We had the sky, up there, all speckled with stars, and we used to lay on our backs and look up at them, and discuss about whether they was made, or only just happened.

Mark Twain, Huckleberry Finn

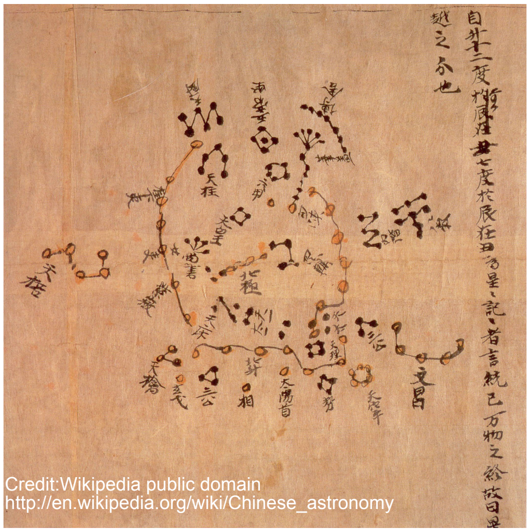
Sky Dances

Greetings AST 111. In this module we'll examine what the dark night sky looks like from Earth.

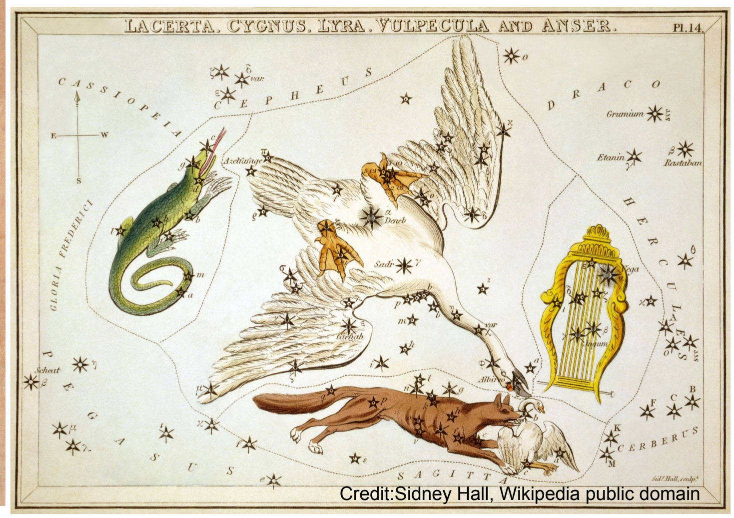
So what does the universe look like from Earth? Well, the human eye can see about 6,000 stars at a dark site on a moonless night, along with that whitish band of light in the sky that we call the Milky Way. In the Milky Way, we are looking towards the center of the disk of our galaxy, but the stars are so far away and there are so many of them that it just appears as this diffuse band of light as we go across.

The image above is at a really dark site, and if you look carefully at this image, you'll see that the Milky Way is casting shadows on those rocks. So this is a fantastically dark site, able, on a moonless night, from the light of the Milky Way being able to cast shadows on there. So about 6,000 stars this is what people can see on a dark site.

People across the globe, across time, have taken those 6,000 or so stars and they've organized them into patterns for storytelling mnemonics, for time keeping and for navigation. Before there was the advent of computers or certainly before the advent of writing on paper, people used these stars as sort of celestial cheat sheets in the sky to remember the stories pass them down from generation to generation. They were like books in the sky, if you like. Then of course, there is the extremely important, pragmatic stuff of knowing what time it is and where are you, and people used stars for those.

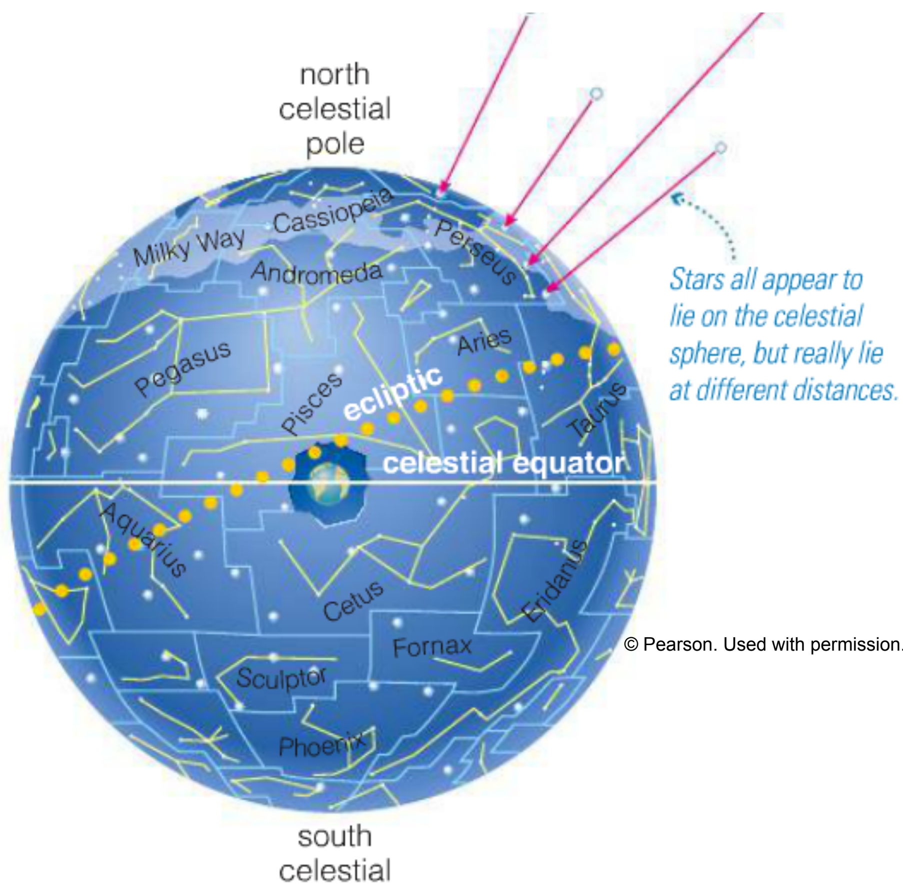


Credit:Wikipedia public domain
http://en.wikipedia.org/wiki/Chinese_astronomy



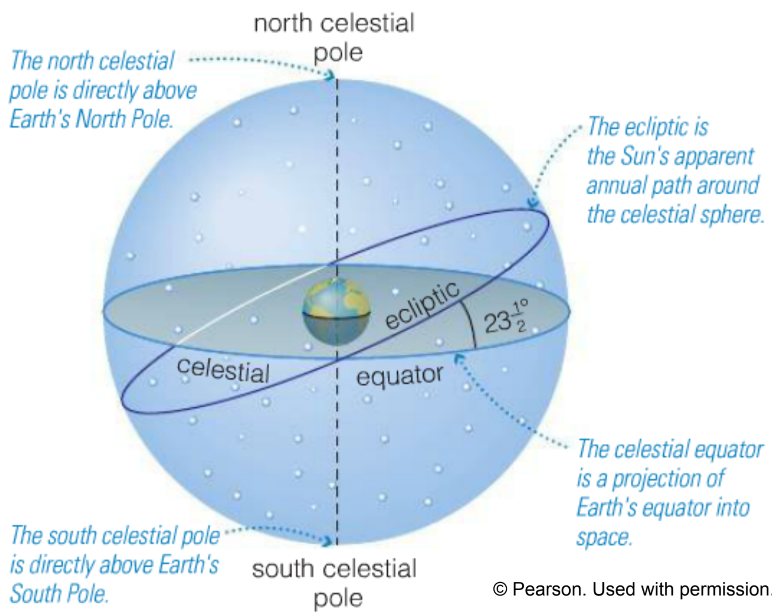
Credit:Sidney Hall, Wikipedia public domain

The left image above is a constellation from the Chinese culture, and on the right is another story of the constellations, which is visible in the northern hemisphere. There are now 88 constellations, which generally refer to areas on the sky rather than a specific grouping of stars. So there'll be a specific star like Orion constellation, but Orion actually encompasses an area on the sky, and not just the stars that make up Orion itself. These 88 constellations are recognized and approved by the body that does that, which is known as the International Astronomy Union.



The stars and the constellations appear to lie on a celestial sphere that's surrounds Earth. That celestial sphere is not real, but because we lack any depth perception on space-- there's no third dimension in space-- everything looks like a sticky dot stuck on the celestial sphere. So while it's an illusion-- things really are at different distances-- it's a very useful way for mapping the sky.

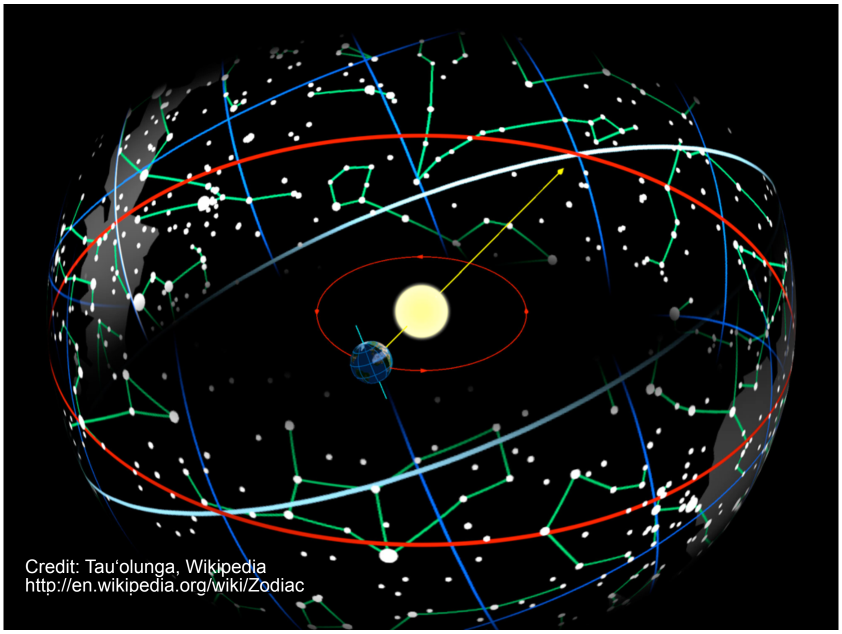
The image above shows the celestial sphere. The horizontal line is the celestial equator. That's the white line going across. And that's just Earth's equator expanded out into space onto the celestial sphere. Then the dotted orange line is the ecliptic. That's the path that all the planets are on. And of course, the angle between the ecliptic and the celestial equator is 23.5 degrees. That's the reason for the seasons, as we'll talk about.



And then basically, you extend Earth's rotation axis out. And so instead of Earth's rotation axis, you talk about the north celestial pole. And so that's basically your coordinate system there, and then the different stars all stuck on, and constellations, on that celestial sphere.

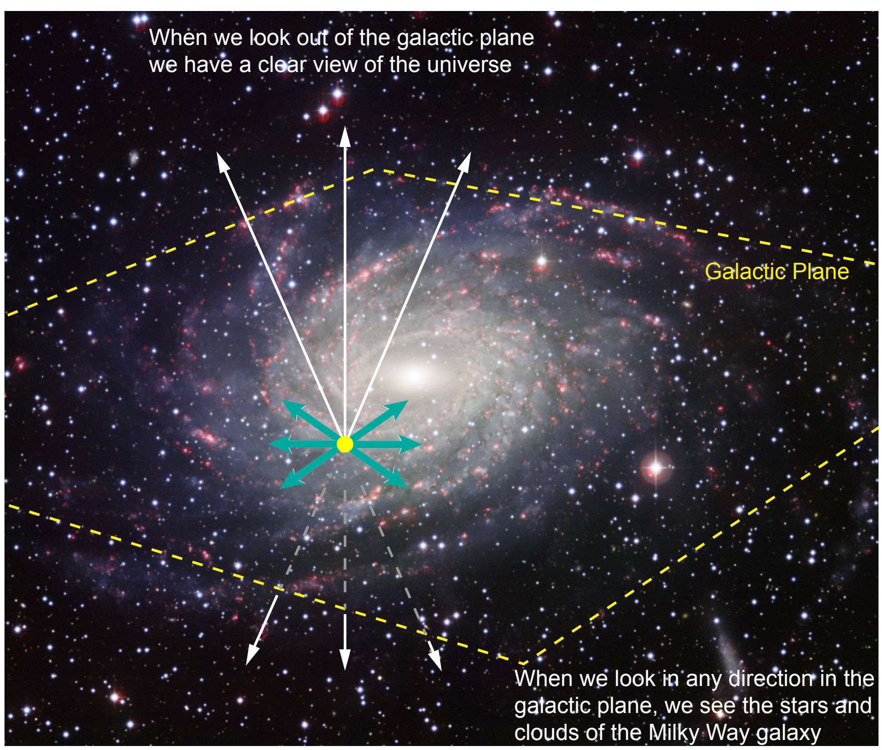
The Sun, as it goes through the ecliptic, will go through a certain set of constellations. And that certain set of constellations is referred to as the zodiac. The image there shows the 13, not 12, 13 constellations of the zodiac. So you're probably use to the zodiac having the 12 astrological signs. I hope I convince you today that you're probably not the astrological sign you thought you were, and there are actually 13.

The 13th is the constellation Ophiuchus. The Babylonians who set up the zodiac certainly knew of Ophiuchus, but at the time the amount of time, that the Sun spent in Ophiuchus is relatively small. They liked the number 12 for a whole host of reasons. 12 was their base counting system, 12 was a holy number to the Babylonians, 12 was all over the place. That's why we have 12 hours of day. It's why we have 12 hours of night. It's why we have 12 months out of the year. The number 12 was all over the place.



Credit: Tau'olunga, Wikipedia
http://en.wikipedia.org/wiki/Zodiac

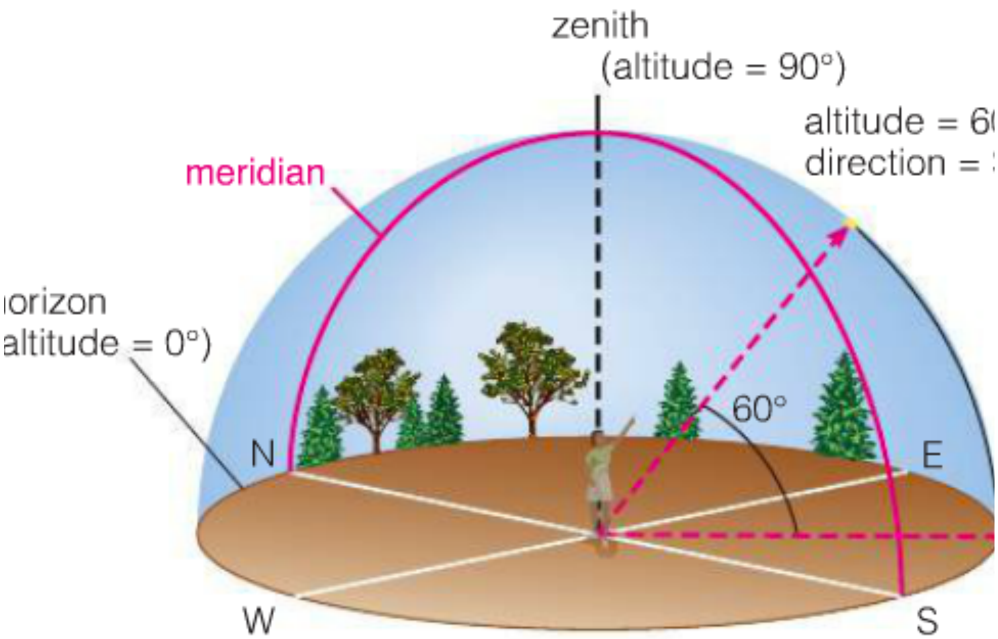
To keep their number system whole, they chose 12 constellations of the zodiac, although in reality there are 13. And these days, the Sun spends more time in Ophiuchus than it does in some of the neighboring constellations.



Credit: NASA,
NGC 6744

The Milky Way then circles all around the celestial sphere. That's what we see as that fuzzy patch of band light as it goes through and traces the galaxy's disks of stars. That's kind of what the illustration above is showing, that if you look inwards, you see toward the center of the Milky Way, where there's approximately a several million solar mass black hole in the center of our galaxy.

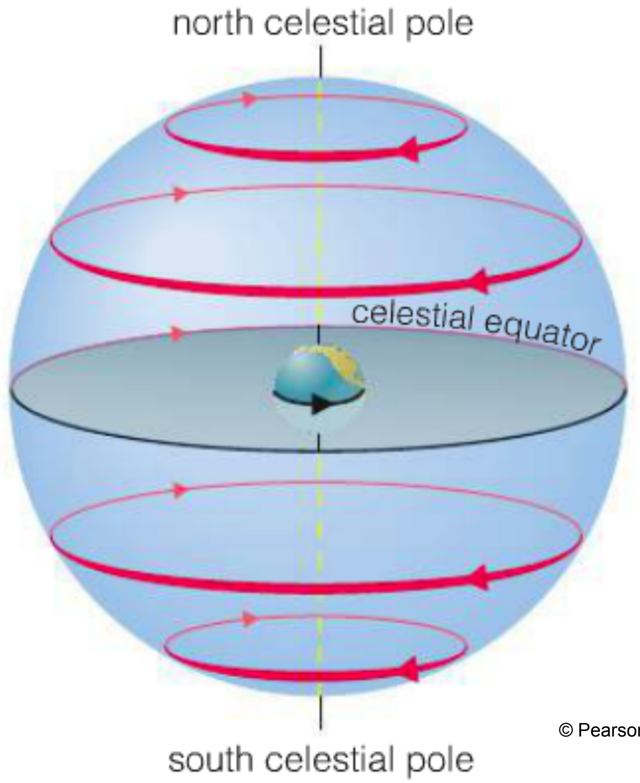
If you look on out, you'll see the outer parts of the Milky Way. If you look in perpendicular directions, you can see out and see other galaxies and the rest of the universe, because there's not a lot of stuff in the way.



So why do stars rise and set? Well, from any place on Earth, the sky looks like a dome. This is essentially your hemisphere, and we can describe any position in the local sky by an altitude, how high it is, and a cardinal direction, North, East, South and West. The image shows you the horizon, which is that imaginary flat surface that goes all the way across your local dome.

And on that dome, you split the dome into two parts. The line dividing them is referred to as the meridian, which you have known your entire life but you might not have known what it was called. Before the meridian when the Sun is rising, we refer to that as antemeridian, AM. And when the Sun is in the second part of the dome, that's postmeridian, that's PM. And so AM and PM, when you tell time, refers to if the Sun is before the meridian or after the meridian.

The direction straight up is referred to as your zenith. The direction straight down is referred to as your nadir. So with this coordinate system, you can determine the position or label the position of any object on the celestial sphere by saying how high up is-- say 60 degrees-- and giving the direction, Southeast.

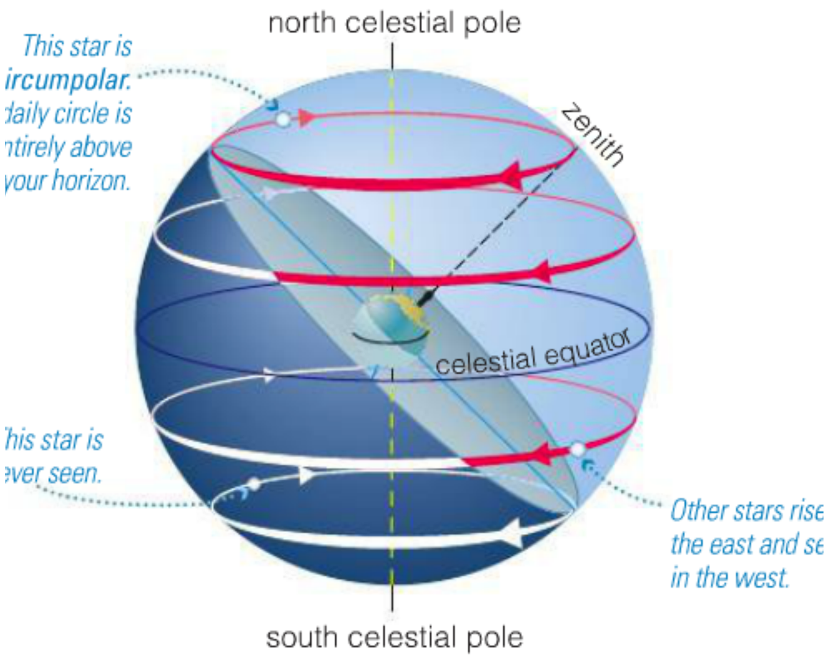


If you spend a few hours taking a look at the stars under a starry sky, you'll notice that the universe seems to be circling around us, with the stars moving gradually across the sky in a generally Eastern direction and setting in a generally Western direction. We can picture the movement of the sky by imagining the celestial sphere is rotating around the Earth.

This was the cosmology of the Greeks. It's wrong. We know that the Earth is actually moving. Nevertheless, it's a very convenient way of looking at the night sky, the Earth is stationary, the celestial sphere is all out here, and it's the celestial sphere that actually is doing the rotation. The celestial sphere rotates from west to east so when we see it on Earth, the objects appear to rise in the East and set in the West.

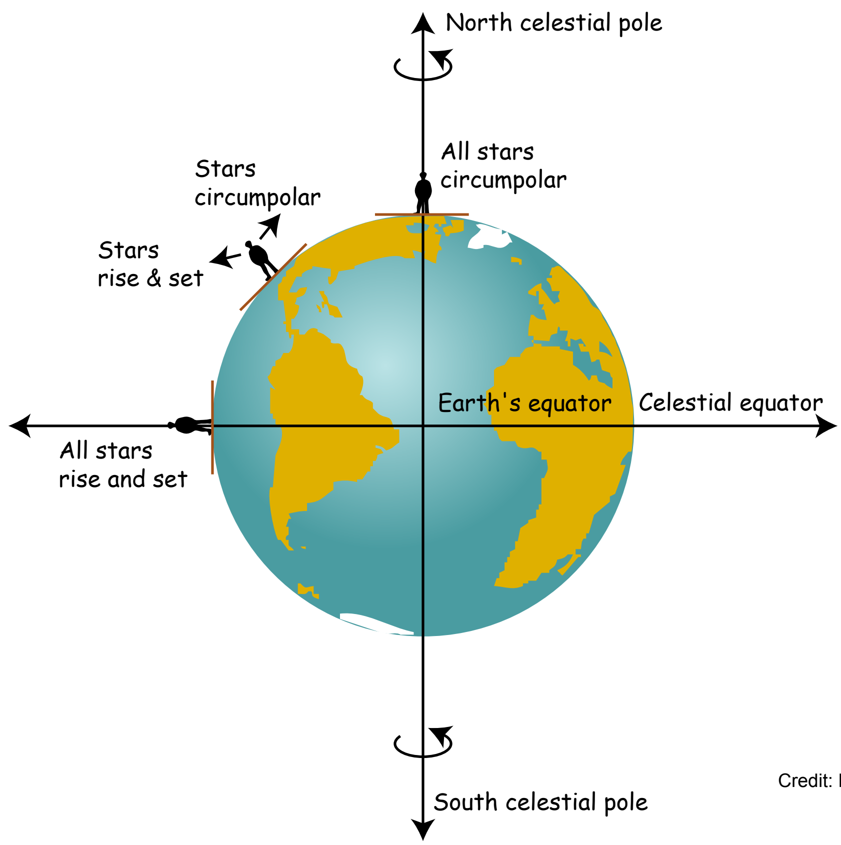
Now, that notion of simple circles can look a little more complicated, because our local sky is cut off by the horizon, which cuts the celestial sphere in half. In other words, the Earth gets in the way of seeing the entire circular motion.

So if you're in a place like the image below, say Tempe, Arizona for example, if you look towards the North celestial pole, toward Polaris, toward the North Star, you will see that some stars never rise and set. They're always visible as they go around in their circle. These are referred to as circumpolar stars.



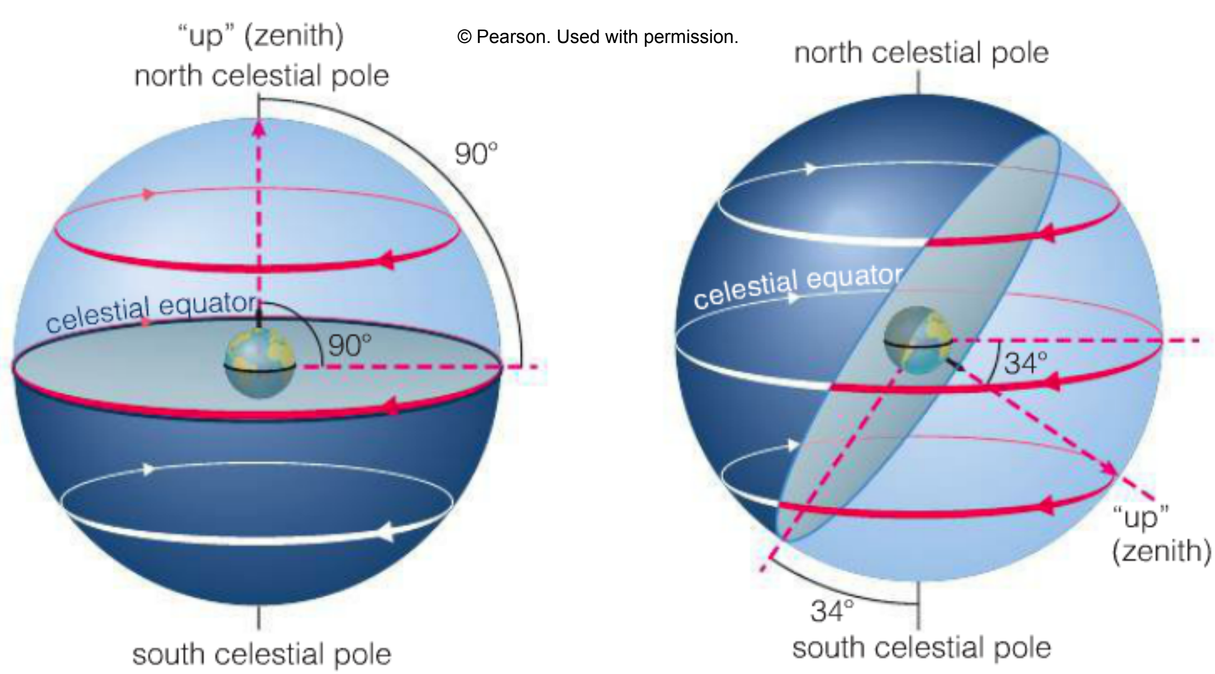
If you look more toward the South, you'll see that a star will rise in the East and it will set in the West. Then there's an entire class of stars in the southern hemisphere that you don't see at all.

So depending on where you look, you'll see some stars that never rise and set, circumpolar, and some stars that will generally rise in the East and generally set into the West.

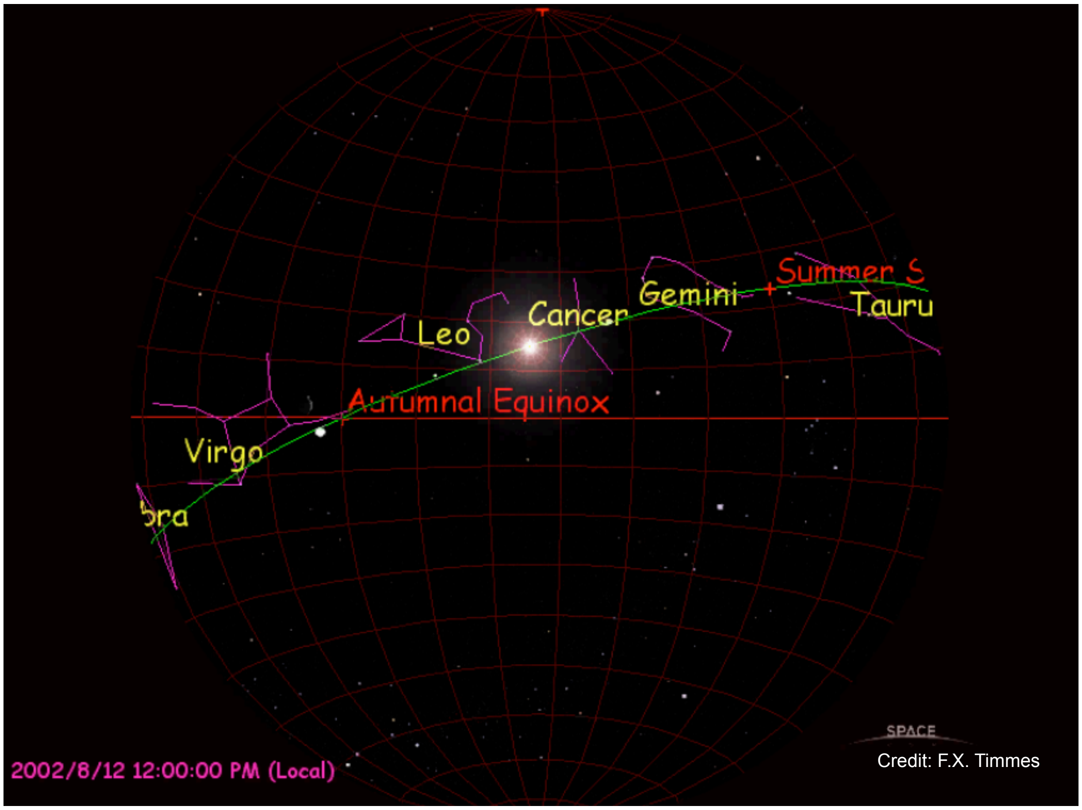


Credit: F.X. Timmes

The illustration above just gets that point across. Depending on where you're standing depends on what you see. So if you're standing at the North Pole, then all stars are circumpolar. No star rises and sets. All stars just do circle around the rotation axis of the Earth-- the north celestial pole, that's the same thing-- as they go around.



If you're in a place like Tempe, if you look toward the North, you'll see circumpolar stars. If you look toward the South, you will see stars rise and set. And if you're at the equator, say in Ecuador, or something like that, then all stars will rise and set, and there will be no circumpolar stars.

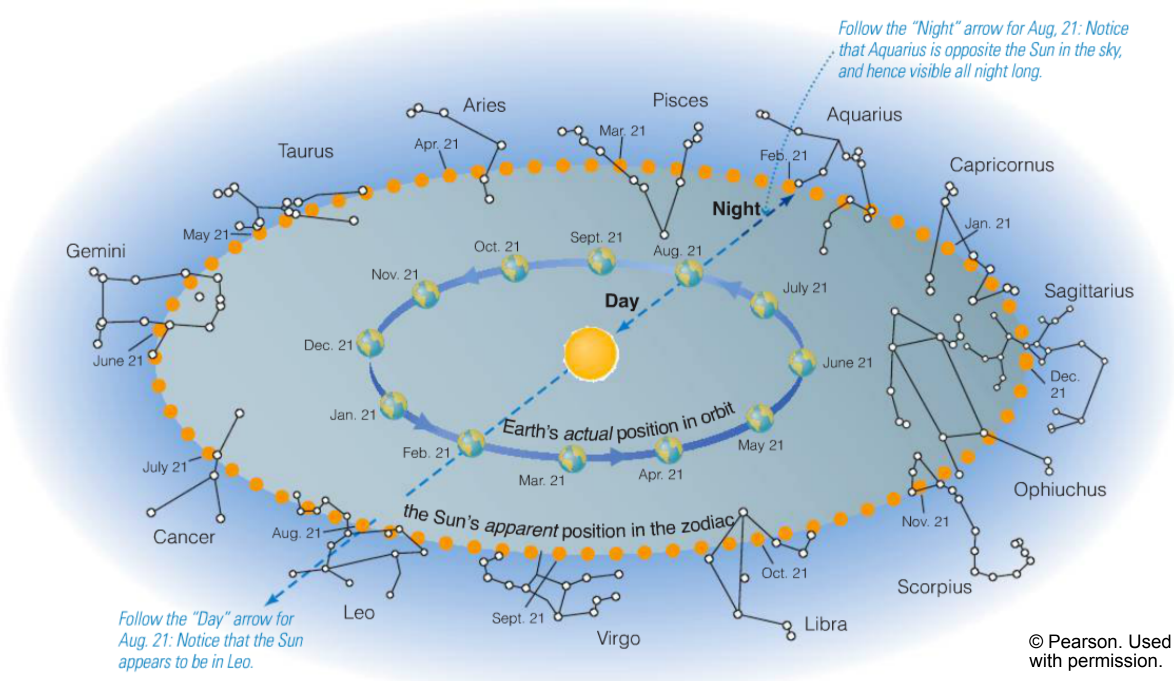


So why do the constellations we see depend upon the latitude and the time of year? Well, the stars we see depend on latitude because the Earth is spherical. And the horizon, the Earth itself, blocks half of the sky. So you're going to see different stars depending on where you are. You don't see stars in the southern hemisphere because the horizon blocks it off so you're only going to see the stars in the northern hemisphere as a result. The rule of thumb here is that the altitude of the north celestial pole, Earth's rotation axis, is equal to your attitude on Earth. So if you're at the North Pole, straight up is zenith, that's 90 degrees. And that is the angle of the north celestial pole. If you're at Tempe, you're tilted over about 60 degrees, and so the angle of the celestial pole is equal to your latitude.

Different constellations are visible at different times of the year because of the relative motion between the Earth and the Sun. The animation above animation showing over the course of a year the motion of the Sun through the classic 12 constellations of the zodiac.

And you'll see it go through Cancer and Leo and Virgo and Libra and so on and so forth. The view here is that flat is the celestial equator, and the path that the Sun is going on is the ecliptic. When those two lines cross, when the ecliptic and the celestial equator cross, when the Sun goes across them, if the sun is going down then that is heading into winter. That crossing is referred to as the autumn equinox. When the Sun is rising and it crosses, the ecliptic crosses the celestial equator, then that's referred to as the vernal equinox, or the spring equinox.

The Sun will go basically in this sinusoidal pattern, this curvy pattern. This goes up and it goes on down. When it reaches its highest point, that's the summer solstice. When it reaches its lowest point, that's the winter solstice. So you can see as this animation plays that the type of stars that you're going to see depends on the time of year because of the relative motion of the Earth and the Sun.



The Sun appears to drift eastward about one degree per day along the ecliptic as the Earth orbits the Sun. The image above shows the Sun against the background of different zodiac constellations at different times of year, one degree per day.

Did you ever wonder why there are 360 degrees in a circle? How come it's not 12? 49? 277? There are 360 degrees in a circle because that is approximately how many days there are in a year. There's 365 days in a year, which of course the Babylonians knew, but 360 is close to 365. And of course, 360 is divisible by 12, which we talked about the Babylonians like a lot. So there are 360 degrees in a circle because that's essentially replicating how many days it takes for the Sun to go around in the Earth.

Study the image above a little carefully because that will show you what constellations, of stars you will see at night depending on what time of the year it is.

A longer one. Thanks for hanging in there! Bye Bye.