and the Sun starts to move west once again as the planet's rotation dominates.

If you're at just the right spot on the planet's surface, this means you could actually watch the Sun rise, slow, stop, set again, then rise again!

And you think time zones on the Earth are a pain.

Mercury's hard to observe from Earth, and much of what we know about it is due to observations from space probes sent there. Mariner 10 made three flybys of Mercury in the 1970s, and mapped about half the surface. We learned that it had almost no atmosphere, and was therefore unsurprisingly covered in craters.

In 2011, the MESSENGER probe entered orbit around Mercury after making a series of close flybys. The pictures it returned were breathtaking, and revealed a world that has seen a lot of pummeling over the eons. It's covered in craters pole to pole, some hundreds of kilometers in diameter.

The largest is called Caloris Basin, a whopping huge impact feature 1600 kilometers across. There are some smoother plains on the planet's surface too, which appear to be older than the cratered regions. These plains are covered in cracks called rupes. These are compression folds, like wrinkles on a fruit rind that's dried out. Apparently, as Mercury's interior cooled after it formed, the planet shrank, and the crust cracked as it tried to shrink as well.

Several of the craters have extensive ray systems. Like on our Moon, these are formed when impacts fling out long plumes of material that then settle down on the surface.

One of my favorite things of all about Mercury: Craters are named after artists. Musicians, writers, painters, and more, so we have craters like Botticelli, Chekov, Debussy, Degas, Okyo, Sibelius, Vivaldi, and Zola. There's even one named Tolkien!

Dipping below the surface, we can only infer what Mercury's internal structure is like. But the planet's dense, nearly as dense as Earth. We know the surface is rocky, so to be as dense as it is it must have a large iron core, far larger in proportion to the planet than Earth's. Mercury's core may reach ¾ of the way to the planet's surface!

Why does it have such a high proportion of iron? Mercury may have formed as a larger planet, then got blasted in a huge grazing impact that blew away the lighter materials that had risen to the surface, leaving behind the denser part. Or maybe the heat of the still-forming Sun vaporized the lighter materials off its surface.

Mercury has a measurable magnetic field, which is a bit surprising since it rotates so slowly—rotation plays a big part in the Sun's and Earth's magnetic fields. But that fits with so much of its interior being molten iron; the bigger core may allow for a stronger field despite its slow spin.

It doesn't have much of an atmosphere, but there is a trace of one, mostly due to its magnetic field trapping the solar wind, and to material flung up from the surface after violent impacts from comets and asteroids. A lot of this material blown off the surface escapes the planet and gets blown away by the solar wind and pressure from sunlight. It forms a long comet-like tail that is tens of millions of kilometers long. This tail is comprised of elements like sodium, calcium, and magnesium, material that's known to be abundant on the surface.

Speaking of which, here's a fun fact: pound for pound, impacts on Mercury are more violent than they are on Earth. Mercury has weaker gravity, so it doesn't pull in impactors as hard as the Earth does, but it orbits the Sun far faster than Earth does, so asteroids and comets tend to hit at higher velocity. That makes the explosive energy higher, making craters bigger.

And there's one more surprise Mercury has, and it's really surprising: Despite being so close to the Sun, and having a surface temperature that can reach 430°C — 800° Fahrenheit — astronomers have found water ice on Mercury!

It exists in the bottoms of deep craters near Mercury's poles, where sunlight never reaches. These are called "cold traps," and temperatures there don't get above -170° C. It's not known for sure where the water comes from, but it's likely to be from comets and asteroids that impacted the planet, scattering the water across the surface. Of course, in the harsh heat that water just goes fsssst and goes away. But in those deep craters it can persist, accumulating over the eons. There may be billions of tons of it there!

It's bizarre to think that in one of the hottest places in the solar system there can be conditions so cold ice can exist, but one thing we've learned about nature over and again: It has a lot more imagination than we do.

Today you learned that Mercury is the closest planet to the Sun. It's airless and dense, and is covered with craters. Its rotation is locked to its orbit in a 2 to 3 ratio, and together with its elliptical orbit makes a day on Mercury very long and very weird. And despite being very hot, there's actually water ice in deep craters at its poles.

Crash Course Astronomy is produced in association with PBS Digital Studios. Head 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 directed by Nicholas Jenkins, edited by Nicole Sweeney, and the graphics team is Thought Café.