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Cosmic Times

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Early Edition

Age of the Universe:
2 Billion Years

Size of the Universe:
280 Million Light Years

Andromeda Nebula Lies Outside Milky Way Galaxy

Spiral Nebulae are indeed "Island Universes"

Astronomer Edwin Hubble of the Mount Wilson Observatory at Pasadena, California has solved a mystery. Spiral nebulae in our universe have been a mystery to astronomers. Nebulae look like fuzzy pinwheels in the sky. Astronomers weren't sure if these nebulae were in our own galaxy or outside of it. Hubble figured out that these objects are much farther away than other astronomers thought. That means they are distant galaxies and not a part of our own Milky Way Galaxy. While figuring this out, Dr. Hubble also figured out how far away the Andromeda Galaxy is from us.

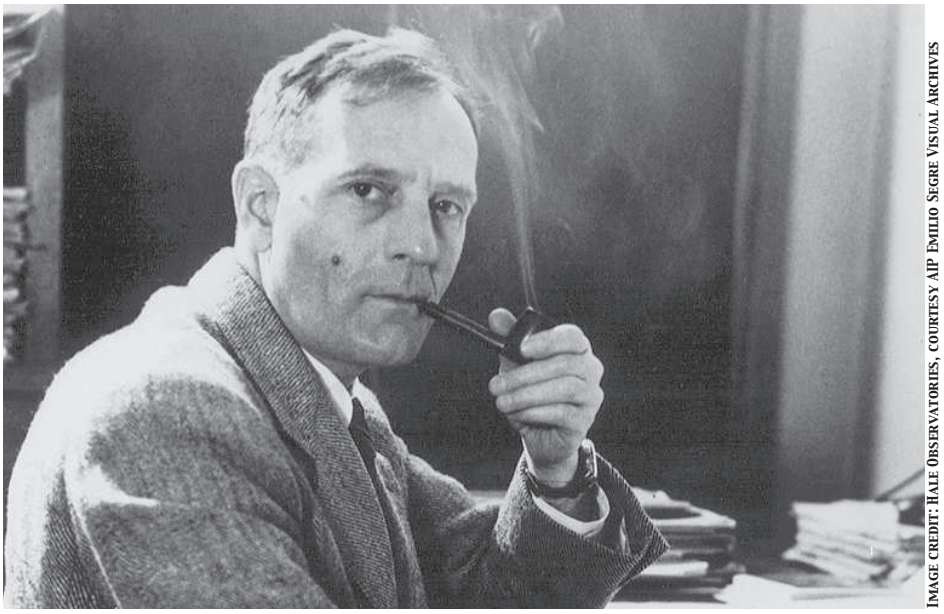

IMAGE CREDIT: HALE OBSERVATORIES, COURTESY AIP EMILIO SEGRE VISUAL ARCHIVES

Edwin Hubble

Dr. Hubble's observations support Dr. Heber Curtis' views. In a debate with Dr. Harlow Shapley in 1920, Dr. Curtis said that bright, spread-out nebulae are fairly close to earth and are a part of the Milky Way. Spiral nebulae, on the other hand, are much farther away and are not part of the Milky Way.

On December 30, 1924, Dr. Hubble announced that he had taken photographs of a few bright spiral nebulae with the Mt. Wilson Hooker telescope, which is the largest reflecting telescope in the world. Hubble said that the telescope focused a few of the closest, neighboring spiral nebulae into swarms of stars. One of the nebulae was the Andromeda Nebula. Hubble estimates that the Andromeda Nebula is as large and holds as much matter as the Milky Way Galaxy. The Andromeda Nebula might contain three to four billion stars that make one billion times the light of the Sun.

The photographs Hubble took showed that there were individual stars in the nebula. They also showed that some of the stars changed in brightness over time. These changing stars, known as Cepheid variable stars, were the key in figuring out distances to nebulae. In the nebulae Hubble studied, the true brightness of the Cepheids was known based on how Cepheid stars change in brightness. Scientists had already known how light dims over a distance. That means the distance to the star and the nebula

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the star is located in can both be found by comparing the apparent brightness of the Cepheid stars to their true brightness.

Dr. Hubble's work builds on the earlier work of Miss Henrietta Swan Leavitt of the Harvard College Observatory and the work of Dr. Harlow Shapley of the Mount Wilson Observatory.

In 1912, Miss Leavitt was the first astronomer to see the importance of the Cepheid variable stars. The giant stars are named after the first star of its kind found—Delta Cephei in the constellation Cepheus. When Miss Leavitt was studying the Cepheid stars in the Small Magellanic Cloud, she saw that the Cepheids would get brighter, then fade, then get brighter again. She also noticed that the length of time, or period, it took for the star to go through this cycle was related to its true brightness. The longer the period of the star, the brighter the star.

The Small Magellanic Cloud, where Miss Leavitt was studying Cepheid stars, is a large group of stars visible in the southern hemisphere of the Earth. Since all of the Cepheid stars she was studying were in the Small Magellanic Cloud, they were all about the same distance from Earth. So each Cepheid's brightness was directly related to its period.

Soon after Miss Leavitt's discovery, Dr. Shapley started looking for Cepheids in globular star clusters in our own Milky Way galaxy. Globular clusters are ball-shaped groups of tens of thousands of densely packed stars. He used Miss Leavitt's period-brightness relationship to figure out the distance to more than 230 globular clusters. He assumed that Cepheids in distant globular clusters act the same as closer Cepheids. Based on that, he found that the most distant clusters in the Milky Way galaxy are about 200,000 light years away.

Dr. Hubble studied the periods of the Cepheid variable stars in the Andromeda nebula. He was able to figure out the true brightness, or absolute magnitude, of each of the stars. He then observed their apparent brightness, or apparent magnitude. Once he knew the difference between how bright a star looked and how bright it truly was, he was able to calculate its distance from the Earth. He found that the Andromeda nebula was about 900,000 light years away. This is the most distant object known so far. ♦

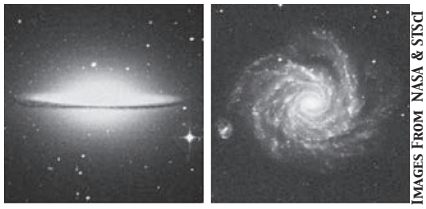
Classifying Nebulae

For over a thousand years, astronomers have wondered about nebulae. Nebulae appear to be faint clouds of gas and dust far off in the universe. Until recently, there haven't been enough observations of nebulae to put them into categories.

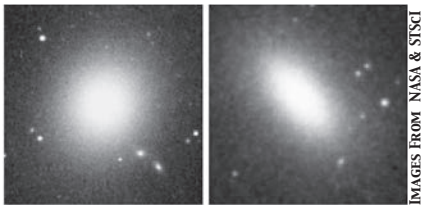
During his study of spiral nebulae, Dr. Hubble came up with a system to classify all nebulae. He put them into three basic categories. These categories are elliptical, spiral, and irregular. The three categories are then divided further based on the nebulae's shapes (like spherical to elongated elliptical, for example) and structure (hazy to distinct spiral arms, barred spirals, etc.)

Although Dr. Hubble's system shows an order of change based on the evolution of the nebulae, it was mainly based on the nebulae's structural forms. Classification through photographic classification should be the independent consideration, Hubble said. Future study of the nebulae will be the test for the new classification system. ♦

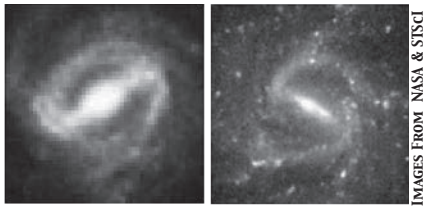
Spiral galaxies



Elliptical galaxies



Barred spiral galaxies



Images From NASA & STScI

Hubble classification of different types of galaxies (also called nebulae)

Universe is Expanding – "Red Shift" is Proof of Einstein's General Theory

Using the 100-inch Hooker Telescope at Mount Wilson Observatory, Dr. Edwin Hubble has studied many spiral nebulae. He has discovered that they are moving away from us at a fast pace. This is strong evidence of an expanding universe. He has also figured out that the farther away a nebula, the faster it moves away.

Hubble and another astronomer and colleague, Milton Humason, measured the speeds and distances of 24 of these nebulae. Because they are moving so quickly, their light waves (electromagnetic spectra) are stretched out. Because red light has the longest wavelength, this is known as "redshift." The team noticed that dimmer, more distant objects have a larger redshift than objects closer to Earth. Hubble said in a recent paper that his measurements led to a useful speed-distance relationship. Hubble found that redshifts increase as they get farther from us.

Dr. Hubble figured out the distances to 24 nebulae using Cepheid variable stars. Astronomers use these stars to figure out the distance to the nebula they are found in. Once Hubble knew how far away the nebulae were, he could then compare their distance to their redshift in order to look for a pattern. He found that the most distant objects are speeding away from us at perhaps thousands of miles per second.

Dr. Hubble's recent discoveries show that the volume of space itself is expanding. Spiral nebulae seem to be moving away from each other at a speed that increases with distance, but the nebulae aren't just moving. The nebulae are being pulled along as space expands.

Hubble's discoveries build on the work of Dr. Vesto M. Slipher of Lowell Observatory in Flagstaff, AZ. In 1912, Dr. Slipher first recorded the electromagnetic spectra of spiral nebulae. Almost all of the 40 spectra Slipher gathered were red-shifted. This means that most of them were moving away from us. However, his study of nebulae led him to the conclusion that they were moving away at only 600 miles per second.

Hubble's work is a large breakthrough in our understanding of the universe. But there is still a big question. How far out into the universe does his model hold up? The 100-inch telescope can show Cepheid variable stars clearly in the nearest nebulae. In far off nebulae, where the Cepheids are barely visible, Hubble uses the brightest individual stars, some of them 50 to 100 times brighter than the Cepheids, as standard candles.

Today's telescopes, and the stars they see, can only show Hubble a certain amount. Astronomers will need larger telescopes and new standard candles in order to measure even greater distances.

A new instrument may help. Last year, the Rockefeller Foundation agreed to give 6 million dollars to pay for the construction of a new observatory with a 200-inch telescope. This new telescope will collect four times more light than the 100-inch telescope Hubble uses right now.

Einstein's General Theory Holds True

The past decade has been an exciting and challenging time for the development of scientific understanding of the universe. Scientists have been testing their ideas about the universe against Einstein's 1916 Theory of General Relativity. Einstein's theory describes the universe as three dimensions of space (length, width, and depth) and another dimension of time. The theory says that gravity curves this space-time and that this curve controls the natural motions of objects in space.

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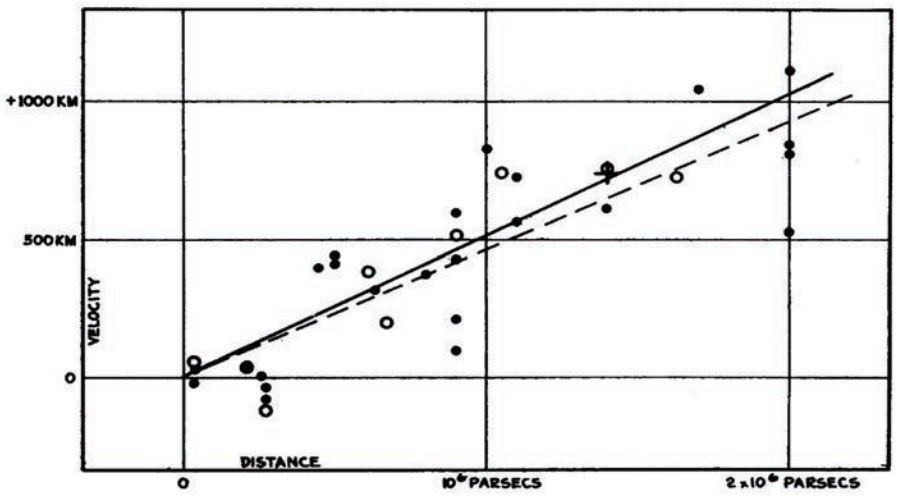

IMAGE CREDIT: HUBBLE, PNAS, 15, 3 (1929)

Hubble's diagram showing the relationship between galaxy distance and velocity

The Minds atop Mount Wilson

High above Pasadena, California in the San Gabriel Mountains, the astronomers at Carnegie Institution's Mount Wilson Observatory are changing our view of the universe. Who are these scientists?

Athlete-Scholar Unveils the Future of the Universe

Born in Marshfield, Missouri in 1889, Edwin Powell Hubble's early life focused on athletics, mainly track and field events. Hubble was quite successful, especially since he was 6 foot 3 inches tall. He set an Illinois state record for the high jump.

At the University of Chicago, he studied mathematics and astronomy. His studies then took a different direction when he attended Oxford University in England as a Rhodes Scholar. When he was there, he studied Roman law and Spanish. He also made time to compete in water polo and field events. He then returned to the United States in 1913 to teach high school physics and Spanish.

A year later, Hubble returned to the University of Chicago to earn his PhD and began to research faint nebulae at the Yerkes Observatory. However, his research was interrupted when the US entered the Great War, and he quickly joined the army. Hubble served in the army in France until the end of the war. Then he returned to civilian life. He took a job offered to him two years earlier at the Mount Wilson Observatory.

Former Mule-Team Driver and Janitor Helps Discover Expanding Universe

Milton Lasalle Humason was born in Dodge Center, Minnesota in 1891, then moved to California with his family when he was a child. He left school in the 8th grade, and had no formal training as an astronomer. His career at the Mount Wilson Observatory began as a mule-team driver for the pack trains that carried large parts of the telescope and its building to the top of Mount Wilson when the observatory was being built.

When the telescope was completed in 1917, Mr. Humason was hired as a janitor and electrician.

Image credit: AIP Emilio Segrè Visual Archives, Brittle Books Collection

Milton Humason

Other people soon noticed his intelligence and curiosity. It wasn't long after that when he was promoted to night assistant on the 60-inch telescope.

Mr. Humason worked under the observatory's director, Dr. George Ellery Hale. Humason became an expert observer. Dr. Hale recognized Humason's talents and hired him as a part of the scientific staff in 1919. Humason soon became an expert at measuring the redshifts of distant nebulae. He then became the chief assistant and co-worker of Dr. Hubble.♦

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Einstein's theory also suggests that the universe is expanding, but Einstein didn't believe this part of the theory could be correct. In 1917, he added a new term to his equations. He called this the "cosmological constant." This constant was made in order to avoid the possibility of an expanding universe. Hubble's recent observations take away the need for the cosmological constant. Einstein has studied Hubble's data and believes that Hubble's research is solid. But Einstein is still not convinced that the universe is expanding.

In 1922, Soviet scientist Alexander Friedman came up with his own solutions to the general relativity equations. He said there were two possibilities for the universe. He said that either the universe was expanding or contracting, but it was not staying the same.

In 1927, Catholic priest and astronomer Abbe George Lemaître said that a homogeneous universe with a constant mass had to be expanding. This, he said, explains the speed that the spiral nebulae are moving away from us. He also described the possibility that the universe was expanding from a single point. Lemaître believed that before the expansion began, the universe did not exist.

Dr. Hubble's discoveries answer many questions, but also give a new direction for future studies of the universe.♦

"Great Debate" Resolved

Dr. Hubble's discovery settles the "Great Debate" about the size of our Milky Way Galaxy. It also figured out the distance to spiral nebulae, and what spiral nebulae are.

The debate about these issues was held on April 26, 1920 at the National Academy of Sciences in Washington, D.C. The focus of the debate was between the views of Harlow Shapley and Heber D. Curtis.

Shapley described the Milky Way as an enormous galaxy of stars that is 300,000 light years across. This size is much larger than most astronomers once estimated it to be. He also said that the solar system is far away from the Milky Way's center and that all nebulae, including spiral nebulae, are inside the Milky Way.

Dr. Curtis used photographs he had taken to present his idea that spiral nebulae are "island universes," or distant star systems similar to the Milky Way. Curtis said these "island universes" are not a part of the Milky Way galaxy. He also said the Milky Way is less than 30,000 years across and 8,000 light years in thickness.

Dr. Hubble's recent observations support Curtis' views. Bright, spread-out nebulae are relatively close and are part of the Milky Way, he said. He also found that spiral nebulae are separate systems located far away from the Milky Way. Hubble estimates that the spiral Andromeda Nebula is as large and holds as much matter as the Milky Way. While Hubble supports Curtis' views about spiral nebulae, he also supports Shapley's ideas about the Milky Way's size and location of the solar system.

Shapley's observations have increased the size of the universe by about 10 times. Hubble's recent discoveries have multiplied that number at least another 10 times. Shapley noticed a progression as history has gone on. First there was the belief that there was a small universe with the Earth at its center. Then, he said, there was the belief in a larger universe with Earth farther from the center. The advance in knowledge of the physical world, he also said, lessens the significance of man and the Earth. ♦

Image credit: National Institute of Standards and Technology

Heber Curtis

Image credit: AIP Emilio Segrè Visual Archives, Shapley Collection

Harlow Shapley

In Their Own Words

New observations by Hubble…make it appear likely that the general structure of the Universe is not static.
- Einstein - 1925

Tomorrow the outlook may change and new methods may dwarf our knowledge and beliefs of today, or convert them into remote history. Soon we may look far beyond the last frontier, now 140,000,000 light years away. We, or our successors, may actually know familiarly the farthest borders of this vast Universe and learn facts about it so astounding that astronomers of today would be nearly unable to comprehend their significance.
- Edwin Hubble - 1927 ♦