The History of the Twentieth Century
Episode 221
"The Great Debate I"
Transcript

[music: Fanfare]

What is our place in the Universe? It sounds like a philosophical question, but is it also a scientific one. In the third decade of the twentieth century, astronomers found the answer.

And it was mind boggling.

Welcome to *The History of the Twentieth Century.*

[music: Opening Theme]

Episode 221. The Great Debate, part one.

The word *nebula* in Latin means a cloud, a fog, a mist, or a vapor. It is of course the root of the English word *nebulous,* which means indistinct or vague.

In the second century, when the Roman Empire was at its height, there lived in the city of Alexandria a Greek-speaking scholar named Claudius Ptolemaeus. In our time, he is usually referred to as Ptolemy. Ptolemy wrote a number of books on subjects of scientific interest, on music, on optics, on geography, and more, but most notably the *Almagest,* a treatise on astronomy that is by far the most important book on that subject that survives from the ancient world. It was regarded as authoritative for over 1300 years.

Ptolemy's *Almagest* is the book that laid out the cosmology of the universe that had Earth in the center as a fixed point, with the sun, moon, planets, and stars circling it. This mathematical model predicted the movements of the planets with amazing accuracy, which is why it was regarded with a reverence bordering on religious and remained unchallenged until Nicholaus Copernicus came along. (I mentioned that Copernicus was Polish, right?)

But today I mention Ptolemy and the *Almagest* for a different reason. The book also contains a catalog of over a thousand stars, which Ptolemy himself described as all the stars it was possible to perceive from his location in Alexandria. This early stellar catalog also included a brief list of stars that appeared fuzzy, including one in particular that lay between the constellations of Ursa

Major and Leo. This fuzzy patch of light later came to be known as the Andromeda Nebula, since it lies in the constellation of Andromeda. Ptolemy is the first astronomer known to have observed and recorded it. The tenth century Persian astronomer Abd al-Rahman al-Sufi also recorded the Andromeda Nebula, which he described as a “little cloud.”

The Andromeda Nebula was unique among these fuzzy stars. The others had an actual star in the center with a glowing fuzziness around them. The Andromeda Nebula, by contrast, appears as a faint patch of white light, not associated with any discernible star. You can see it yourself with your naked eye, if you know where to look and you can find someplace where the sky isn’t washed out by artificial light.

These few visible nebulous objects in the night sky are difficult to examine by eyesight alone. Once the telescope was discovered, it became possible to study them more closely and to discover new ones. The most famous cataloguer of nebulae—or nebulas, if you like—is undoubtedly the 18th-century French astronomer, Charles Messier. Messier was a comet hunter. He discovered thirteen comets over his career. For Messier, these nebulae were an irritation; they looked too much like comets, so he created a catalogue of the most prominent ones so that he and his fellow comet hunters wouldn’t be distracted by them. His final catalog, published in 1781, numbered 103 objects.

It’s a famous historical irony that today Messier is best known not for his comets, which were his passion, but his catalog of nebulae, which he only compiled because they were a nuisance that was interfering with what he really cared about, which were the comets. In our time, the Messier catalogue is a well-known challenge for amateur astronomers, many of whom try to personally observe every one of the 103 nebulae on the list, in the same way birdwatchers pursue lists of, say, every species of bird known to be native to a given place.

The Andromeda Nebula was number 31 on Messier’s list. Thus, in the parlance of astronomers, the Andromeda Nebula is denoted M31.

The same year Messier published his catalog, the German-British astronomer William Herschel became the first person to discover a new planet, Uranus. We talked about that discovery in episode 56. Herschel came across the new planet accidentally; he was working on a comprehensive survey of the entire sky, the most complete survey of the stars that had yet been done. Herschel was interested in the apparent motions, or proper motions, as they’re called, of the stars as a way of deducing the movement of our solar system through space. Each individual star exhibits a tiny motion that can be measured, if your observations are accurate enough, and after Herschel allowed for each star having its own individual motion, he noted a more general motion exhibited by a large number of stars. This was, in fact, the motion of our own solar system through space, which makes it appear that other stars are moving in the opposite direction, in the same way that the landscape appears to be moving past you as you ride through it in a automobile.

This discovery was, in its way, as revolutionary as the work of Copernicus. Copernicus demonstrated that the Earth was not necessarily at the center of the universe; Herschel demonstrated that the sun wasn't, either. Instead, the sun simply moved on its own path through space, one star among many in the galaxy.

"Galaxy," you say? What's up with this "galaxy" thing? There's a band of faint light that circles the sky that we know as the "Milky Way," I suppose that's because people imagined it looked like a faint trail of milk across the sky. The word galaxy derives from the Greek *galaxías kýklos*, or "milky circle," and yes, it means that the words *galaxy* and *lactose* are etymologically related.

Once telescopes were invented, it was soon determined that the Milky Way was merely a large number of very faint and distant stars. About 25 years before Herschel discovered Uranus, the German philosopher Immanuel Kant proposed that all the stars we can see are arranged into a formation shaped roughly like a disk or a convex lens. Herschel attempted to estimate where our sun was, within this disk. Since the number of stars you can see in the sky is about the same in every direction, Herschel concluded that we were at or near the center of the Milky Way.

Herschel also cataloged nebulae, just like Messier. Unlike Messier, he categorized them by types. By the 19th century, it was clear that some nebulae were literal clouds. There were dark clouds, called absorption nebulae, and glowing clouds, called emission nebulae, the latter illuminated by the energy of stars in or near them. Other nebulae, when examined with high-power telescopes, proved to be clusters of stars. There were globular clusters, elliptical clusters, and spiral clusters, like Andromeda. Or were those spirals actually clouds, or perhaps more complex structures made of clouds and stars?

A century after Messier, and after a century of improvements in telescope design, the Danish-British astronomer John Louis Emil Dreyer, collected a much larger catalog of nearly 8,000 nebulae. He called it the *New General Catalogue of Nebulae and Clusters of Stars,* and it was published in 1888, so, hardly new anymore, although we still call it the New General Catalogue. The Andromeda Nebula is object number 224 in the New General Catalog, so it is thus also known as NGC 224.

In the early twentieth century, the Dutch astronomer Jacobus Kapteyn repeated the work of William Herschel 130 years earlier, only with modern telescopes that could see a whole lot more stars. Kapteyn had spent time in Cape Town, South Africa, where he catalogued nearly half a million stars not visible from Europe or North America, bringing maps of the skies in the Southern Hemisphere up to date. In 1897, he discovered what we call Kapteyn's Star, which was interesting because it had the highest proper motion of any star known at the time, although this record was superseded by the discovery of Barnard's Star in 1916.

In 1904, Kapteyn announced that the observable stars around us were not moving randomly, as had previously been supposed. Rather, he detected two identifiable streams of stars, moving in opposite directions. He didn’t know it, but he had discovered the first evidence of the structure and rotation of our galaxy.

Two years later, Kapteyn repeated Herschel’s survey of the distribution of stars across the sky, searching for evidence that there might be more stars in one direction than in others, which would tell us something about the location of our solar system within the galaxy. By 1906 telescopes were so good that counting every star would take more than a lifetime, so Kapteyn adopted a statistical approach, selecting certain regions of the sky and counting the number of stars in each of those regions. He found roughly the same density of stars in every direction he looked, so he agreed with Herschel’s conclusion that our solar system lay about in the center of the galaxy. Specifically, he concluded from his observations that the galaxy was wheel shaped, about 30,000 light years across and 6,000 light years thick, that it contained a few hundred thousand stars, and our sun was no more than 1,500 light years from the galactic center. This was the entire universe, as early twentieth century science understood it; you may recall I referenced this picture of the universe back in episode 114, while talking about Einstein and relativity.

Except…except…there were those globular clusters, those elliptical and spiral nebulae, that looked tantalizingly like huge clusters of stars very far away. Might it be possible that these objects represented, as some put it at the time, island universes, separated from ours by oceans of nothingness, unimaginable distances away?

Most orthodox astronomers dismissed this idea as fanciful. Don’t be too hard on them. Remember this is the same period when there were people arguing for canals on Mars, a ninth planet, life on other planets, even the transmigration of souls from one planet to another, as we discussed back in episode 56. It’s a basic and too often overlooked principle of science that extraordinary claims require extraordinary proof. If you want to argue the universe is actually millions of times larger than anyone previously believed, you’ll have to do better than point to a few poorly understood objects in the night sky and attach great significance to them.

Take the Andromeda Nebula, for example. Conceivably, it’s a mirror image of our own galaxy, in which case it’s millions of light years away, but it could just as easily be a smaller and closer cluster of stars, arranged in a spiral for some not-well-understood reason. Some suggested it was closer still, and actually a solar system in the process of formation. A couple of astronomers claimed they detected movement over time in spiral nebulae, which would be clinching proof that they were relatively small objects, relatively close to us.

The root difficulty here is that astronomers had no means of measuring the distance to far-off objects, like the Andromeda Nebula. If you knew the distance to the nebula, you could work out how big it is, and that would answer a lot of your questions. But at the time, there was no celestial yardstick capable of taking such a measurement.

One finally became available, thanks to the work of an astronomer named Henrietta Leavitt. Leavitt earned a bachelor’s degree in art and philosophy from what we now call Radcliffe

College in 1892, but she took a course in astronomy her senior year, which sparked a lifelong interest in the field. Astrophotography was just getting off the ground at that time, and she took a position at Harvard Observatory as “Curator of Astronomical Photographs,” allowing her to combine her interests in astronomy and the visual arts. She was paid thirty cents an hour for her work, which involved collating and studying multiple photographs of the same region of the sky, looking for changes and variations.

Sadly, Leavitt was also chronically ill, and her illness would interfere with her work and gradually take away her hearing, leaving her deaf. In 1912, she published results of a study of a certain kind of variable star known as a Cepheid variable. Variable stars are stars that change in brightness, often in a regular, predictable way, like a beating heart. Cepheid variables proved particularly interesting because there is a correlation between the period of their variations and the luminosity of the star. This makes them exactly the kind of interstellar yardstick astronomers had been yearning for, because if you observe a Cepheid variable long enough to determine its period, which typically runs from a week to a couple of months, you can deduce its luminosity, and if you know its true luminosity and compare that figure to how bright it appears from Earth, that’s all the information you need to calculate how far away it is.

Leavitt’s discovery of this relationship between period and luminosity of Cepheid variables provided astronomers with a powerful new tool to study the cosmos. One of the first astronomers to put it to use was the 30-year-old American astronomer Harlow Shapley, who began studying globular clusters in 1915. Shapley grew up in rural Missouri and attended the University of Missouri where, as he told the story, he went down the list of majors in alphabetical order, first rejecting archaeology because he didn’t know how to pronounce it and then settling on astronomy because it was the next subject on the list.

Globular clusters are, as their name implies, globular or spherical clusters of stars. About a hundred of them were known at the time, and oddly enough, they were not distributed evenly across the sky. In fact, more than thirty of them could be found in a single constellation: Sagittarius. Here was something interesting: the first ever astronomical observation that showed a distribution of objects in space that was something other than uniform, as seen from Earth.

Shapley studied these globular clusters at the Mt. Wilson Observatory in Los Angeles County, California, which housed the world’s largest telescope, with a mirror sixty inches across. While he was there, in 1917, the observatory added a second telescope with a one-hundred-inch mirror, the largest telescope ever built, at the time.

These powerful telescopes allowed Shapley to peer into the interiors of these globular clusters and identify individual Cepheid variables within. This made it possible for him to calculate how distant each cluster was from Earth. When he collected and collated this information, his observations showed that these globular clusters are arrayed in a spherical halo about 300,000 light years across. The surprising part was that this spherical halo was not centered on our solar system, as you might expect if we're at the center of the galaxy. It was actually centered on a point about 50,000 light years away from our solar system, in the direction of the constellation Sagittarius, which explains why so many globular clusters can be seen in that direction.

There's only one explanation for this result. Our solar system is not at or near the center of the Milky Way galaxy, as everyone had previously believed. First Copernicus told us the Earth was not at the center. Then Herschel told us that the sun was only one ordinary star among many, with no special distinguishing characteristics. Now, in 1918, Harlow Shapley delivered another crushing blow to our human egos. We aren't even in the center of the galaxy, where cool people hang out in coffee shops. We're out in the suburbs, where you need a car to get anywhere and the local supermarket doesn't know what lemongrass is.

But this is not the end of the humiliation of our species. This is just the beginning.

[music: Berg, *Four Pieces for Clarinet and Piano*, No. 1]

At the same time Harlow Shapley was studying globular clusters in Southern California, that is to say, roughly during the Great War, another astronomer, the 43-year old Heber Curtis was studying spiral nebulae at the Lick Observatory, outside San Jose, in Northern California, and in particular, he was watching the Andromeda Nebula.

Curtis's study of Andromeda and other spiral nebulae convinced him of the "island universe" theory; these spirals were galaxies just like our own. If this were true, the fact that they appear so small and dim from Earth would suggest they are enormous distances away, distances measured not in tens or hundreds of thousands of light years, but in millions. The smallest and faintest spiral nebulae might be hundreds of millions of light years away.

These are unimaginably large numbers. The size of the Milky Way is almost too great to grasp, and here is Heber Curtis, the latest in a series of fringe astronomers arguing that our own galaxy, huge object though it is, exists inside a universe so big that in comparison, it is nothing more than a dust mote, one among many, floating through the dark emptiness of the cosmos.

The mind recoils from such thoughts. It is an image so bizarre, so stark, so downright frightening, that, as I said earlier, it demands an extraordinary level of proof to be accepted. But don't count out Heber Curtis just yet, because he's coming armed with some pretty convincing evidence. For instance, modern telescopes show clearly that Andromeda is made up of individual stars. Lots of them. Spectroscopy confirms this. Spectroscopic analysis of light from Andromeda shows that it is made up of a mix of light from many kinds of stars, just the same as light from any cluster of stars.

Most significantly, Curtis and the astronomers he worked with at Lick Observatory observed sixteen novas in Andromeda in just a few years. You probably already know what a nova is. Sometimes a star flares up and becomes tremendously more bright, in just a matter of hours or days, then fades back into obscurity a few weeks or months later. But novas are rare events. By way of comparison, astronomers had only observed 35 novas in our galaxy over the past three centuries, a rate of roughly one every decade. Andromeda was producing one or two every year.

You have to consider that we live inside our galaxy, meaning it's all around us, while Andromeda is only one small patch of light in the night sky. It's quite possible astronomers are missing a lot of the novas that happen in our galaxy, but in any case it seems clear that if Andromeda is producing novas at that rate, it must contain a number of stars on the same scale as our galaxy, meaning, it is also a galaxy.

At this time, the most prominent critic of the "island universe" theory was the man himself, Harlow Shapley, who was by this time the most prominent astronomer in the field, period, thanks to his work on pinpointing the center of our galaxy. On April 26, 1920, the Smithsonian Museum of Natural History sponsored a presentation, inviting both Shapley and Curtis to deliver papers outlining their ideas on the scale of the universe, and then that evening to take part in a joint discussion examining and questioning their ideas.

This was a pivotal moment in the history of astronomy, so much so that it became known as the Great Debate, although it wasn't heated or anything. It was more a quiet, academic discussion about what was known, how that information could be interpreted, and what new information needed to be discovered.

In hindsight, we now know that Curtis got the better of the debate. His ideas were closer to what we now know to be true, although Shapley did present a good summary of the arguments against the "island universe" theory. One was the observation of other astronomers, who claimed they had detected motion in other spiral nebulae. If a spiral nebula was a galaxy, this would have been impossible; it strongly suggested these nebulae were smaller objects, much closer to Earth. Of course, we now know that those other astronomers were simply mistaken.

Another one of Shapley's arguments even touched upon Curtis's favorite subject: novas in Andromeda. In 1885, a nova had been observed in Andromeda that was so bright it briefly outshone the rest of the nebula, and was almost visible to the naked eye on Earth. This was just before astrophotography became established, so, sadly, there are no photographs of what must have been a striking event. But if Andromeda truly was a galaxy, that nova must have been a tremendously bright object, brighter than millions of ordinary stars. No such object had ever been observed before, which made that interpretation seem unlikely. It was far more probable that it was an ordinary nova and appeared so bright because it was much closer to us than Curtis figured, and it outshone all of Andromeda only because Andromeda itself wasn't very big.

The Great Debate didn't settle the question, but it did lay out the arguments for what was the biggest unsolved problem in astronomy. At the time of the debate, Harlow Shapley was under consideration to take over as the new Director of the Harvard Observatory, where Henrietta Leavitt was still working. We now know that Shapley was wrong about the universe, though he would stubbornly continue to resist the island universe hypothesis for almost another decade, but don't feel too sorry for him, because he did get the job at Harvard, and that was pretty sweet.

As Director of the Harvard Observatory, Shapley supervised Henrietta Leavitt, who was still working there; alas, her health problems led to her death just a few months after Shapley arrived, in 1921. She was 53 years old.

Meanwhile, in California, at the Mt. Wilson Observatory, where Shapley had been working before he got the Harvard gig, they had just recently taken on a new young astronomer, the thirty-year-old Edwin Hubble. Hubble was also born in Missouri, like Shapley; his family moved to Illinois when he was still a boy. In his youth, he was more noted for his athleticism than his scholarship. He was a track star in high school; at the University of Chicago, he led the basketball team to its first conference championship.

Hubble studied law at Chicago, became one of the first Rhodes scholars, a beneficiary of the program set up by Cecil Rhodes, episode 11. He completed his law degree at Oxford and returned to the United States where, like so many law school graduates, was disappointed to discover that the practice of law is the worst job in the world and not at all the lucrative and glamorous career everybody thinks it is, so he returned to Chicago and enrolled in graduate school, where he earned his Ph.D. in astronomy in 1917. His dissertation was on nebula photography. By then the United States had entered the Great War. Hubble enlisted in the Army, was given the rank of major, and sent to Europe in August 1918, but he never saw combat. After he was discharged from the Army in 1919, Hubble was offered a position at Mt. Wilson Observatory, where Harlow Shapley was working.

Hubble made good use of the world's-largest, one-hundred-inch telescope at Mt. Wilson, continuing his work on spiral nebulae. This telescope made it possible for the first time to actually capture photographs of individual stars within Andromeda and other nearby spiral nebulae. Once that had been done, it was inevitable that Hubble would identify Cepheid variables, which would in turn make it possible at last to come up with a reliable figure for Andromeda's distance from our solar system.

When Hubble announced his findings, it was big enough news to earn a headline in the *New York Times*, on November 23, 1924, just a few days after his 35th birthday. The Andromeda nebula was 800,000 light-years away. Hubble also had distance figures for about two dozen other spiral nebulae; all of them were even farther away than Andromeda.

There was no longer room for debate. Our Milky Way is only one of many such collections of stars in a universe that is inconceivably vast. Astronomers had to learn to stop calling it the Andromeda Nebula. The word galaxy was redefined to mean not just our Milky Way but any similarly-sized collection of stars, so now it was the Andromeda Galaxy. Even Harlow Shapley eventually gave in, declaring that Edwin Hubble had "destroyed my universe."

You might be wondering about that 1885 nova in Andromeda that seemed to be such a strong argument against Andromeda being a galaxy. Well, now that we know Andromeda really is a galaxy, in 1929 astronomers would conclude that the only possible explanation for the 1885 event was that it was not an ordinary nova, but something else, a much rarer and more violent event, in which a star essentially blows up and destroys itself. Because they are so rare, this was the first one observed since the invention of the telescope almost 300 years earlier. This bigger and more destructive nova event would be dubbed a supernova. A galaxy the size of the Milky Way might have fifty novas every year, but a supernova only once every fifty years.

Edwin Hubble also developed a system for classifying galaxies based on their shapes: irregular galaxies, elliptical galaxies, spiral galaxies, and barred spiral galaxies. His classification system is still in use today.

And Hubble was not yet finished destroying other peoples' universes. He also studied other galaxies spectroscopically, using the Doppler Effect to measure their motion. The Doppler Effect is a shift in the frequency of light waves that occurs when an object is moving toward you or away from you. You've probably already encountered this phenomenon in connection with sound waves. A car's horn sounds at a higher pitch when the car is moving toward you than when it's moving away from you, like so:

[sound effect: car horn]

Notice the higher frequency, or pitch, as it approaches, and a lower frequency, or pitch, when it's moving away. If you measured those frequencies, you would be able to calculate how fast the car was moving. The same thing happens with light. Higher frequency of light means the colors shift toward blue and violet, while lower frequencies mean the colors shift toward red. The speed of light is so great that these shifts are too subtle to be seen with the naked eye, but they can be measured with a spectroscope.

It was already well known that the Andromeda Nebula—pardon me, the Andromeda Galaxy—was moving toward us. Other galaxies were moving away. But Edwin Hubble was the first astronomer to measure these motions statistically, across a large number of galaxies, and the result was shocking. If galaxies are just wandering around the void at random, you'd expect about half of them to be moving toward us and the other half to be moving away from us. That was not at all what Hubble discovered. Andromeda, the galaxy approaching us, was an outlier. Almost every other galaxy in the universe was moving away from us, as if there is something particularly repulsive about the Milky Way.

Not only were they moving away from us, but the farther away a galaxy was from us, the faster it was moving away from us. This came to be known as Hubble's Law. The relationship was linear and could be expressed as a single number, which astronomers call the Hubble Constant. Hubble's original figure for his constant was 500 kilometers per second per megaparsec.

Once Hubble's Constant is pinned down, you can use it as a whole new intergalactic yardstick to measure distances to galaxies that are too far away to identify individual Cepheid variables. And indeed, astronomers still use Hubble's Law to this day to measure intergalactic distances.

The other galaxies are not in fact moving away from us in particular. Hubble's result means that every galaxy is moving away from every other galaxy at the same rate. Which is another way of saying that the Universe is expanding.

No one was more chagrined by this result than Albert Einstein, who just a decade ago had published his General Theory of Relativity, episode 114. As you recall from that episode, when Einstein worked out his equations, they seemed to indicate an expanding universe. Since there was no evidence the Universe was in fact expanding, Einstein added an arbitrary constant as a sort of "fudge factor" to keep the equation balanced without need to resort to an expanding universe. In the decade or so since then, other theoreticians had discovered that an expanding universe was one possible interpretation of the mathematics of relativity. Now, Edwin Hubble had proved observationally that it was in fact true. The universe really is expanding.

In other words, if Einstein had stuck to his guns and had the courage to publish his theory with the prediction that the Universe was expanding, Edwin Hubble would have made him look like a genius…well, an even bigger genius. But he got cold feet and missed the opportunity. He would later call this the biggest blunder of his career.

But wait, there's even more. Here's a nifty trick I learned in one of my college astronomy classes: Hubble's Constant is expressed as kilometers per second per megaparsec. As you can see, that is units of distance divided by units of time and distance. Distance divided by distance cancels out, meaning the Hubble Constant can be expressed in reciprocal seconds. So if you take the reciprocal of the Hubble Constant, you get a unit of time. A very, very large unit of time. I just did the math myself, based on Hubble's original number, and I get 6.16×10^{16} seconds, which I think we can all agree is a very large number indeed. If you convert it to years, you come up with 1.95 billion years.

That period of time, 1.95 billion years, is the reciprocal of the Hubble Constant. What does that represent? If you think about it for a minute, it amounts to running the Universe backward in time to the moment when all these galaxies were in the same place. In other words, the reciprocal of the Hubble Constant is a measure of the age of the Universe.

Longtime listeners will remember all the way back to episode 9, in which I talked about the age of the Earth as it was understood at the beginning of the century, thirty years ago. At that time, both astronomy and geology seemed to indicate that the Earth was about twenty million years old. But that number didn't jive with what the biologists were saying. They were saying that twenty million years was just not long enough to account for the wide variety of species on the Earth and so the planet must be much older.

Since that time, the geologists have updated their estimate. The discovery of radioactivity and the properties of radioactive decay gave them a tool to measure the age of rocks. For example, when radioactive elements decay, they often release alpha particles, which are also helium nuclei. On Earth, helium can be found in the planet's crust, and by measuring the amount of radioactive elements in the crust and the amount of helium, you can calculate how long the radioactive elements must have been decaying. As of 1930, the numbers the geologists were coming up with were in the range of two to three billion years. That's plenty of time for evolution to take place, but it still doesn't jive with Hubble's Constant, which gives a number slightly less than two billion years.

So the astronomers, the geologists, and the biologists are still not all on the same page, but at least they're getting closer. The Universe is proving to be much larger, more complicated, and frankly, much scarier than anything old Lord Kelvin could have imagined back in 1901. The Universe is unimaginably vast, and our Earth is nothing more than a speck of dust circling a speck of dust embedded within a slightly larger speck of dist. The twentieth century is not being kind to human vanity.

We'll have to stop there for today. Thank you for listening. This episode is a special bonus episode that is my Christmas gift to you, dear listener, and I hope you enjoyed it. And I hope you'll join me again on Sunday, here on *The History of the Twentieth Century,* as we resume the narrative on India in the early twentieth century. We left off just as Mohandas Gandhi was on his way to South Africa. Find out what happened after he got there, on Sunday, here, on *The History of the Twentieth Century*.

Oh, and one more thing. Several things, actually. I threw a lot of numbers at you in today's podcast, and I want to emphasize that these figures were the ones originally announced a hundred years ago. In the century since, these figures have been refined and are in some cases quite different, though not different enough to change the overall conclusions about the scale of the Universe.

Harlow Shapley's figures on the size of our galaxy were too large. This is because there is dust and gas in interstellar space. Not a lot, but enough to dim the light when you're looking through tens of thousands of light years of it. Shapley's calculations didn't account for that, making objects appear to be farther away than they actually were. In our time, the center of our galaxy is believed to be only about 26,000 light years away, half the distance Shapely calculated. Our galaxy and the halo of globular clusters around us is believed to be about 100,000 light years in diameter.

Harlow Shapley remained Director of the Harvard Observatory until his retirement in 1952. He was also active in the Independent Citizens Committee of the Arts, Sciences and Professions. Ronald Reagan was another member. In 1946, Shapley was subpoenaed by the House Un-American Activities Committee and questioned about his involvement in that organization.

Shapley accused the Committee of "Gestapo methods," while the Committee chair said of Shapley, "I have never seen a witness treat a committee with more contempt." A few weeks later, Shapley was named President of the American Association for the Advancement of Science, which tells you something about the Association's opinion of the House Un-American Activities Committee. Harlow Shapley died in 1972, at the age of 86.

Although he was a reluctant convert to the enormous universe Edwin Hubble described, once he accepted the idea, Shapley and his Observatory undertook a survey of distant galaxies. Shapley was one of the first astronomers to suggest that galaxies collect in clusters just as stars sometimes do. He identified one such cluster in the constellation Centaurus that in 1989 was named the Shapley Supercluster in his honor by the Indian astrophysicist Somak Raychaudhury.

In contrast to Shapley's error, Edwin Hubble's measurement of the distance to the Andromeda Galaxy was too conservative. Today, it is generally believed to be about 2.5 million light years away. And Hubble's early figure for the Hubble Constant was too large. Today, it is believed to be around 70 kilometers per second per megaparsec, which gives an age for the Universe of a little over thirteen billion years.

Edwin Hubble died in 1953, at the age of 63. His discoveries made clear for the first time the scale of the Universe, making him the most important astronomer of the twentieth century, and surely one of the most important of all time. He received numerous honors and awards during his life, but, alas, no Nobel Prize. This is because there was no Nobel Prize for astronomy. The Nobel Committee later decided to include astronomy within the prize for physics, but that decision was not taken until shortly after Hubble's death, and since they don't give posthumous Nobel Prizes…oh, well.

On the other hand, as you probably already know, the Hubble Space Telescope was named after him. The Hubble Space Telescope was placed into Earth orbit in 1990 and is still operating, as of when I release this episode. It has produced a wealth of data and photographs that not only expanded our understanding of the Universe but also produced a wealth of space porn for us science geeks to stare at, and making the name Hubble instantly recognizable by anyone with even a slight interest in astronomy, so there is that.

[music: Closing Theme]