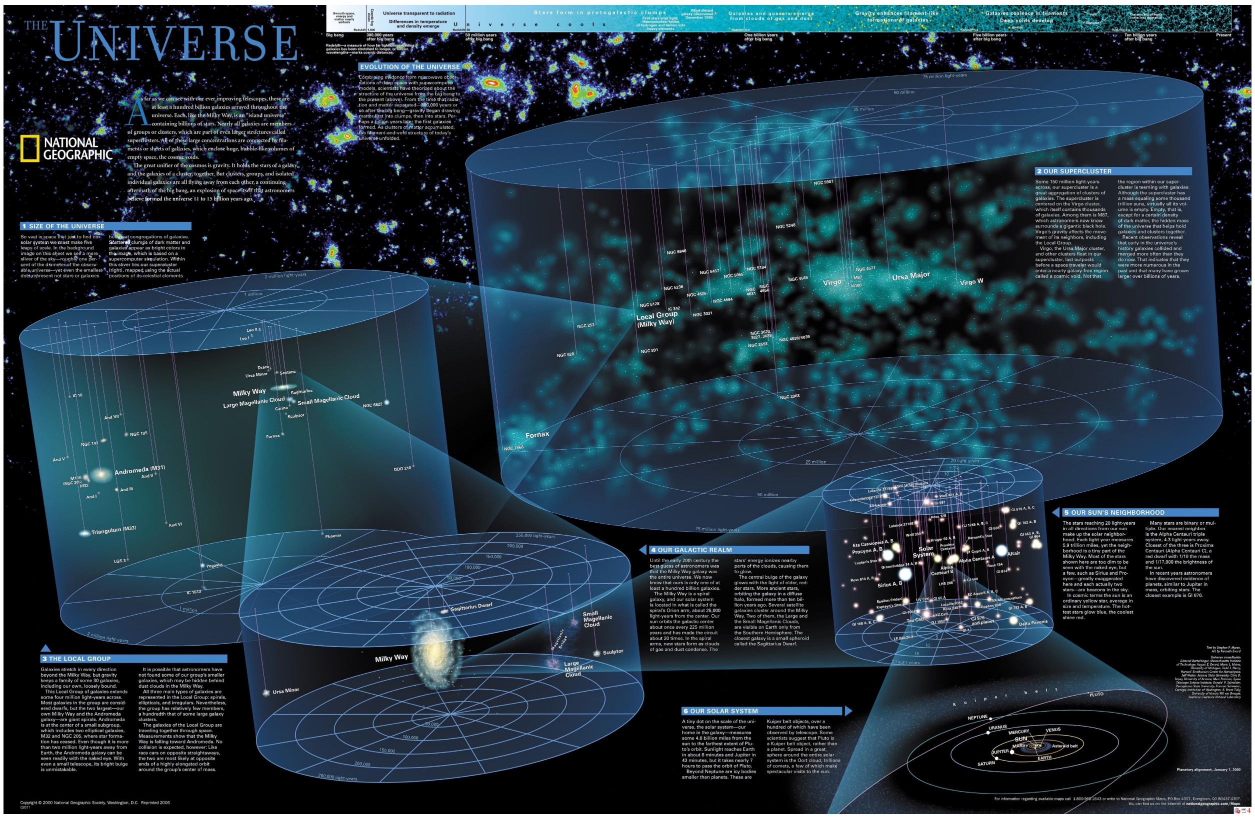
From now on, we live in a world where man has walked on the moon. It wasn't a miracle, we just decided to go.

Jim Lovell, Apollo 13

Our View From The Garden

Hello AST 111! In this module we'll explore our postal address in the universe and how we got here.



Credit:National Geographic
http://maps.nationalgeographic.com/maps/print-collection/universe.html

The image above shows our postal address in the Universe. Earth is a planet orbiting the Sun, of course. This fact has been drilled into your head since you were a child, probably because it's not obvious that the Earth goes around the Sun - a source of one of humanity great intellectual revolutions. The sun is part of the Milky Way galaxy. There are about 100 billion stars inside the Milky Way. The Milky Way is about 100,000 light years across, and if you don't know what a light year is, that's OK. We'll cover that in a few minutes, but essentially it takes light about 100,000 years to go from one side of the Milky Way to the other side.

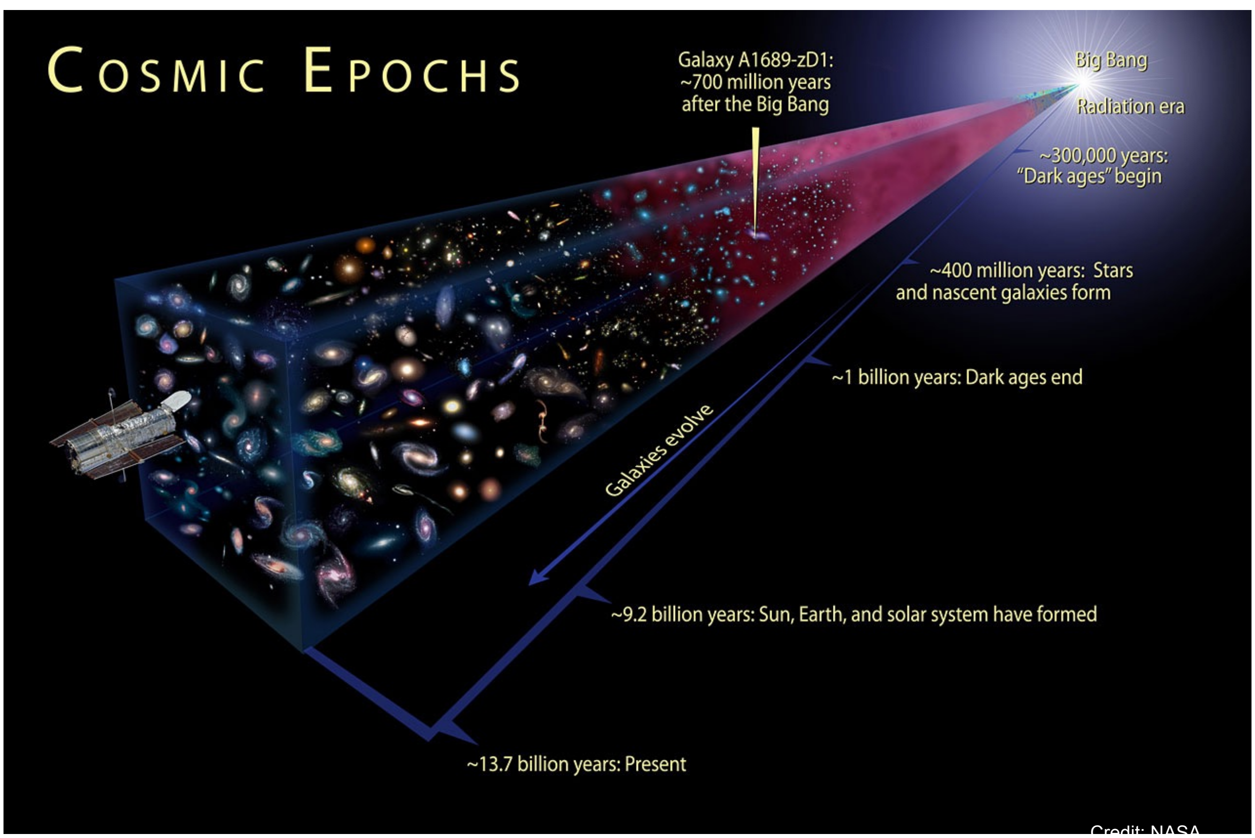
Our Milky Way galaxy is then part of what's referred to as a Local Group of galaxies, which is a group of about 40 galaxies. The other largest member of the local group is the Andromeda galaxy. The Milky Way and Andromeda are on a collision course. In about 5 billion years or so, the Milky Way and Andromeda are going to merge, which is also about the lifetime remaining left in our sun. So in about 5 billion years, we should be in a very interesting place, as our sun is beginning to die, the two big galaxies are starting to collide - it should be a fun and exciting time.

The Local Group is then embedded in what's called the Local Supercluster, which contains about 1,000 galaxies in a relatively small volume of space.

The background image is what the universe looks like in toto. You can see that on the largest scales, galaxies are distributed in sort of this lacy, filamentary pattern. The galaxies are arranged like pearls on a string, and in between those galaxies are very large voids where there's hardly any galaxies at all.

So this is sort of our postal address in the universe, our view from the garden. We're primarily going to be concerned with the first two steps on this “distance ladder,” between the Earth and the planets, the solar system, and other solar systems.

For a video of our postal address, take a look at the American Museum of Natural History video http://www.amnh.org/our-research/hayden-planetarium/digital-universe



Credit: NASA

So how did we come to be? The universe began in the Big Bang and has been expanding ever since, except in localized regions where gravity has caused matter to collapse into stars and galaxies. When the universe began, the only elements that were made were hydrogen and helium, the two lightest, odorless, colorless gases. It's stars that are the element factories. It's stars that make the periodic table. It's stars that make you and me. Hence the phrase, we are star stuff. Every atom of carbon in your body, every atom of iron in your blood, everything that you see around you every little bit of that, was forged in the center of a star a long, long time ago.

It wasn't like all of the elements were made all at once by a single generation of stars. Instead it's a continual process of the star-gas-star cycle. Stars are born, stars live, stars die. And every time they go around that cycle, every time a star dies, it puts out a new generation of fresh elements, new carbon, new iron, new calcium, new uranium. And slowly, the galaxy and the cosmos enrich itself in elements - the stuff of life.

How do we know what the universe was like in the past? That comes down to a very basic physical phenomenon. It takes light a finite amount of time to go from A to B. In our everyday existence, when you turn on a light switch, that light turns on, and it looks almost immediate. But it does take a little bit of time for light to go from the bulb to your eye, and that effect gets bigger and bigger as the distances grow larger and larger.

If you take a look at the Sun (not advised!), when photons, or particles of light, leave the surface of the sun, it takes about eight minutes for those photons to reach the Earth. So when we look at the Sun, we don't see the sun as it exists right now in its frame. We see the Sun as it looked eight minutes ago. So in a very real sense, we are looking eight minutes into the past.

Take a look at Pluto. We don't see Pluto as it is right now. We see Pluto as it was approximately about one light hour ago. And the farther out you go, the bigger the effect. When you start looking at galaxies that are millions of light years away, you are seeing back into the universe millions of years ago. And similarly, all the way out to the very distant fringes of the universe, out to several universes about 13 billion years old--so when we look at galaxies that are just starting to form about 13 billion years ago, we're seeing that today as it looked in the past.

Our telescopes are honest-to-goodness time machines. We look back as the universe was many light minutes, many light hours, millions of light years, billions of years ago.

Can we see the entire universe? No, because it takes light a finite amount of time to go from A to B. We can only see that part of the universe where light has had enough time to reach us. And we call this the observable universe, which is embedded in a much larger, or the whole universe, if you like. So on the one hand, there's the observable universe here, and this is embedded in the entire universe. And the size of our observable universe gets larger and larger with each passing year. It gets one light year larger in radius. And so while we can't see the entire universe, we do see everything that we see around us within the observable universe.

The image down there on the bottom sort of gets that point across. As I was talking in the previous slide, in this one, just that it takes light a finite amount of time to go from A to B. So when you look into things that are very far away, you're seeing them as they were in the distant past.

I'm going to introduce several pieces of jargon that we're going to use over and over in this class. A star is a large, glowing ball of stuff. The sun is a star, right up close. A planet is an object that orbits its star, has enough mass for gravity to make it round-ish, and has cleared other objects from its path, And there are three criteria by which we decide whether something is a planet or not.

The third one is where Pluto falls down. There are other objects out in what's called the Kuiper belt that are just like Pluto, that are just as large as Pluto, and in some cases even larger than Pluto. So Pluto has not cleared out its neighborhood like the Earth has, or Jupiter has. So this is the basis for Pluto being re-classified as a dwarf planet. On the other hand, Pluto was sort of always the odd planet out, and now it has a family.

A moon is a body that orbits another planet or a satellite. Then we have asteroids and comets. An asteroid is a rocky body, and a comet is a dirty snowball. We'll go into why these objects are important later in this course, but for now, they're important because they're the most numerous objects in our solar system. By number, they utterly dominate our solar system. They also tell us the original composition of our solar system and have a unique way of changing life on a planet.

Then there's a hierarchy on how we organize objects in the universe, in the cosmos. We start with a solar system, which could be our solar system, could be exo-solar systems. Then one can have star systems, where you'll have binary stars, triple stars, quadruple stars. These then rolled up into what are called clusters of stars, where you have hundreds to hundreds of thousands of stars. Going to larger scales, you have galaxies. A galaxy typically has anywhere from 100 billion to a trillion stars in it. Then we have superclusters of galaxies, where you have thousands to tens of thousands of galaxies, all bound together by their mutual gravity. Finally, we have the observable universe, which is what we talked about — the size of the universe that we can see, where light has had enough time to get to us.

We're going to use two main distance units in this course. The first one is called the astronomical unit. It is the average distance between the Earth and the Sun. It's about 150 billion meters. So the Earth, by definition, is 1 AU from the sun. Something like Mars is about 1.5 AU from the sun. So it's a relative distance measure.

We'll also use a different unit of distance called the light year, which is the distance that light travels in one year. It's about 10 trillion kilometers. And so those are two basic distance units that we'll be using in this course.

Finally we'll have terms relating to motion where we talk about rotation of an object, or how fast it spins. This is different from the revolution of an object as it orbits.

Thanks! Bye Bye.