National Aeronautics and Space Administration

Cosmic Times

Home Edition

Age of the Universe: 12-20 Billion Years

1993

Size of the Universe: 30 Billion Light Years

Baby Universe's 1st Picture

What did the newborn universe look like? In 1965, scientists used a radio telescope and found the answer. They discovered a background of microwave radiation that was very plain. Today's technology shows a more detailed picture of this cosmic microwave background (CMB), and it tells us there's a lot more to the story. The detail also provides further evidence of the Big Bang.

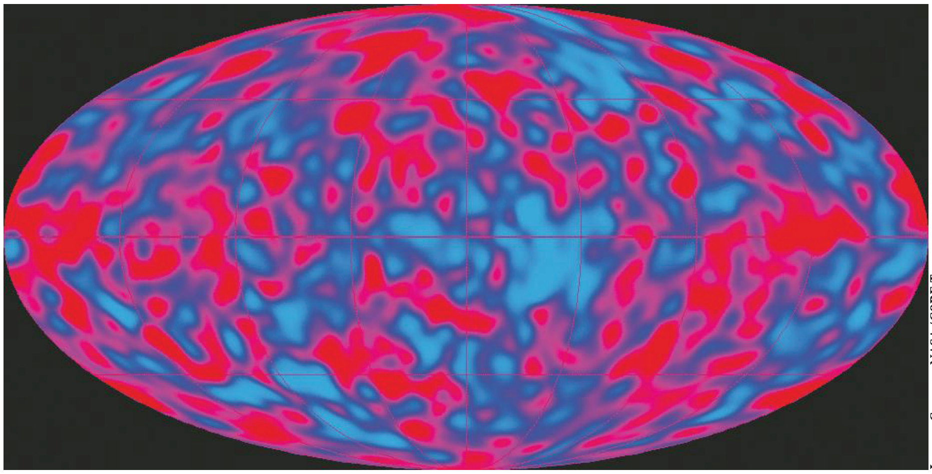

IMAGE CREDIT: NASA/COBE TEAM

COBE's map of the sky, showing minute fluctuations in the cosmic microwave background. Astronomers estimate that this map shows the background radiation 300,000 years after the Big Bang.

"If you're religious, it's like looking at God," said George Smoot, a scientist at the University of California. Dr. Smoot is the leader of the research team that made the discovery. He was addressing a room packed with scientists at a meeting of the American Physical Society

According to the Big Bang theory, the universe expanded from an unthinkably small and dense ball of energy. An "explosion" caused this dense ball of energy to expand. This sent very hot radiation, and space itself, moving outward in all directions. As the universe expanded and cooled, this ball of energy produced particles of matter in the form of quarks and electrons, and then protons and neutrons. Protons and neutrons combined to make the nuclei of the gases hydrogen and helium. This hot gas also gave off radiation in all directions that gradually cooled down to the microwave energy range. Today, we detect the radiation as a cosmic microwave background (CMB). Over time, gravity gathered the denser clumps of gas into the familiar galaxies, stars, and planets of today's universe.

Data from the 1960s showed the CMB energy was the same across the entire sky. But in 1967, astrophysicists Martin Rees and Dennis Sciama predicted the CMB should not be the same everywhere. However, the very slight differences in temperature were extremely hard to detect until NASA's Cosmic Background Explorer satellite (COBE) was launched in 1989.

Scientists have now confirmed the existence of very slight – but measurable – energy differences. Dr. Smoot and his team created an all-sky map of these microwave variations. This map shows

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these "lumps" in the oldest light in the universe. The COBE data shows the light from the very early universe, only 300,000 years after the Big Bang. The current age of the universe is estimated at 12 to 20 billion years.

Three years ago, COBE excited scientists with data that exactly matched predictions about the spectrum of light in a universe that began with a Big Bang. These data were collected by COBE on an instrument designed by John Mather of NASA's Goddard Space Flight Center. With the addition of the latest findings of "lumps" in the oldest light, the Big Bang theory, is now firmly the lead model for how the universe began. Other models either cannot account for COBE's results or require very awkward and unlikely explanations.

The lumps in the map do not match up with anything in the night sky today, but they are very important, say the researchers. If the CMB was perfectly smooth, according to theory, we could not exist! Although the greatest variations (lumps) in the CMB are only at a level of one part in 100,000, they are big enough to lead to the current structures in the universe (galaxies, stars, etc).

Princeton astrophysicist David Spergel observed at the meeting, "It's the most important discovery in cosmology in the past 20 years." ♦

Inflation in the Universe

The Big Bang theory has a problem, say scientists. It can't go from a tiny ball of energy to the universe we see today without some help. It needs an adjustment called inflation.

Astronomers observe that the temperature of the cosmic microwave background (CMB) is nearly smooth and uniform. The temperature can become uniform only if distant regions of the universe can interact and exchange energy. The fastest interactions occur at the speed of light. However, at the time the CMB radiation was given off, two regions that are far apart in space today would have been separated by a greater distance than the radiation could have ever traveled…even moving at the speed of light.

This situation would be similar to someone handing you a cup of very hot tea and handing your friend a cup of iced tea. If you and your friend were close enough, you could mix your cups of tea so that the tea in both cups would be nearly the same temperature. But

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Pancake or Oatmeal Universe

What's for Breakfast?

Over its lifetime, the universe started out fairly smooth, but has grown lumpy.

Data from the COBE satellite show what's been called a smooth, early universe – with measured variations in the cosmic microwave background (CMB) radiation of only 1 part in 100,000! At that very early time, the universe was like the surface of a pancake. If you glance at a pancake it looks smooth, but differences in texture can be seen if you look more closely.

The universe today is more like a bowl of oatmeal, with real "lumps" and clumps of matter and energy. Objects like planets, stars, galaxies and galaxy clusters are the "lumps" which are easily detectable. Even with these lumps, the overall universe is much smoother than was predicted by the original Big Bang. This problem has been solved by inflation.

While the early universe was extremely smooth compared to today, those tiny lumps in it were vital. Through the action of gravity, they led to the much bigger lumps we see today, the ones that make our very existence possible. ♦

Image Credit: Public Domain

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imagine that immediately after you and your friend were handed your cups of tea, someone quickly pulled you and your friend so far apart that you would never be able to meet up again…even if you ran as fast as you could for your entire life. If this happened you would expect your cups of tea to always have a big difference in temperature. So why is the CMB temperature so nearly uniform?

Inflation Theory explains this by stating that shortly after the Big Bang, the universe expanded tremendously in a very short amount of time. This expansion grew the size of the universe from submicroscopic to the size of a golf ball in 10^{-35} seconds. Thus, regions once in contact with each other are now far apart in the universe. So if you and your friend were able to mix your cups of tea while you were still in contact with each other, then the temperature in your cups of tea would always be very similar no matter how far apart you moved.

After inflation, the expansion of the universe continued, but at a slower rate. As space expanded, the universe cooled and matter formed, and then protons and neutrons formed.

Inflation also predicts how stars and galaxies formed in the universe. Our universe would have been microscopic in size prior to inflation, and small differences in the density of matter would also be stretched by inflation. After inflation, these differences in the density of matter would be faint, but over time, the slightly overdense regions would attract neighboring matter through the action of gravity. This would begin the gradual process of galaxy formation. So Inflation Theory explains why the CMB is so nearly uniform, and also how galaxies, stars, planets and people came to be!

Scientists are now more satisfied that with the addition of inflation, the Big Bang describes the universe we live in. ♦

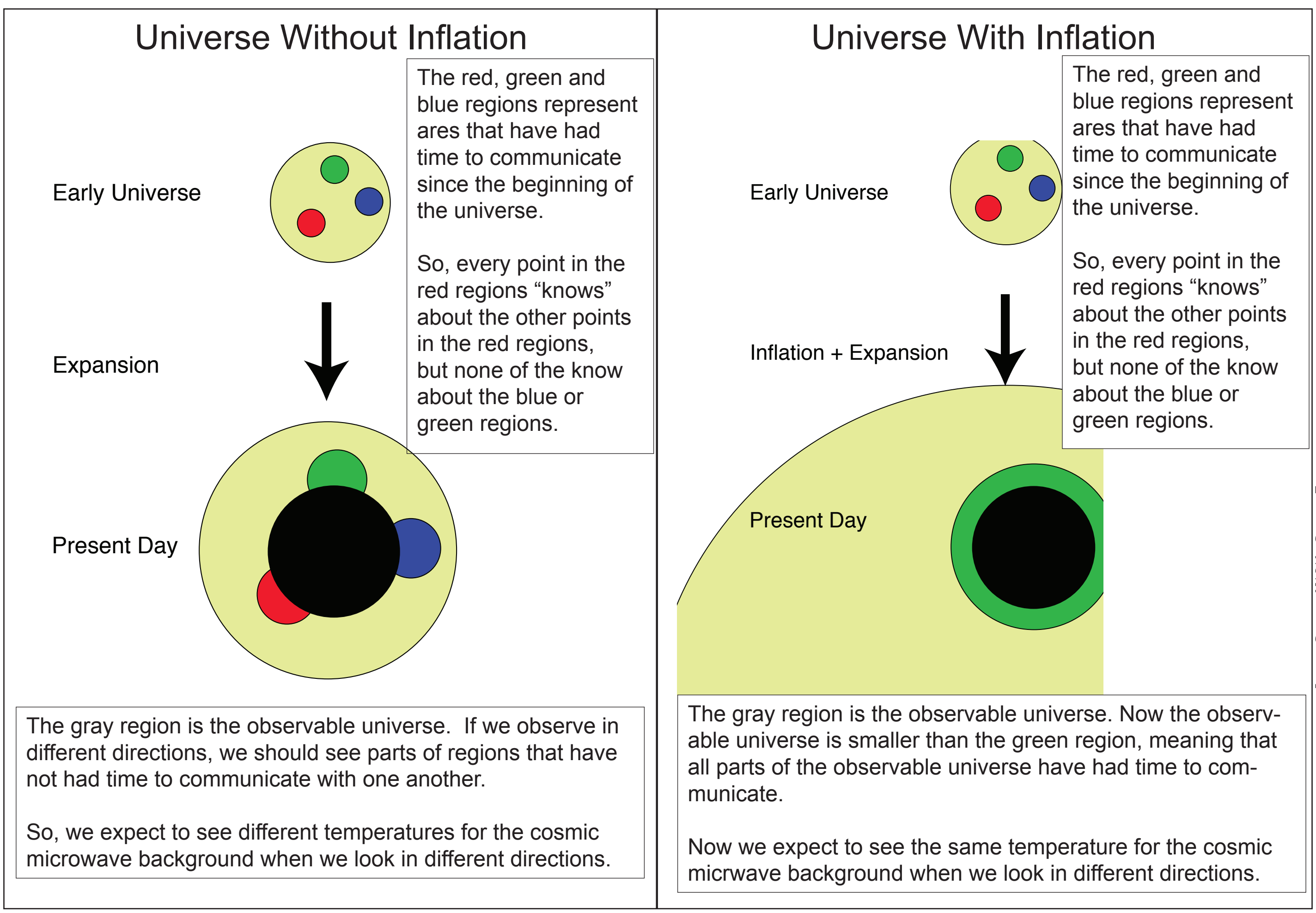

Image Credit: NASA's Cosmic Times

Evolution of the universe without inflation (left) and with inflation (right)

Fool-Proofing Galactic "Candles"

The "standard candle" used for measuring the distance to other galaxies just got a much-needed tune-up.

Some bright supernovae are created by the deaths of white dwarf stars in binary systems. These are Type Ia supernovae, and they have been used as a standard candle for many years. Wherever they occurred, they were believed to have roughly the same actual brightness. For this reason, scientists used them to measure the distance to the galaxies they are located in. Imagine that an astronomer observes two Type 1a supernovae, one that is dimmer than the other. Because all of the Type 1a supernovae have the same actual brightness, the dim one only appears dimmer because it was further away. Recent research has revealed a way to greatly improve the accuracy of these calculations.

In the 1940s, astronomers realized supernovae came in two forms: some (Type I) did not contain hydrogen, while others (Type II) did contain hydrogen. The lack of hydrogen means that the star has used up the basic fuel that drives nuclear reactions in stars. Type II supernovae were found to result from the collapse of a single, massive star. In the 1980s, however, it became clear that some Type I supernovae also come from the collapse of massive stars. The remaining Type I supernovae, now called Type Ia, were found instead to result from the collapse of a white dwarf star in a binary star system.

In a binary system, a white dwarf can gravitationally pull mass from its companion star. If enough mass is pulled from the companion, the white dwarf reaches a critical mass and gravity will crush it. The white dwarf collapses and explodes as a Type Ia supernova.

Since all Type Ia supernovae are created by the explosion of a white dwarf star as it exceeds the critical mass, astronomers believed they should all have the same actual brightness and should be useful as a measuring stick to distant galaxies. Type Ia supernovae may also be visible at distances greater than the Cepheid variable stars. Cepheids were identified as standard candles in 1912 by Henrietta Leavitt.

But it turns out that not all Type Ia supernovae are equal either. Scientists have discovered that they show a pattern of brightening and fading over several days and that the pattern varies a great deal. Astronomer Mark Phillips at the Cerro Tololo Interamerican Observatory in Chile found that some brighter Type Ia supernovae fade more slowly over the first 15 days than do dimmer ones.

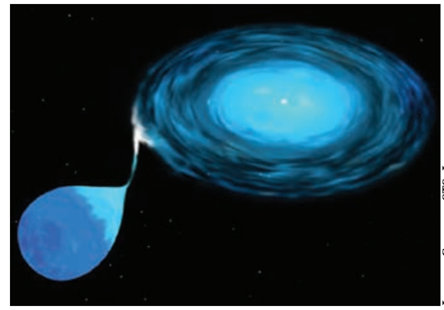

Image Credit: STScI

Artist's concept of a white dwarf in a binary system with another star. The white dwarf is pulling material from the companion, and may eventually gain enough mass to become a Type 1a supernova.

By sorting the dim, fast-fading supernovae from the bright, slow-fading ones, Phillips arrived at a luminosity-decline relation. By using this relation, astronomers can adjust the distance measure, and increase the accuracy of the distance measurements. ♦

Pulsar Gravitational Waves
Win Nobel Prize

This year's Nobel Prize in Physics was awarded for the amazing discovery of the first indirect evidence for the existence of gravitational waves.

In 1974, Princeton University astronomers Russell A. Hulse and Joseph H. Taylor located PSR 1913+16. This object is a special type of super-dense neutron star called a pulsar. A pulsar emits beams of light that sweep through the earth's line-of-sight. As the pulsar rotates on its axis, the light sweeps across our vision, and we see the pulsar pulse. We see a radio pulse from PSR 1913+16 every 59 milliseconds. It orbits another star, which is likely another neutron star. These stars orbit each other at super-high speed every eight hours.

Four years after first discovering PSR 1913+16 and after some careful timing measurements of the pulsar, Hulse and Taylor found that the two stars move closer to each other by about three millimeters per orbit. That could only happen if something was pulling energy out of the system. But what was it?

Einstein's theory of general relativity provides the answer. It predicts that two massive objects moving around in a strong gravitational field will send gravitational waves out into space. This takes energy from

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Dark Matter Hunt *Heats Up*

The mystery of dark matter just deepened. A new report takes a look at a huge mass of dark matter (equal to about the mass of about 20 trillion Suns) located in a small cluster of galaxies. Dark matter isn't visible, and scientists can't explain what it is.

A large amount of dark matter was found using the ROSAT X-ray satellite. ROSAT detected a gigantic cloud of very hot gas in the empty space between two galaxies. This was a very unexpected place to find this gas. Scientists detected the hot gas because it gives off X-ray radiation. This cloud is a surprise, because its great heat should have made the gas quickly dissipate.
The existence of the hot gas cloud can only be explained by the existence of a gravitational force to hold it in place. Only dark matter could do the job without being seen, explains Richard Mushotzky of NASA'S Goddard Space Flight Center.

To hold the gas in place, a very strong gravitational force is needed. The gravity caused by the visible matter in the galaxy cluster isn't nearly strong enough. To create enough gravity, there must be 30 times more matter present than what can be seen. This unseen matter is dark matter. The normal matter ROSAT observed is just a small fraction of what's really there.

If there is that much dark matter compared to visible matter throughout space, then dark matter could determine the fate of the universe. Its gravity could be enough to someday reverse the direction of matter and energy flung out by the Big Bang and pull the universe back together into a "Big Crunch," say some researchers.

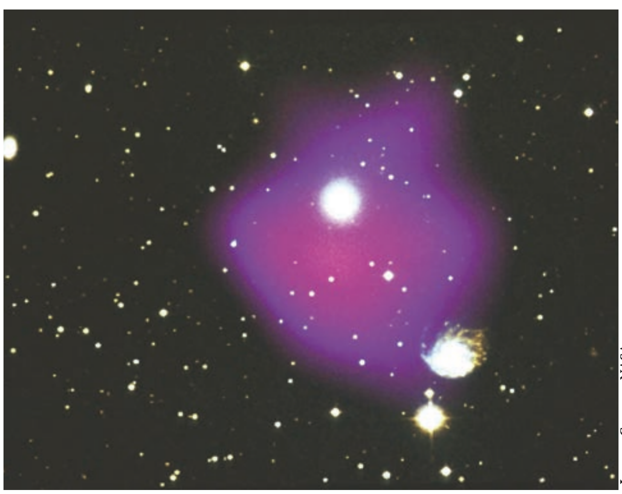

Image Credit: NASA

Hot X-ray emitting gas (shown in purple) was discovered by the ROSAT satellite to be present in this group of galaxies. The presence of the gas provides evidence for the existence of dark matter.

In 1970 astronomer Vera Rubin also found signs that dark matter existed. She studied the rotation rate of stars in the Andromeda galaxy and found that it just didn't make sense. Scientific models predicted stars farther from the center of the galaxy should revolve more slowly than stars closer to the center. However, this is not what is observed.

The simplest explanation is that matter is a lot more evenly spread through the galaxy than it appears. This would cause the force of gravity to be fairly equal throughout the galaxy. Therefore, dark matter must be what is creating the gravity that is tugging at these stars and keeping them in the galaxy.

Despite the new ROSAT discovery and its enormous implications, scientists haven't been successful in figuring out exactly what dark matter is. Some think it might be a type of subatomic particle that has mass but only interacts with normal matter through gravity. These Weakly Interacting Massive Particles (WIMPs) could be shooting harmlessly through us right now, a million per second, and we wouldn't know it.

Another possibility is that the there are a lot of dark, cold dead stars out there that can't be detected with our current technology. These MAssive Compact Halo Objects (MACHOs) would probably be concentrated in the halo of stars found immediately above and below the galactic disk. ♦

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their orbits, and causes them to fall closer to each other. The 8-hour orbit should be 75 microseconds shorter every year.

After 18 years of careful measurement, Taylor has now precisely timed PSR 1913+16's orbital periods and found they are within 0.3 percent of general relativity's predictions. This is strong evidence of the existence of the gravitational waves predicted by Einstein.

The pulsars won't be colliding any time soon. Although each neutron star is 7 miles in diameter and 1.4 times the mass of the Sun, they are still about a million miles apart. At their present rate, it will take 300 million years for the stars to collide. ♦