The Milky Way: Crash Course Astronomy #37

Crash Course: Astronomy
https://youtube.com/watch?v=tj_QPnO8vpQ
https://nerdfighteria.info/v/tj_QPnO8vpQ

Over the past few weeks, I've talked about our Sun, the planets and other objects in our Solar System, stars (both big and small), brown dwarfs, exoplanets, supernovae, and clouds of gas and dust. What do all these things have in common? Well they, we, all live in the same town. It's a big town and it's called The Milky Way Galaxy.

Let's cut to the chase. The Milky Way Galaxy is a vast, flat, disk-shaped collection of gas, dust, and stars. A sprawling megalopolis that's a mind-crushing 100,000 light years across and several thousand light years thick. The Sun is but one of hundreds of billions of stars in it, and we're located halfway out from the center, in the suburbs. The disk has two major spiral arms in it, and two minor ones. These come together more or less in the middle of the galaxy. Located in the center of the disk is a bar, an elongated, roughly cylindrical collection of old red stars.

I know, this is a lot to take in. I'll go over it piece by piece, and how we know all this, like with so many other such deep astronomical discoveries, begins simply enough: going outside and looking up.

(Crash Course intro plays)

If you happen to be in a dark spot on a moonless night, you'll see a faint fuzzy glow stretching across the sky. It's brighter in some spots than others and if the constellations of Sagittarius and Scorpius are visible, you'll notice the stream broadens there, forming a bulge apparently bigger than your outstretched hand.

This glow's resemblance to a pathway or river is strong, and many ancient cultures saw it that way as well. Because it glows a dull white, the ancient Greeks called it *galaxius*, or milky. Over the millennia that name stuck and now we call it The Milky Way, or redundantly, the Milky Way Galaxy.

But what *is* that glow? It was thought to be nebulous, cloudy, until one day a guy by the name of Galileo pointed his newly crafted telescope at it. He was astonished to see that it was actually made up of stars, thousands of them. They were so close together and so faint that our naked eyes couldn't see them individually. Instead, they blended together to create that glow.

Clearly there were far more stars in the sky than the 6,000 or so visible to our unaided eyes. But how many more? and what overall shape did they form?

Astronomers reasoned that counting stars in different directions might
reveal the shape. If the galaxy is longer in one direction than others, you should see more stars in that direction. Over the centuries, maps were made this way, and they generally showed the galaxy to be oval shaped, or a flattened disk with the Sun near the center. This star counting method is a good idea, but it's fatally flawed. It doesn't account for interstellar dust.

As we saw in our episode about nebulae, dust absorbs visible light from stars, hiding them from our view. It's like being in a smoky room where you can't see the walls. It looks like the room is smaller than it really is, and you look like you're in the center, even if you're near one of the walls.

Globular clusters were a good clue that there was more going on. These spherical balls of stars orbit the galaxy well outside the main body of the galaxy itself. There are more of them on one side of the sky than the other, which you wouldn't expect if they were evenly distributed in space.

The simplest explanation was that they actually *were* evenly distributed in space, but it was *we* who were off center. Measurements put the Sun about 25,000 light years from the galactic center, which was in the direction of Sagittarius. Hey, that's where the glow of the Milky Way in the sky gets brighter and broadens out too. Coincidence?

So at this point, things were coming together. The Milky Way must be a flattened disk with a bulge in the middle. The Sun is in that disk, far from the center. From inside it, we see it as a broad line in the sky, and when we look toward the center, towards Sagittarius in the sky, we see that bulge as a big blob. The disk is thinner than it is broad, so we see more stars looking into the disk than when we do looking up or down out of it.

But what about the disk itself? Does it have structure in it, or is it more like a smooth, flat plate? That's hard to determine using visible light. Dust severely restricts our view. Looking into the disk, we can only see about a thousand light years before dust blocks everything behind it. But with the advent of radio astronomy, we figured that out too.

Star-forming gas clouds emit a very narrow wavelength range of radio waves, and this could be used to measure their Doppler shift (how quickly they were moving toward or away from us). Making a few other basic assumptions, their rough distance could be found as well.

An amazing result was found. The locations of these nebulae indicated that the disk of the Milky Way was divided into spiral arms, huge sweeping curving arms that were tens of thousands of light years along their lengths.

Interestingly, all the young massive bright stars appeared to be in these spiral arms too, with none in the apparent gaps between the arms. But that makes sense. Like all stars, these massive ones form in giant nebulae, but unlike most stars, they don't live very long before exploding in supernovae. If most nebulae are in the arms, then these massive stars will be too. They don't live long enough to get very far from their nurseries before they explode.

Here's where things get a bit weird. You might want to think of the arms as structures; huge collections of stars and nebulae moving together around the galaxy's center, but that can't be right. If that were the case, they'd wind up like string on a spool, since the stars in nebulae closer to the galactic center orbit faster. But we know the spiral arms have been around a while, and aren't wound up.

That's because they aren't actual structures. They're traffic jams. Think about a highway with heavy traffic on it. For some reason one car slows down a little. The car behind it slows, and the car behind that one hits the brakes too. It's like a wave that moves backwards through traffic, slowing everyone down. Where they slow down, they tend to clump up too, so you see more cars and trucks in the jam.

The funny thing about traffic jams is they tend to persist for a long time, even as cars move out of them. The car in the front might slow for a moment then accelerate away, but the cars behind it are still moving slowly and more cars are piling up in the rear. For every car that leaves the jam in the front, another enters from the back. Even though the actual individual cars come and go, the jam persists.

Spiral arms are the same sort of phenomenon. The initial wave, the jam, may be started by some sort of disturbance in the disk. Perhaps an over-dense region created when a couple of giant molecular clouds smash together. Once created, this effect propagates outward like a ripple in a pond, and gets sheared into a spiral wave pattern by the rotation of objects in the disk. Stars and nebulae enter the wave, pile up a bit, move through it, and resume their merry way once they leave it.

Our Sun takes about 250 million years to orbit the galaxy, which means it's made about 20 orbits since it was born. It's moved in and out of spiral arms many times over its long life. That's why spiral arms don't wind up. The arms are waves made of objects in them, but the objects themselves are transient.

However, there's more to it. A nebula entering a spiral arm might hit another one already in there. A cosmic fender bender. But when that happens, the nebulae can collapse, forming stars.

Some of them are massive, luminous, blue and hot. These stars are very easy to spot at great distances, making the galaxy's spiral arms look blue. They also light up the gas around them, accentuating the spiral arms. Spiral arms are where the majority of star birth occurs in the galaxy, which helps maintain the spiral pattern. They're the ultimate crowdsourced projects.

After all that, it's actually hard to say how many spiral arms the Milky Way has. It's been though to have two for a long time, but a recent study of the locations of star clusters seems to indicate there are actually four. Milky-Wayologists are still arguing about it, but either way, there are also short spurs that stream off of the major arms as well. Our Sun is located just outside one of these smaller arms called the Orion Arm.

Mapping the galaxy's spiral arms is ongoing work, and it's kind of a mess. It's like being inside a hurricane and trying to figure out its structure. But we're doing pretty well so far.

In the center of the galaxy is the bulge. Recent observations indicate this is actually a cylindrical bar of redder stars that's pointed nearly directly at us, so it looks more circular to us. This region is very old. All the star birth in there happened long ago and ceased when the gas ran out. Unlike the spiral arms where stars are still actively being born, all the blue stars in the bar are long dead, exploded, leaving behind billions of lower mass redder stars.

The bar is probably about 20,000 light years long. This odd structure is due to the weird gravity of the galactic disk. Unlike our Solar System where the central Sun dominates the gravity, the gravity of the galaxy is spread out over a huge area. This distribution of stars and gravity means weird structures can pop up and self-maintain, like spiral arms and central bars. Unlike the arms though, the bar rotates as a single unit. Stars near the edge make one orbit in the same time as the stars closer in.

In the very center of the galaxy sits a very massive black hole, one with 4 million times the mass of the Sun. This might seem huge, but remember, the galaxy has hundreds of billions of stars in it. The central black hole is actually just a teeny tiny part of the galaxy by mass. But we'll learn more about it in a future episode and see that it may have played a very big role in our galaxy's formation and evolution.

The last component of the Milky Way is its halo, a vast spherical cloud of stars surrounding it out to great distance, more than 100,000 light years. We don't know much about the halo, but we know the stars in it are old. No star formation occurs there, so any stars we do see would be old. It's possible some stars in the halo formed there, while others were flung out into the halo after collisions with other stars and clusters. Speaking of which, most of the globular clusters orbiting the Milky Way are in the halo. There are more than 150 in total.

So, there you have it, our local galactic town. But like any denizen of a small town, it's natural to wonder if this is all there is. What else is out there? And at the beginning of the 20th century, astronomers started to ask the same thing. Is the Milky Way *the* galaxy, or *a* galaxy? Ohhh we're about to take a big step here with Crash Course: Astronomy, a really big step. Better strap in. Starting with the next episode, the universe is about to get a lot bigger.

Today you learned the Milky Way is a disk galaxy: a collection of dust, gas, and hundreds of billions of stars with the Sun located about halfway out from the center. The disk has grand spiral patterns in it formed by the traffic jams of stars and nebulae, where stars are born. The central region is shaped like a bar, and is mostly old, red stars. There's also a halo surrounding us of old stars.

Crash Course: Astronomy is produced in association with PBS Digital Studios. Head over to their YouTube channel to catch even more galactically cool 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. The sound designer is Michael Aranda, and the graphics team is Thought Cafe.

(Crash Course outro plays)