National Aeronautics and Space Administration

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COSMIC TIMES

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Age of the Universe:
6 Billion Years

Size of the Universe:
4-8 Billion Light Years

DEATH OF A GENIUS: ALBERT EINSTEIN

The world has just lost its greatest scientific mind. On April 18th, Albert Einstein died in his sleep from complications with an infection. Einstein was 76 years old. No other man had ever looked as closely at the Universe than Einstein. This white-haired, pipe-smoking, wrinkle-clothed man joins the few other geniuses like Newton, Copernicus, Archimedes, and Pythagoras who have changed history.

Many people began praising the German-born Einstein as soon as they found out about his death. This instant praise shows everyone his important place in history. President Eisenhower said that no other man had added so much knowledge to the 20th century. The Prime Minister of Israel, Moshe Sharett, also said that the world has lost its leading genius. Even in Russia, behind the "Iron Curtain," memorials were held. Russia's official newspaper Pravda said that Einstein transformed natural science.

Einstein's achievements are better known to people he worked with and to his students, who still work to understand and test his theories. Some examples of his accomplishments are:

- His science-changing way of looking at light as not just a wave, but also a particle
- His "theory of special relativity," which explains that nothing in the Universe can move faster than the speed of light
- His famous equation, $E=mc^2$, which explains how energy can change into matter, and matter can change into energy
- His theory of gravitation, which bends space-time

By putting all of Einstein's ideas together, these are the basis for all modern physics.

Non-scientists know that Einstein was a genius, even if they don't really understand his theories. The average person knows that the television and the hydrogen bomb came about because of Einstein's work, but the average person doesn't understand how that happened. Just as most people don't exactly understand how Einstein has changed scientific thought, the nurse who was standing next to Einstein on his deathbed didn't understand Einstein's final words because they were spoken in German. The nurse did not speak German, and most of us do not speak physics. Instead, we just sense his importance. We watch his life and accomplishments like children watch a parade — we watch as his genius passes by us.♦

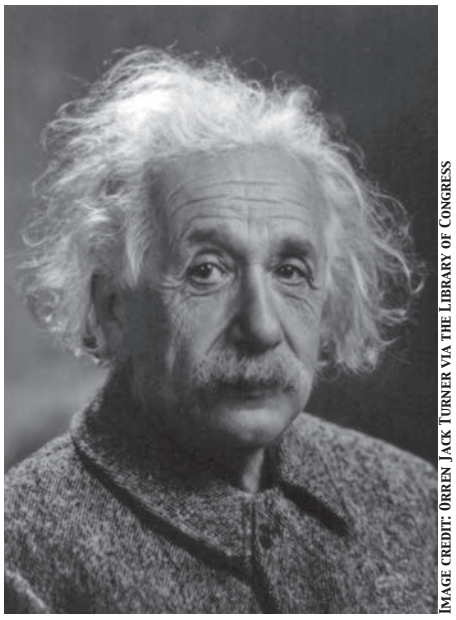

IMAGE CREDIT: ÖRREN JACK TÜRNER VIA THE LIBRARY OF CONGRESS

Albert Einstein

"Yardsticks" in Neighbor Galaxy Double Universe's Size

The Universe is twice as large as we thought. Astronomer Walter Baade from California Institute of Technology measured the size of the Universe using the giant 200-inch reflecting telescope at Mount Palomar.

Baade's measurements of the Universe were difficult to make. In order to measure the distances to stars and the scale of the Universe, he first had to discover a new measuring tool, or "yardstick." Until a few years ago, there was only one measuring tool astronomers knew about, and they were using it incorrectly. Blackouts in Los Angeles during World War II began to fix the errors. These war-time blackouts were periods of time at night when people had to turn off all of their lights or use heavy curtains to block light from their houses. This was done to reduce the chance of night-time bombings or spying raids. During this time, light pollution was reduced. This allowed astronomers to study light from space better.

The first "yardstick" astronomers discovered was around the beginning of the 20th century. The yardstick was a kind of pulsing, variable star called a Cepheid. Cepheid stars are very bright, then become very dim over a period of time. The time over which they vary (or pulsate) takes between several days to several weeks. Astronomer Henrietta S. Leavitt of the Harvard Observatory was studying the Magellanic Clouds, which are small galaxies outside the Milky Way. While studying them, she saw that brighter Cepheids pulsed slower than dimmer ones. She thought this was interesting because all of the stars in the Magellanic Clouds are basically the same distance from earth. This means that the speed that the Cepheids pulsate is a clue about their brightness, or luminosity. If astronomers compare how bright the stars really are to how bright they look (their apparent magnitude), their distance can be calculated.

For example, imagine that an astronomer sees a dim Cepheid star in the Milky Way galaxy. The astronomer can then determine if the star is close by or far away by observing how fast it pulsates. They use Miss Leavitt's brightness/pulsation relationship to do this. If the pulsing is fast, then the star really is dim and not far away. If the star is pulsing slowly, then the star is actually bright and only looks dim because it is very far away.

After Miss Leavitt finished her work, astronomer Solon Bailey discovered that the same seemed to be true for Cepheid stars found in dense star clusters in our own galaxy. Next, astronomer Harlow Shapley standardized the Cepheid "yardstick" so he could measure the distance of both fast-period and slow-period Cepheids inside the globular star clusters and outside the star clusters in the Milky Way galaxy.

During a speech at an awards ceremony of the Astronomical Society of the Pacific, Baade said that these discoveries and calculations of Cepheid star distances set up a period-luminosity relationship that was accepted for the next 30 years.

The problem was that the yardstick had flaws. In 1931, Dr. Edwin Hubble began to study the starlight from globular star clusters in the Andromeda Galaxy, which is near the Milky Way. For some reason, those star clusters were burning more dimly than similar star clusters in our Milky Way galaxy. This

"Yardsticks" continued on page 3

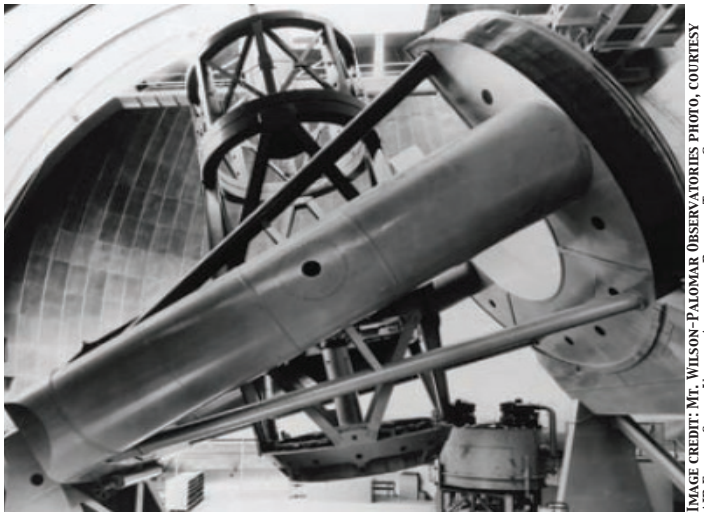

Image credit: Mt. Wilson-Palomar Observatories photo, courtesy AIP Emilio Segrè Visual Archives, Physics Today Collection

Below: This 200-inch Hale telescope at Mt. Palomar, completed in 1949, confirmed the size of the Universe.

Radio "Ear" on the Universe Being Built

The Earth's largest steerable radio antenna for studying radio waves from space is being built. The huge, 250-foot-wide metal dish of the Mark I radio telescope is designed to be fully adjustable.

Astronomers have found that the sky glows not only in visible light, but also in radio waves. The telescope, being built at Jodrell Bank in England, will let astronomers explore the entire sky for radio transmissions. Astronomers can't do that today. It will be able to study the newly discovered 1420.4 megahertz radio emissions that scientists think is coming from hydrogen gas at the center of the Milky Way.

The radio telescope, called MK1, will replace an older antenna already at Jodrell Bank. That antenna is only partly adjustable. It needs the spin of the Earth in its orbit to change the antenna's view of the sky.

Even though the older antenna has its limits, the 8-year-old parabolic aerial antenna has led to some important discoveries. The antenna's designer, Dr. Bernard Lovell of the University of Manchester, said the older antenna's discoveries convinced people to build the new Mark 1 antenna. One of the most surprising discoveries the older telescope made was that there were radio emissions coming from the Great Andromeda Nebula and that the brightest radio emitter in the night sky is from a little nebula in the constellation Cassiopeia.♦

IMAGE CREDIT: JODRELL BANK, UNIVERSITY OF MANCHESTER

The Jodrell Bank's Mark I radio telescope being built.

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difference meant that either the globular clusters in Andromeda were different than the ones in our Milky Way or that Andromeda was farther away than astronomers originally calculated.

The answer came during the wartime blackouts in California in 1943. Dr. Baade made observations during these times, when the night skies were darker. He used the power of the 100-inch telescope at the Mount Wilson Observatory near Los Angeles to study Andromeda's star clusters again.

Using special photographic plates that are sensitive to red light, Dr. Baade discovered two different groups of stars:

- Redder, dimmer "Type II" stars in globular clusters were close to Andromeda's center and in the surrounding halo (the same set-up as in the Milky Way)
- Bluer, brighter "Type I" variable stars were in open clusters in Andromeda's disk, or outer spiral arms.

Dr. Baade said that Shapley did not realize that Cepheids found in globular clusters had a different period-luminosity relationship as compared to Cepheid stars found in open clusters. Shapley made the mistake when he treated them the same on his "yardstick." This would be like making the mistake of using a yardstick the same as a meter stick. The yardstick would be the Type I Cepheid and the meter stick would be the Type II Cepheid.

At Mount Palomar Observatory, Baade and his computer assistant Henrietta Swope recently confirmed that both Type I and Type II Cepheids are very different types of stars. After re-calibrating his measuring sticks, in 1952 Dr. Baade surprised other astronomers at a Rome meeting of the International Astronomical Union. At the meeting, he announced that the Andromeda galaxy was not 800,000 light years away, like Hubble thought, but 1.8 million light years away. With the two different measuring sticks figured out, the Universe astronomers knew in 1929 to be one billion light years wide has now doubled to two billion light years across.♦

Origin of Everything: Hot Bang or Ageless Universe?

Did the Universe always exist? Does it have a beginning, middle, and end? It is hard to imagine questions tougher than these. This subject was just talked about at a meeting of the National Academy of Sciences in Pasadena, California.

Some people say the Universe is ageless, and that the Universe looks like it stays the same, or in a "steady-state." At the conference in California, this side of the argument was presented by astrophysicist Jesse L. Greenstein and physicist William A. Fowler from the California Institute of Technology (Caltech). This steady-state theory, as it is known, says that the Universe always has, and always will, look mostly like it looks today.

Another theory, the "evolutionary theory," competes with the steady-state theory. The evolutionary theory says a beginning collection of hot particles exploded at the beginning of time. These particles formed all of the Universe's hydrogen (and maybe its helium) in one huge event.

In completely different ways, both theories explain that the Universe is expanding. The expansion of the Universe was first found in 1914, when an American astronomer named Vesto Slipher studied some galaxies and saw that light from all of them was "red-shifted." All light travels in waves. In the spectrum of visible light, red light has the longest wavelength. That means if an object (like a galaxy) gives off light and the object is moving away, then the movement of the object makes the wavelength longer, making the light "red-shift." This is like the sound of a train moving away from you making a lower sound as it gets farther from you. Those sound waves are also getting longer.

The steady-state theory explains the expansion of the Universe from the continuous bubbling up of the element hydrogen, coming from empty space at a speed of one particle for every cubic meter of space every 300,000 years or so. This hydrogen finally gathers together and condenses into stars. Then, through nuclear fusions in the center of stars, where hydrogen atoms combine to form larger elements, stars make all of the heavier elements like carbon, oxygen, silicon, iron, copper, etc. Then, as stars age, die, and explode, they scatter the heavier elements around the galaxies. These heavier elements then mix with other hydrogen, and new stars form with rocky planets around them—just like our own Solar System. Scientists Greenstein and Fowler used red giant stars from our own galaxy, which make heavy elements, as evidence for the steady-state theory.

An important part of the steady-state Universe theory is that the Universe does change in some ways over time. Hoyle, a scientist who supports the theory, compares the deathless steady-state theory to a river. The Universe might look like it doesn't change, but there is plenty of movement and change under the surface, much like a river is constantly changing beneath the surface. There is an old river saying that says that you can never step into the same river twice. The same could be said about the Universe.

In contrast, there is the "evolutionary theory." An American physicist who was born in Russia, George Gamow, along with physicists Ralph Alpher and Robert Herman, developed this theory. These scientists say that the explosion and radioactive

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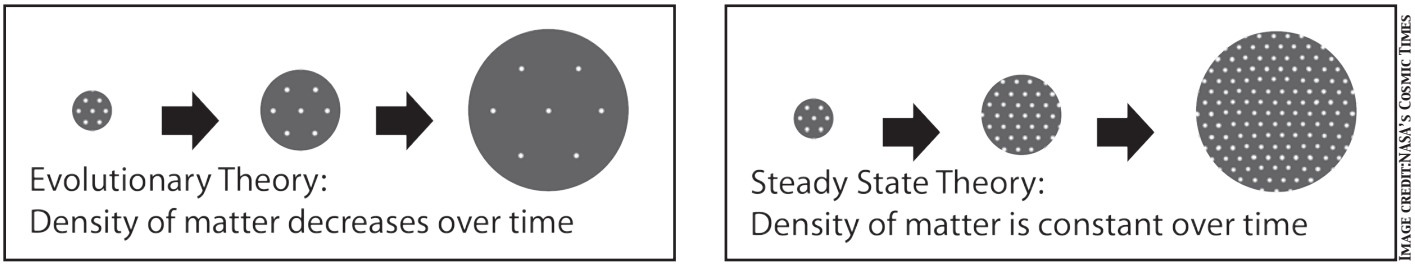

Illustration of the matter-density history of the Universe according to the evolutionary theory (left) and the steady state theory (right).

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decay of a hot ball of neutrons at the birth of the Universe created all hydrogen and some helium. These elements formed as the blast expanded and then cooled. The very first stars were made up only of the original hydrogen and helium. Then those stars fused hydrogen and helium into new, heavier elements. The new, heavier elements were then scattered through the galaxies when the first stars died, and this made more complex mixtures of elements found in stars today.

The evolutionary theory also explains why galaxies are moving away from each other. The galaxies are still moving from the power of the initial explosion. Newton's laws of motion help to explain this. Newton found that an object in motion will remain in motion unless an outside force acts on it. And there might be other direct evidence of an original blast as well. Both Alpher and Herman predicted there would be a very small, left-over heat from the explosion that would still exist in the form of stretched-out light waves called "microwaves." The microwaves would be just a few degrees above absolute zero. The only problem is that no one has yet figured out how to detect these left-over microwaves.

More evidence for an evolutionary Universe comes from Edwin Hubble's 1929 measurements of the speed of galaxies outside our galaxy. Hubble found that the farther away a galaxy is, the faster it seems to be moving away. If there was an ancient blast that started the Universe, that is the exact thing scientists would expect to find.

The bad part of an evolutionary Universe is that it doesn't have a happy ending. There is a limited supply of hydrogen (the steady-state theory provides an unlimited supply of hydrogen). In the evolutionary Universe, the Universe might expand forever and will finally run out of hydrogen. The stars will burn out, and the Universe will cool down into a huge graveyard of dead stars. Another possibility of the future of the evolutionary Universe is that gravity of all matter might eventually pull everything back together again in a gigantic collapse that explodes and starts the Universe all over again. This possibility is an endlessly exploding and collapsing Universe that was described by the late physicist Richard Tolman from CalTech.

Which theory is correct? Only more research and better telescopes will be able to tell us.♦

Hoyle Scoffs at "Big Bang" Universe Theory

During a recent radio broadcast, British cosmologist Fred Hoyle criticized the evolutionary theory of the Universe. This theory competes with Hoyle's belief in the steady-state theory of the Universe. Both theories try to explain where and when all elements in the Universe were made. Hoyle called Gamow's theory a ridiculous "big bang."

Gamow's evolutionary theory of the Universe says an initial group of super-hot nuclear fusions of basic particles created all of the hydrogen in the Universe in one explosion. This same blast caused space itself to expand. The continuous expansion from that "big bang" is observed by astronomers today.

Hoyle strongly disagrees with this theory. He wrote that Gamow's theory cannot be described in scientific terms and can't be challenged by observation.

One problem, Hoyle said, is that the "big bang" theory needs something to exist before the bang, and no one knows what that might be. But, if the Universe is eternal and stars are always being made, and forever make heavier elements, as Hoyle says, then there is no need for an initial explosion. Recent advances in physics seem to support Hoyle's "steady-state" view. Pressures and temperatures inside stars seem to be able to make all the heavy elements seen in space today.♦

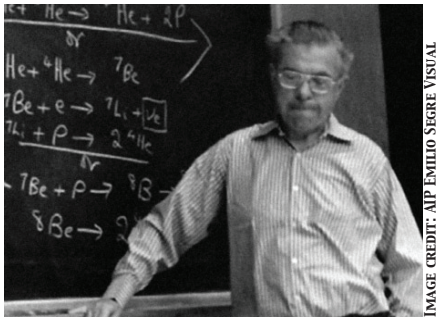

Image credit: AIP Emilio Segrè Visual Archives, Clayton Collection

Fred Hoyle

It's a Star!

It's a Nova!

It's a Super-Nova!

Astronomers say that there is more than one kind of "new" star in the sky. They have been collecting evidence for decades that there are two types of novae, which are stars that light up suddenly to great brightnesses and then fade away. Astronomers now know that there are the ordinary novae and the truly "super" novae.

The first clue astronomers had of super-novae was 35 years ago. Edwin Hubble, who died recently, was using his revolutionary method for measuring distances in space, when he calculated that a nova that was observed in 1885 in the Andromeda Galaxy must have been 100 times brighter, or more luminous, than any nova that had been recently observed in our own Milky Way galaxy.

Fourteen years later, in 1934, physicists Walter Baade and Fritz Zwicky used the term "super-nova" when they found that these novae were not just brighter than normal nova, but were rare events in any particular galaxy. They thought that the most recent super-novae in our own galaxy were seen by Johannes Kepler in 1604, and another one seen by Danish astronomer Tycho Brahe in 1572.

New super-nova observations were added in 1941 by astronomer Rudolph Minkowski. He found the light from 14 far-off super-novae and split the light into their component colors. He found that nine of the spectrums contained no evidence for hydrogen gas in the super-novae, and that five other super-novae did contain hydrogen. Super-novae without hydrogen are Type I super-novae. Super-novae with hydrogen are called Type II super-novae. British astronomer Fred Hoyle says that a possible reason for this is the amount of energy in their deaths may be different. Giant stars that become super-novae might be able to fuse hydrogen and helium to make heavier elements like carbon and iron. These super-novae, then, are not only "super," but Stars of Steel! ♦

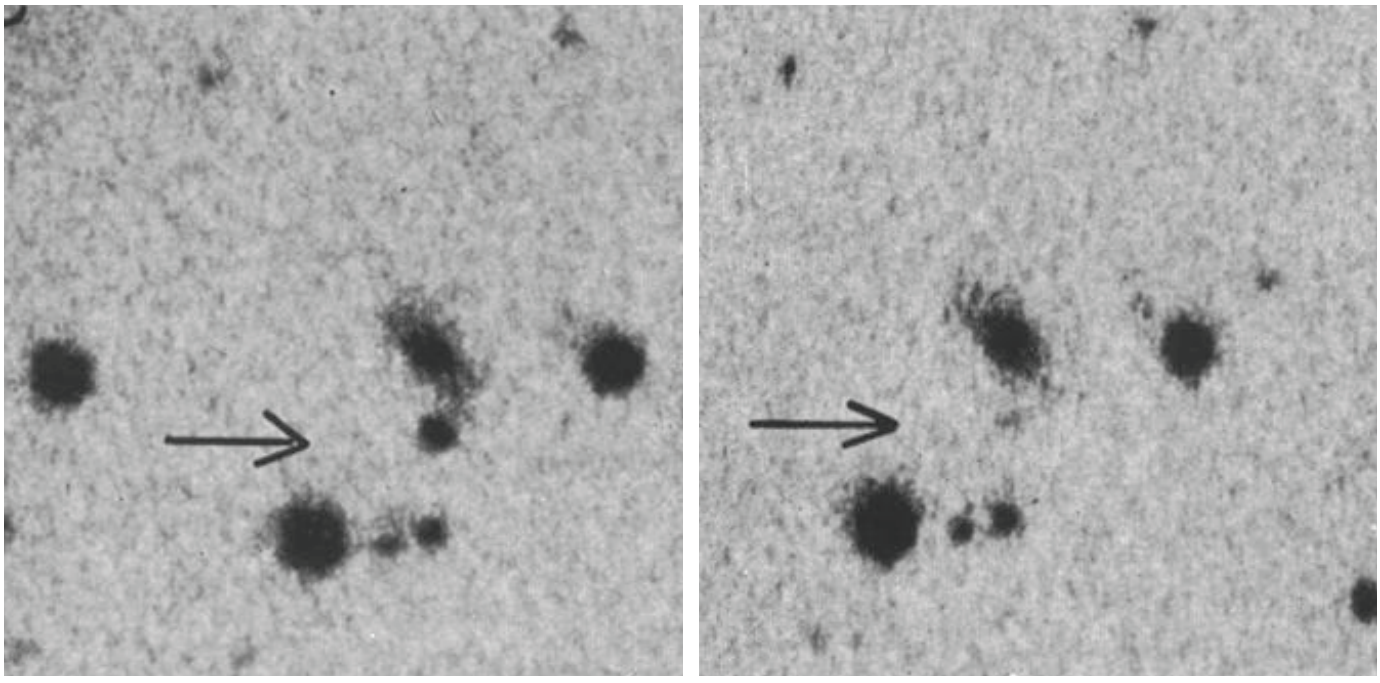

Image showing a super-nova in a barred spiral galaxy a few days after peak brightness (left), and the same field two months later, when the super- nova had become much fainter.