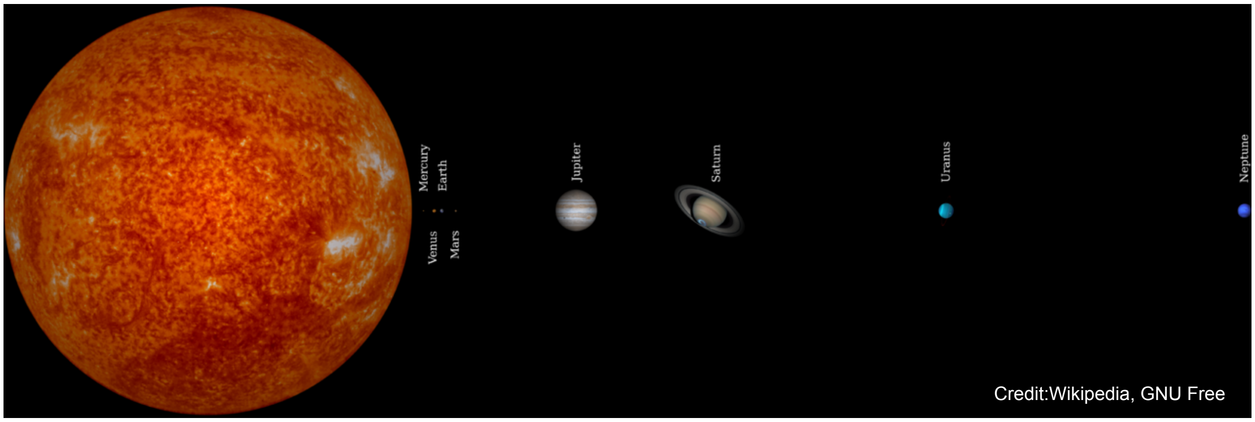
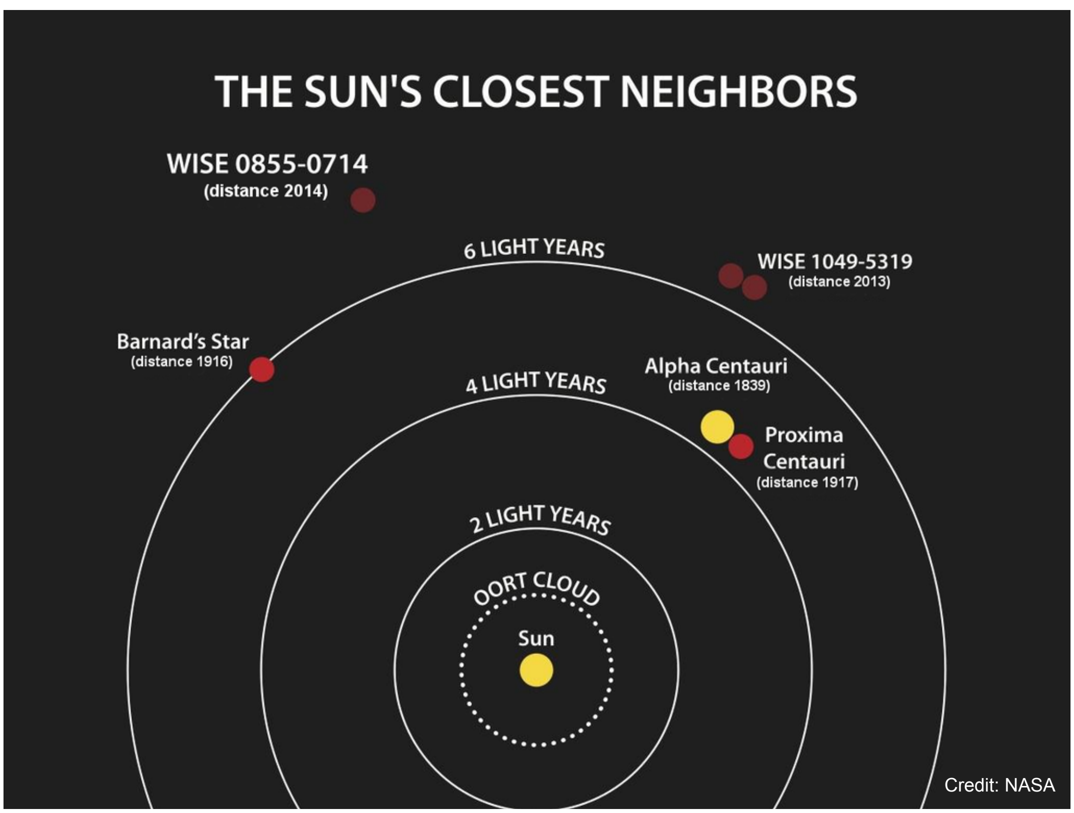
In this module we'll cover the scale of the universe. We'll talk a little bit about how big is the Earth compared to the solar system. We'll talk about how far away are the stars, and how big is the Milky Way. How big is the universe, and how do our ages, our human lifetime ages, compare to the age of the universe?



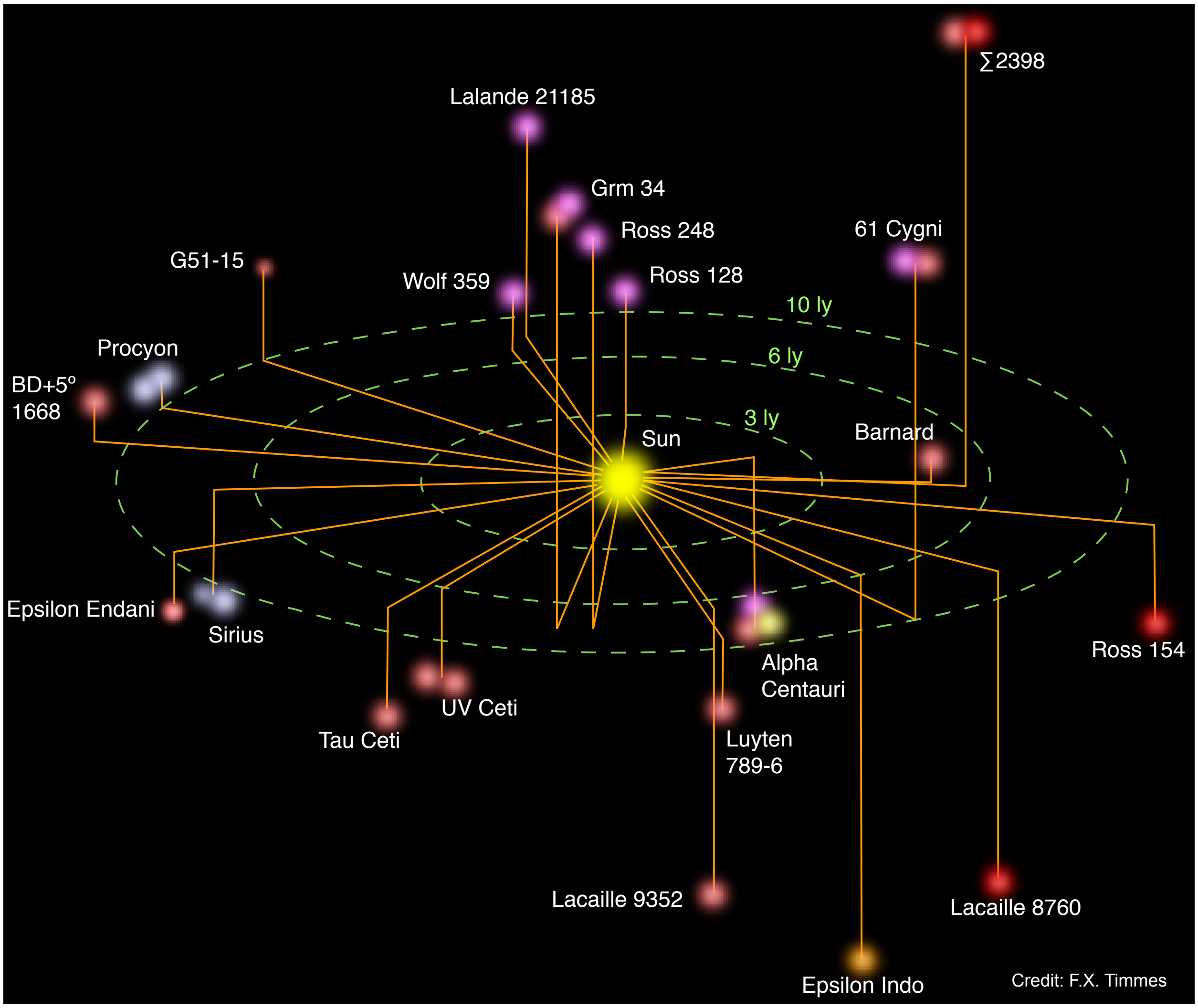
Credit:Wikipedia, GNU Free

So how big is the Earth compared to the solar system? Well, on a scale of about 1 billion to 10 billion, the sun is about the size of a grapefruit. And the planets are much smaller, with Earth about the size of a ballpoint pen, and Jupiter about the size of a marble on this scale. And the distances between planets are huge compared to their sizes, with Earth orbiting about 15 meters-- the size of a ballpoint pen going about 15 meters one the Earth on this scale. And the image there shows the planets around the sun-- Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and no dwarf planet Pluto on this one. So we'll be talking about these plans a lot in this course.

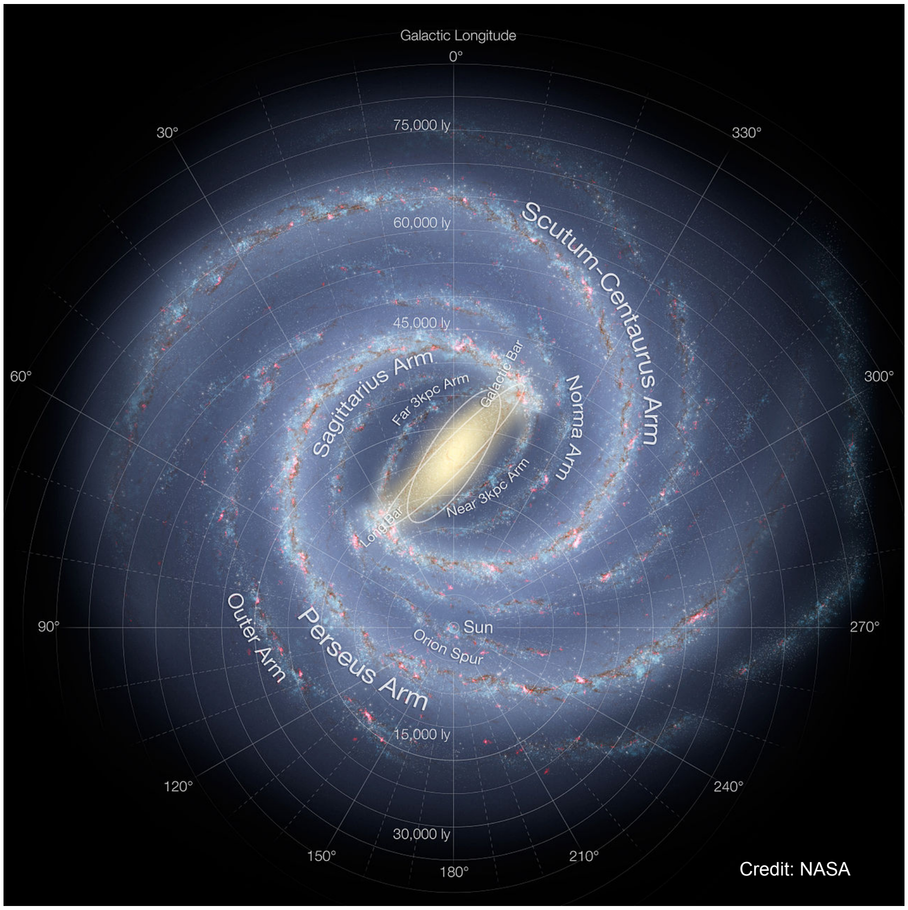


Credit: NASA

So how far away are the stars? Well, on this 1 billion to 10 billion scale, it's possible to walk from the sun to Pluto in a few minutes. On the same scale, the 1 billion to 10 billion scale, the nearest stars, besides the sun, are thousands of kilometers away. And the shot here is of a star system with some of the nearest stars to us on the order of about four or five light years away. But on this compressed scale that we're dealing with, it's about several thousand kilometers away.



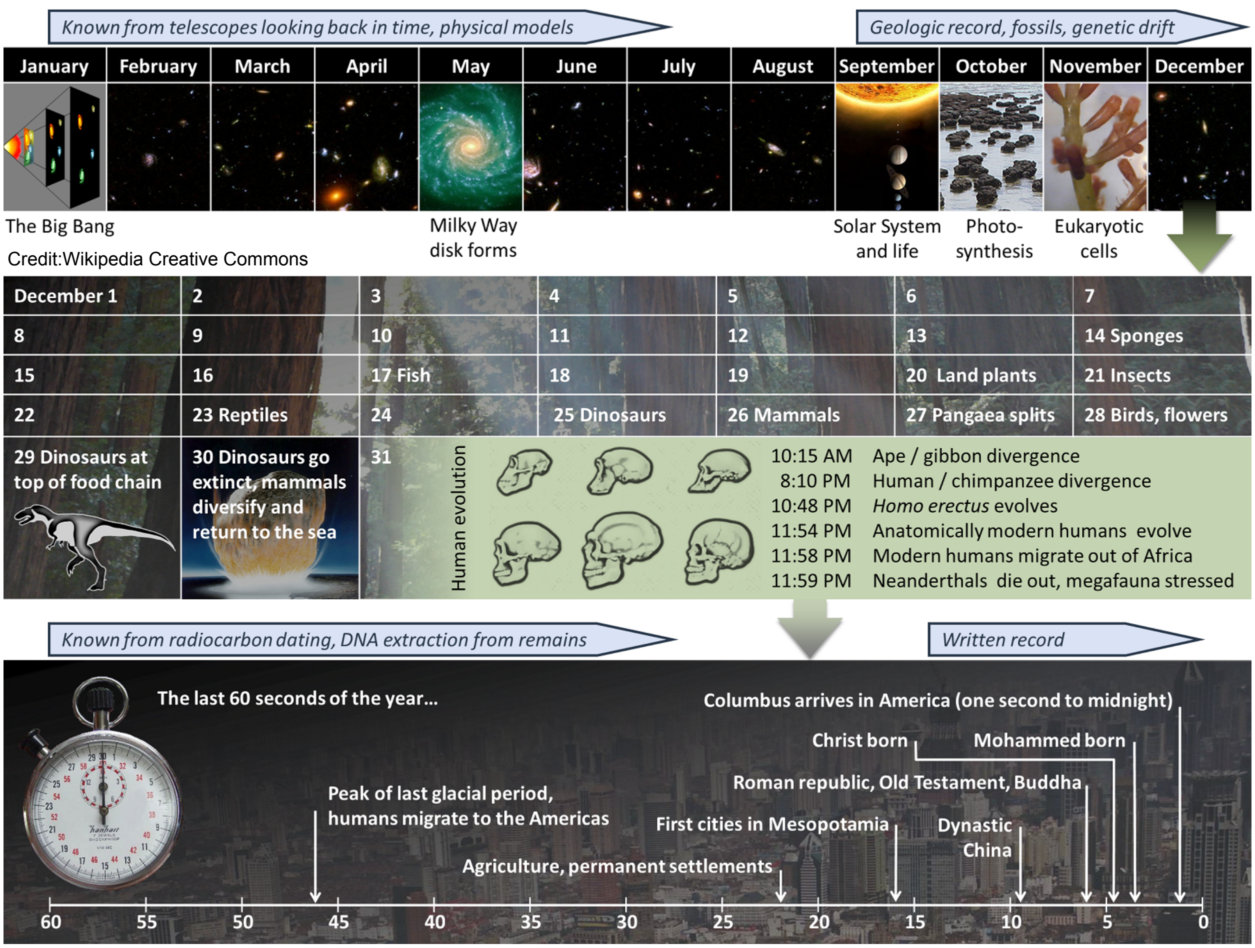
So there's a lot of space between the stars. Typical distances between stars are on the order of 10 light years between different stars. And if you keep on going outwards, then using a scale on which the Milky Way is the size of a football field, the distance to the nearest stars would be about four millimeters or so. And there are so many stars in our galaxy, about 100 billion, that it would take thousands of years to count them individually. And the next image there shows a cartoon drawing of the Milky Way.



We've talked a little bit about this last time, where this is a face-on view of a spiral galaxy. So you see the beautiful spiral arms. Note that they're in blue-- that's from the hot, massive, blue stars. And you've got a red background from the red-yellow stars in between the spiral arms. Then you have a nucleus, or a bulge. And the sun is located comfortably out in the suburbs at about 28,000 light years from the center.

So how big is the observable universe? Well, as we saw last time, when we're taking a look at the universe there's about 100 billion galaxies in the universe, and the total number of stars in all those galaxies-- so about 1000 billion stars per galaxy, 100 billion galaxies-- that is comparable to the number of dry sand grains on all the beaches on Earth. So if you've ever been to the beach, and you've taken a bunch of sand, and you take a look at all that sand, there are more stars in the universe than there are grains of sand on that particular local beach on which you are sitting. Kind of amazing.

So how do our lifetimes compare to the age of the universe? Well, on a cosmic calendar that compresses the entire history of the universe into one year-- so the universe begins on January 1, and it brings us up to the present at 11:59 PM on December 31. Then, human civilization is just a few seconds old, and a whole human lifetime lasts just a fraction of a second.



And the image here goes through that calendar, starting from the beginning of the universe and the big bang on January 1, and it walks on through, through the formation of the Milky Way, through the formation of the solar system, which is about 4.7 billion years. So that's old the Earth is, that's how old the sun, that's how old our solar system is. And it walks on through all the way up until-- humans don't even begin to arrive until late in December 31. And of course all of the modern stuff-- and by modern, I mean from Babylonians to the Egyptians into the present-- is all packed into that final second of the cosmic calendar.

So let's do a typical calculation that you'll experience in this class. On average, there's going to be about one quantitative problem per week to do. It's all algebra. It's nothing more complicated than that. There's no trigonometry, there's no calculus, none of that. It's just algebra. So let's walk through one of the problems.

And so we claimed that a light year-- that light in one year travels about 10 trillion kilometers. But how do we know that? That distance is far greater than anyone can measure or any spacecraft has ever traveled, so we can't possibly measure it. So how far is a light year? And so all problems in this course are going to be solved with arithmetic and simple algebra. And if it helps, there's a three-step process that could help you solve these kinds of quantitative problems.

The first one is just understand the problem. Ask yourself what the solution should look like. What units should it have? How big-- is it going to be a big number, a small number? What information is given to you in the problem? And then, how might you solve it? Sometimes it can be helpful to draw a diagram or a simple figure. Or it can be helpful to do an analogy problem to help grasp what the problem is asking for. That's the most important step, is understanding the problem.

The second step is really kind of mechanical-- solve the problem. Carry out the necessary calculations. Pull out your calculator and crank, crank, crank, and you'll come up with an answer. But once you get that answer, then you go to step three, which is to explain your result. Does it make sense? Is the number supposed to be big? Is the number supposed to be small? What are the units of the answer? So this little guide goes by USE. So understand, solve, and explain.

So let's walk through this mechanism for this problem. So step one, the problem asks how far? And so we are looking for a distance. And it's that distance light travels in one year. We're given the time. We know that's one year. And we know that the speed is the speed of light.

And so we know that we need to multiply the speed of light by one year. And the speed of light is approximately 300,000 kilometers per second. And because this time is given in seconds, and the time is in one year we need to convert a year into seconds. And so now we simply carry out the calculation, carrying the units if you like, if it helps. So I'll do it in this example problem. You don't need to do it if you don't want to, but I'll just make it really explicit here.

So we have one light year is equal to a speed, times the time. So that's a distance is equal to a speed times the time. The speed here is the speed of light, 300,000 kilometers per second. In the second line there, I convert one year into seconds. So I take one year. There are roughly 365 days per year. There are 24 hours in a day, 60 minutes in an hour, 60 seconds per minute. The reason I put in all those units-- as you can see that they're all going to cancel. The minutes are going to cancel, the hours are going to cancel, the days will cancel, and the seconds will cancel.

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\begin{aligned}
1 \text{ light year} &= (\text{speed of light}) \times (1 \text{ yr}) \\
&= \left(300,000 \frac{\text{km}}{\text{s}}\right) \times \left(1 \text{ yr} \times \frac{365 \text{ days}}{\text{yr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{60 \text{ s}}{\text{min}}\right) \\
&= 9,460,000,000,000 \text{ km} \\
&= 9.46 \times 10^{12} \text{ km}
\end{aligned}
$$

And so what you're left with, after you multiply all those out your calculator is about 9.46 times 10 to the 12 kilometer. Does the answer make sense? Yeah, because you know light moves very quick and a year is relatively long, so you should expect a big number for that. Now, when you're talking about it, you're never going to remember 9.46 times 10 to the 12 kilometers, but it's relatively easy to remember 10 trillion kilometers. So for most problems, it's quite OK to round that off to 10 trillion kilometers when you need it.