Cycles in the Sky: Crash Course Astronomy #3

Crash Course: Astronomy
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Under a dark sky, you can see thousands of stars. If you watch for a few hours, you can see them rise and set as the Earth rotates once a day. And if you go outside the next night at the same time, youâ€™ll see that thingsâ€™ll look pretty much the same as they did the night before. The stars rise and set, Polaris hangs to the north, and so on. One day hardly makes any difference to the skyâ€™s appearance. But what if you wait for another night? Or a week? If youâ€™re that patient, and observant, you can spot subtle changes in the sky. Letâ€™s say a couple of weeks have passed. Remember that star that was just over a tree in the east when the Sun set -- the one that made you first notice the stars are rising and setting? Go look at it again. If you happen to be out at the same time, youâ€™d expect that star to be in the same place. But itâ€™s not. Itâ€™s actually a bit higher above the tree. And if you look west, stars that were well off the horizon just after sunset last week are now lower. If you wait a month, this effect is even more pronounced; all new constellations will be visible in the sky after sunset. This is because the Earth is going around the Sun, literally changing our viewpoint on the sky. The Earth takes a year to orbit the Sun once. Every day, it moves a little bit along its orbit. And as it does, from Earthâ€™s perspective, distant stars appear to move their positions relative to the sun. So, one day we might see a star very near the Sun, but the next day the angle is a bit bigger. At some point, about six months after we first saw it, the star is directly opposite the Sun in the sky. Then the angle starts to shrink again as the star approaches the Sun from the opposite side, until, after a full year, the cycle repeats. What this means to you, the naked eye observer, is that the stars appear to rise and set at different times over the course of the year. Stars in the east rise about four minutes earlier every night, and stars in the west set four minutes earlier. A constellation that was entirely below the eastern horizon at sunset one month might be completely visible after sunset the next month. Another way to think about it is that the stars appear to be fixed, and as the Earth circles the Sun, the Sun moves through the stars over the course of the year, making a complete circle around the sky once per year. The path it takes is a reflection of the Earthâ€™s path around the Sun, a line in the sky. We call that line the ecliptic. That means the Sun passes through the same constellations in the sky every year. We give those constellations a special name: the zodiac. Every year, during a given month, the Sun will appear to be in a certain zodiacal constellation, from Sagittarius through Scorpius, Libra, Virgo, Leo, Cancer, and the rest. Eventually, over a year, the Sun returns to Sagittarius, and the cycle starts again. But even though we talk about this process in terms of the sunâ€™s movement, itâ€™s really the path traveled by the Earth that creates this effect, as our perspective moves with it. And of course, the planets move in the sky as well. Mercury, Venus, Marsâ€¦ they orbit the Sun, too, and they do so in approximately the same plane the Earth does. If you could see the solar system from the side, it would look flat! So to us, on Earth, the planets go around the sky over the course of a year, and they also appear to change their positions relative to the Sun and the stars. The inner planets, Mercury and Venus, move so rapidly you can see their motion after a single night. The outer planets are more leisurely, but wait long enough and they too will be seen to move, sliding through the constellations. By the way, the word â€œplanetâ€• is Greek for â€œwanderer.â€• Thereâ€™s another aspect of all this you might notice over time. Youâ€™ve probably seen a globe, and noticed that the axis of it is tilted; that is, itâ€™s not straight up-and-down, perpendicular to how it sits. Thatâ€™s because a globe is modeling the Earth and the Earth is tilted. The Earth spins on its axis once per day, and orbits the Sun once per year. But the Earthâ€™s axis is tilted with respect to its orbital plane by 23.5 degrees. And this has a profound effect on our planet. Imagine for a moment that the Earthâ€™s axis were exactly perpendicular to its orbit, straight up and down. If that were the case, every day, the Sun would take the same path across the sky. If you were on the equator the Sun would rise, go exactly overhead, and then set. If youâ€™re on the pole, the Sun will appear to go around the horizon every day, neither rising nor setting â€" it would always be twilight. But thatâ€™s not the case. The Earth is tilted. In the months of June and July, the Earthâ€™s north pole is tipped toward the Sun. Six months later itâ€™s pointed away. This affects the path the Sun takes across our sky. Instead of it taking the same path every day, in the northern summer, when weâ€™re tipped toward the Sun, the Sun takes a higher path in the sky. Because that path is longer, the days are longer, too. Six months later, in December and January, the Earthâ€™s pole is tipped away. The Sun takes a lower path in the sky, and because the path is shorter days are shorter too. Thatâ€™s why we have seasons! When the Sun is up high in the sky it shines straight down on the ground, heating it better, and days are longer so it has more time to heat us up. It gets hot. In the winter, itâ€™s the reverse: The Sun is lower so it canâ€™t warm us up as efficiently, and it has less time to do so. It gets cold. There you go: seasons. The Earthâ€™s axis is tipped. If it werenâ€™t, the seasons wouldnâ€™t occur, and the temperature of the Earth wouldnâ€™t change month to month. Thereâ€™s a common misconception that the Earth has seasons because it orbits the Sun on an ellipse, and so itâ€™s closer to the Sun in summer and farther in winter. While itâ€™s true the orbit is elliptical, Earth is closer to the sun in January -- on the order of 5 million kilometers or so -- than it is in July. Itâ€™s the angle of the sunâ€™s rays that makes winter cold and summer hot, not our distance from the sun. Also, you may know that when itâ€™s summer in the northern hemisphere, itâ€™s winter in the southern. When the north pole is tipped toward the Sun, the south pole is tipped away, so northern and southern hemisphere seasons are opposite each other. But nothing in astronomy is permanent. The north poleâ€™s not always going to point toward the sun in June, and Polaris is not always going to be the North Star. Thatâ€™s because our planetâ€™s axis is actually moving. Have you ever seen a spinning top start to wobble, its axis moving in a slow circle even as the top itself spins? This is called precession, and the Earth does it too! Our planet spins on its axis once per day, but the axis wobbles, making a very slow circle that takes 26,000 years to complete. This affects a lot of what we see in the sky. For example, Polaris wonâ€™t always be the pole star! Every year, the pole points a little farther from that star, making a big circle 47 degrees across. For ancient Egyptians, the star Thuban was the pole star, and in about 11,000 years that position will be held by the bright star Vega. Also, the date the Sun is in a particular zodiac constellation changes slowly due to precession as well. When the ancients first thought up this idea, the Sun was in Aries on March 22, the vernal equinox (what some people call the first day of spring). But due to precession, itâ€™s now in Pisces! Thatâ€™s why your astrological sign doesnâ€™t match where the Sun actually is in the sky; 2000 years of precession has changed themâ€¦one of the many reasons astrology is silly. Itâ€™s incredible to think about: The Earth, the Sun, the stars: they allow us to tell the time and time of year just by looking up and paying attention. This is why the stars were so important to ancient humans. The stars were like a clock and a calendar in the sky, long before we had invented either. Weâ€™ve actually learned a lot about the sky just by looking at it. Of course, some of the stuff Iâ€™ve explained weâ€™ve learned through other means â€" the Earth is spinning, stars have different intrinsic brightnesses, and so on. But all of that knowledge, and far more, got its start by people who went outside and looked up. Later, as we applied math and physics to what we observed we learned even more, and could then go back and explain what we saw. So donâ€™t discount naked eye astronomy; itâ€™s all we had for thousands of years. In fact, I think we lost something when we started using clocks and calendars, and moving to cities with bright lights that washed away the stars from the sky. Those folks long ago were tied to the sky; they knew it like you know the streets in your neighborhood. They could see the stars rise and set, they knew the glory of the Milky Way sprawled across the heavens, even if they didnâ€™t know exactly what it was. We do know, now, with our knowledge gained over the centuries. But it comes at the cost of losing touch with the sky, not living under it as much as we once did. Iâ€™ve spent thousands of hours over

my life at night just simply looking up, watching the stars, appreciating the Universe as I can see it. The things I have witnessed have shaped my life, and instilled in me a permanent and endless sense of wonder and joy. The Universe belongs to everyone. Go outside and, if you can, soak up your share. Today we talked about cycles: As the Earth goes around the Sun we see stars rising and setting at different times, the Sun moves along a line in the sky called the ecliptic, through a set of constellations called the zodiac â€" really a reflection of the Earthâ€™s motion around the Sun â€" that the planets move more or less along the ecliptic as well, and that seasons are caused by the tilt of the Earthâ€™s axis together with its annual orbit around the Sun. Crash Course is produced in association with PBS Digital Studios. 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, and the graphics team is Thought CafÃ©.