National Aeronautics and Space Administration

Cosmic Times

1993

Early Edition

Age of the Universe:
12-20 Billion Years

Size of the Universe:
30 Billion Light Years

Baby Universe's 1st Picture

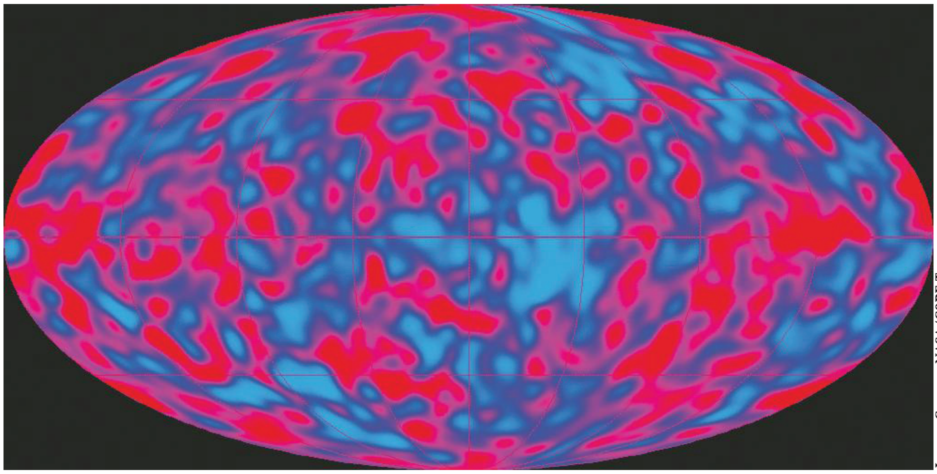

IMAGE CREDIT: NASA/COBE TEAM

COBE's map of the sky, showing tiny fluctuations in the cosmic microwave background (CMB). Astronomers predict that this map shows the CMB radiation 300,000 years after the Big Bang.

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. The background was very plain. It did not have many features. But today's technology shows a better picture of the "cosmic microwave background" or CMB, and tells us there is a lot more to the original story. This newly found detail gives more evidence of 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 a research team that made the discovery.

The Big Bang theory says the universe expanded from an incredibly small and dense ball of energy. This "big bang" made this dense ball of energy expand. The expansion sent very hot radiation, and even space itself, out in all directions. Then, as the universe expanded and cooled off, the energy made particles of matter. The particles of matter made were quarks and electrons, then protons and neutrons. Then the protons and neutrons combined and made the center, or nuclei, of hydrogen and helium. These two hot gases, hydrogen and helium, gave off radiation in all directions. The radiation slowly cooled down enough to become microwave energy. Today we can find this radiation as cosmic microwave background, or CMB. Over a period of time, gravity has pulled together the denser clumps of gas to form galaxies, stars, and planets we see in today's universe.

Data from the 1960s showed that the CMB energy was the same throughout the whole sky. In 1967, scientists Martin Rees and Dennis Sciama thought the CMB should not be the same everywhere. But the very small differences in energy and temperature were very hard to find until better technology from NASA's Cosmic Background Explorer Satellite (COBE) was launched into space in 1989.

Scientists have now been able to show that there are very, very tiny energy differences in the CMB. Dr. Smoot and his team of scientists created a sky map

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of these microwave differences. The map shows these "lumps," in the oldest light in the universe. The COBE data shows light from the very early universe. So early, in fact, that astronomers can see back to the time when the universe was only 300,000 years old. Astronomers estimate that the age of the universe right now is between 12 and 20 billion years old.

Three years ago, in 1990, COBE found information that made scientists very excited. Data from the satellite exactly matched the spectrum of light that they predicted would have existed if the universe had begun with the Big Bang. COBE collected the data on an instrument designed by John Mather at NASA's Goddard Space Flight Center. The discovery of these lumps in the light from the young universe makes the Big Bang the lead theory of how our Universe began. Other theories or models cannot seem to fit COBE's results into their predictions.

The lumps in this background radiation do not match up with anything we see in the night sky today, but they're still important. Researchers say that if the CMB was smooth, as they observed in the 1960s, then we couldn't exist! The greatest lumps or variations in the CMB are very slight, but they are big enough to be the beginning of the current structures like galaxies and stars in the universe.

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

Pancake or Oatmeal Universe
What's for Breakfast?

Over the universe's lifetime, it started out pretty smooth, but has grown lumpy.

Data from the COBE satellite show a young universe that was smooth. The early universe's CMB—cosmic microwave background--hardly had any difference. Only 1 part in 100,000 was different! At that very early time, the universe was like the surface of a pancake. Like a pancake, if you just glance at it, it looks smooth. Differences in a pancake's texture can only be seen if you look closely. The same is true for the CMB of the early universe.

Today's universe is more like a bowl of oatmeal. There are "lumps" and clumps of matter and energy. The "lumps" of the universe are objects like stars, galaxies, and galaxy clusters, which are easily found. Even though the universe has lumps, the universe is still smoother than the Big Bang theory would have predicted. Inflation explains this difference.

The early universe was much smoother than today's universe, but without the very tiny lumps of the young universe, larger lumps of today could not have formed. Even the small lumps have gravity, and this gravity was needed to make larger lumps, like planets. ♦

Image Credit: Public Domain

INFLATION IN THE UNIVERSE

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

Astronomers see that the temperature of the cosmic microwave background, or CMB, is nearly smooth throughout. The temperature can only be uniform if far sections of the universe can interact and exchange energy with one another. The fastest of these interactions happen at the speed of light. But, when the CMB was first given off, two sections that are far apart today would have been separated by more distance than light could have ever traveled.

This situation can be compared to two people holding cups of tea. If someone handed you a cup of very hot tea, and handed your friend another cup of iced tea, they would be different temperatures. If you were both close enough to each other, you could mix your cups of tea so they were both almost the same temperature. But what if you and your friend were handed your cups of tea, then quickly pulled apart so you could never meet again…even if you ran as fast as you could for your entire life? If this happened, you should expect your cups of tea to always have different temperatures. So why then is the CMB temperature, even in different sections of the universe, almost the same?

Inflation Theory explains this. The theory says that just after the Big Bang, the universe expanded in huge amounts in a very short amount of time. The universe grew from submicroscopic size to the size of a golf ball in 10^{-35} seconds. So, regions that were once in contact with each other are now far apart in the universe. If you and your friend had time to mix the cups of tea while you were still in contact with each other, then your cups of tea would always be a similar temperature to one another no matter

"Inflation" continued on page 4

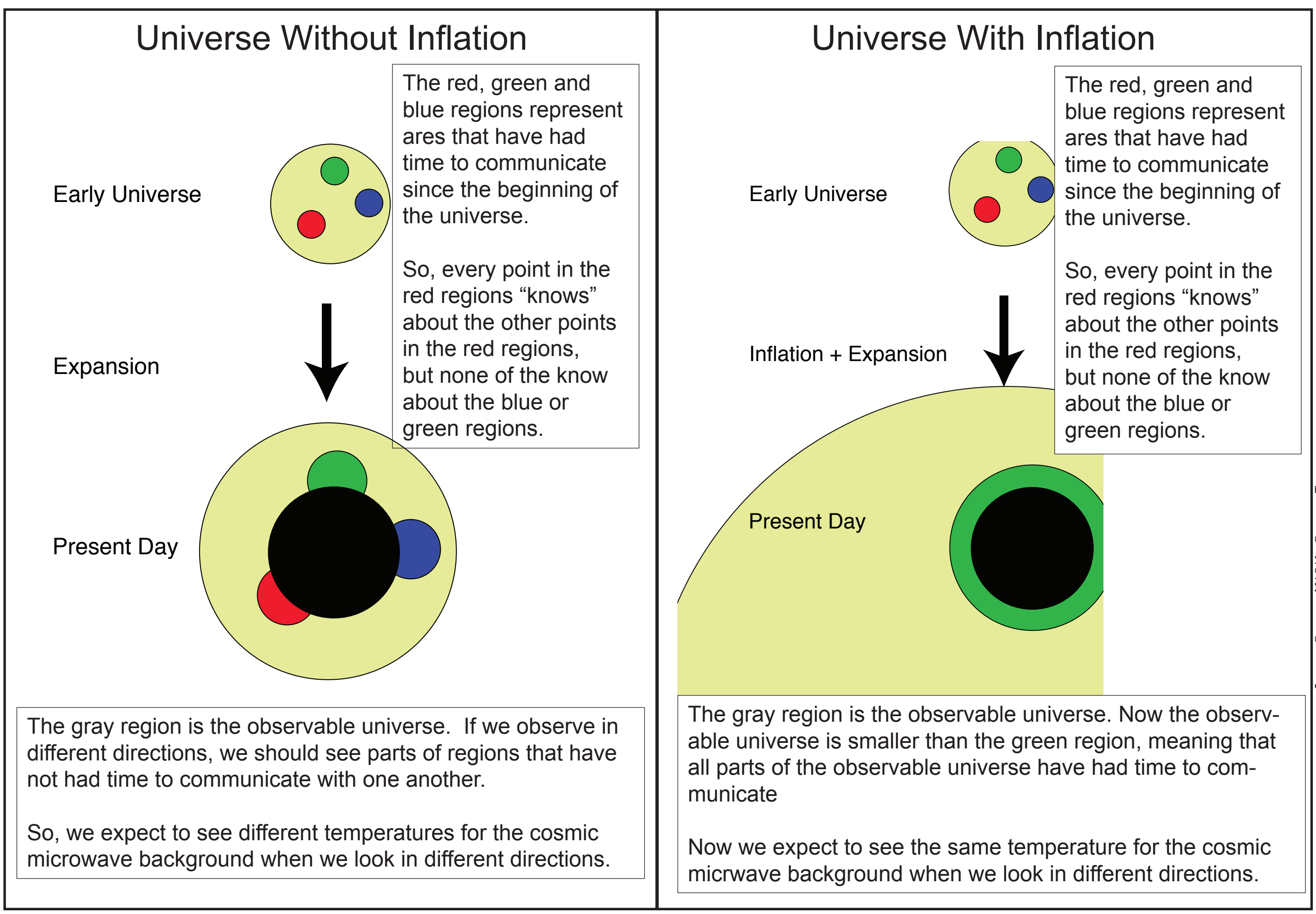

IMAGE CREDIT: NASA'S COSMIC TIMES

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

Pulsar Gravitational waves Win Nobel Prize

Scientists have searched for evidence of gravitational waves in the universe. The Nobel Prize in Physics this year is awarded to two scientists, Russell A. Hulse and Joseph H. Taylor, for making just that amazing discovery.

Back in 1974, the two Princeton University astronomers found a special star PSR 1913+16. This star is pulsar, which is a type of neutron star. A pulsar emits beams of light that sweep through the earth's line-of-sight. As the light sweeps across our vision, we see the pulsar pulse. Many pulsars give off pulses in radio light. For PSR 1913+16, the radio signal is given off every 59 milliseconds. PSR 1913+16 also orbits another star, probably another neutron star of some kind. The two stars orbit each other at a very high speed every eight hours.

Hulse and Taylor carefully timed measurements of the pulsar for four years. They found that the two orbiting stars move closer to each other by about three millimeters every orbit. That could only happen if something was pulling energy out of the two-star system. But what was pulling energy out of the system?

The answer was provided by Einstein's Theory of General Relativity. The theory predicts that two large, massive objects moving around a strong gravitational field will send gravitational waves out into space. As this happens, energy is taken out of the objects' orbits, which causes them to fall closer to each other. Following Einstein's theory, the two orbiting stars should have a 75 microsecond shorter orbit every year.

After carefully measuring for 18 years, Joseph Taylor has now timed PSR 1913+16's orbital periods. He found that they are within 0.3 percent of the Theory of General Relativity's predictions. This is strong evidence that gravitational waves predicted by Einstein exist. The discovery of PSR 1913+16, the measurements by Taylor, and the pulsar's support of gravitational waves is the reason these two astronomers won the Nobel Prize this year.

Even though the two stars are getting closer to one another, they won't be colliding soon. Each of the stars is 7 miles in diameter and about 1.4 times the mass of the Sun, they are still about one million miles apart. At the speed they are orbiting and their distance from one another, it will take 300 million years for the stars to collide.♦

Image Credit: Department of Energy

Image Credit: Princeton University

Russell Hulse (left) and Joseph Taylor (right)

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how far apart they were. The same happened with the regions of the universe.

After the inflation of the universe, expansion of the universe continued, but much more slowly. As space expanded, the universe cooled and matter formed, then protons and neutrons formed.

Inflation Theory also predicts how stars and galaxies formed in the universe. Before inflation, our universe would have been microscopic in size. Small differences in the density of matter would be stretched by inflation. After inflation, these differences would only be small, but over time, areas that were only slightly more dense would attract nearby matter through the pull of gravity. Very slowly, galaxies would form this way. Inflation Theory, added to the Big Bang theory, explains why the CMB is so smooth and even. It also explains how galaxies, stars, planets, and we formed.

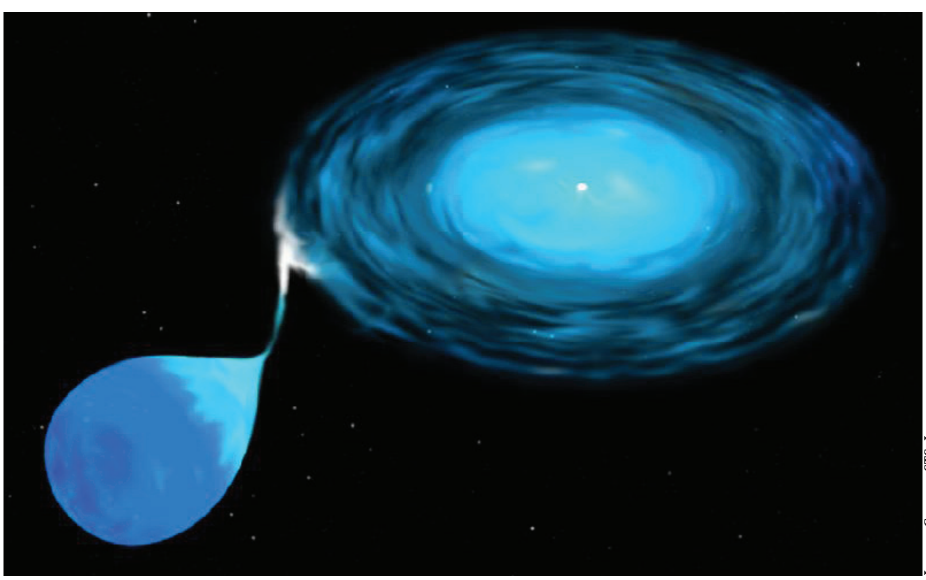
By adding Inflation to the Big Bang theory, scientists are now more satisfied that the Big Bang describes how the universe came to be. ♦

Fool-Proofing Galactic "Candles"

Measuring the distance to other galaxies often uses a measurement method called the "standard candle." This candle has just been given an update.

A type of bright supernova is created by the death of white dwarf stars in binary systems. This type of supernova, called Type Ia, has been used as the "standard candle" for many years. No matter where they happened, astronomers thought they all had about the same actual brightness. Because of this, scientists used the supernova to measure the distance to the galaxies where they one happen. 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. New research has shown a way to greatly improve the accuracy of these calculations.

As stated above, the standard candle is a Type Ia supernova. In the 1940s, astronomers found that supernovae can be either Type I or Type II. Type I supernovae contain hydrogen gas and Type II do not contain hydrogen. If a supernova does not contain hydrogen, that means the star has used up the hydrogen that causes its nuclear reactions. These Type II supernovae are the result of a single, massive star collapsing. But there was a problem with this explanation. In the 1980s, scientists found that some Type I supernovae also came from collapsing, massive stars. The rest of the supernovae, now called Type Ia supernovae, are not formed by collapsing, massive stars. Type Ia supernovae are instead formed by the collapse of a smaller white dwarf star in a binary system.



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.

In what is called a binary system, a white dwarf star can pull mass from its partner star through gravity. If the dwarf star can pull enough mass from its partner star, the white dwarf reaches a "critical mass." Gravity crushes the dwarf star. The white dwarf then collapses and explodes, becoming a Type Ia supernova. Astronomers thought that all Type Ia supernovae should have the same actual brightness as each other, since they all form by the explosion of white dwarf stars when they exceed their critical mass.

But astronomers found that not all Type Ia supernovae are equal. They show a pattern of growing brighter and then fading over several days, but the pattern varies between supernovae. 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 less bright ones do.

Phillips sorted the supernovae into dim, fast-fading supernovae and bright slow-fading ones. When he did this, he came up with a "luminosity-decline relation." This relation, or comparison of supernovae, allow astronomers to adjust their measure of distances, which makes "standard candle" measurements more accurate. ♦

Dark Matter Hunt Heats Up

Dark matter is a mystery, and this mystery is getting tougher to solve. A huge mass of dark matter equal to about 20 trillion suns is being studied in a small group of galaxies. The problem is that dark matter is invisible, and scientists don't know what it is.

Astronomers found most dark matter using an X-ray satellite called ROSAT. ROSAT found a huge cloud of very hot gas in the empty space in-between two galaxies. They were able to find the gas because very hot gas gives off X-rays. These scientists were surprised to find gas between galaxies because the giant amount of heat given off by this gas should have made the gas quickly dissipate, or spread out.

The only explanation for this hot gas staying between the two galaxies is that a gravitational force must be holding it there. Since there is nothing visible around this gas, dark matter has to be keeping the gas in place, explains Richard Mushotzky of NASA's Goddard Space Flight Center.

A very strong force is needed to hold gas in place, something like a gravitational force. The visible matter in the galaxy cluster doesn't have enough strength to do that. There would have to be 30 times more visible matter to create enough gravity. The unseen matter in that galaxy cluster is dark matter. ROSAT observes normal, visible matter. That visible matter is only a small amount of the matter that is really there.

If most of the matter in our universe is dark matter, then dark matter could determine what happens to the universe in the future. Some researchers say that the gravity of dark matter could be strong enough to someday pull the matter and energy back together into a "Big Crunch." This would reverse the Big Bang.

In 1970, astronomer Vera Rubin also found signs that dark matter existed. She studied the rotation speed of stars in the Andromeda galaxy, but the speed did not make sense. Scientific models predicted that the stars that were farther from the center of the galaxy should have been revolving slower than the stars close to the center. But this is not what she saw.

The easiest explanation is that matter is more evenly spread out through the galaxy than it looks like. If matter was more spread out, then the force of gravity would be more equal throughout the galaxy. This would make stars and other matter in the galaxy revolve at about the same rate. Dark matter must be in-between visible matter, gravitationally pulling at the stars, keeping them in the galaxy.

Even with the new discoveries of the ROSAT satellite, and what those discoveries could mean, scientists still can't figure out exactly what dark matter is. Some scientists think dark matter might be some kind of subatomic particle (a particle that is smaller than an atom) that has mass but can only interact with normal matter through gravity. These WIMPS, or Weakly Interactive Massive Particles could be everywhere, shooting through us right now, a million of them per second, and we wouldn't even know it.

Another possibility is that there might be lots of dark, cold, dead stars that we can't see or detect with current technology. These Massive Compact Halo Objects, or MACHOS, if they existed, would probably be found mainly in the outer halo of stars found just above and just below the galactic disc.♦

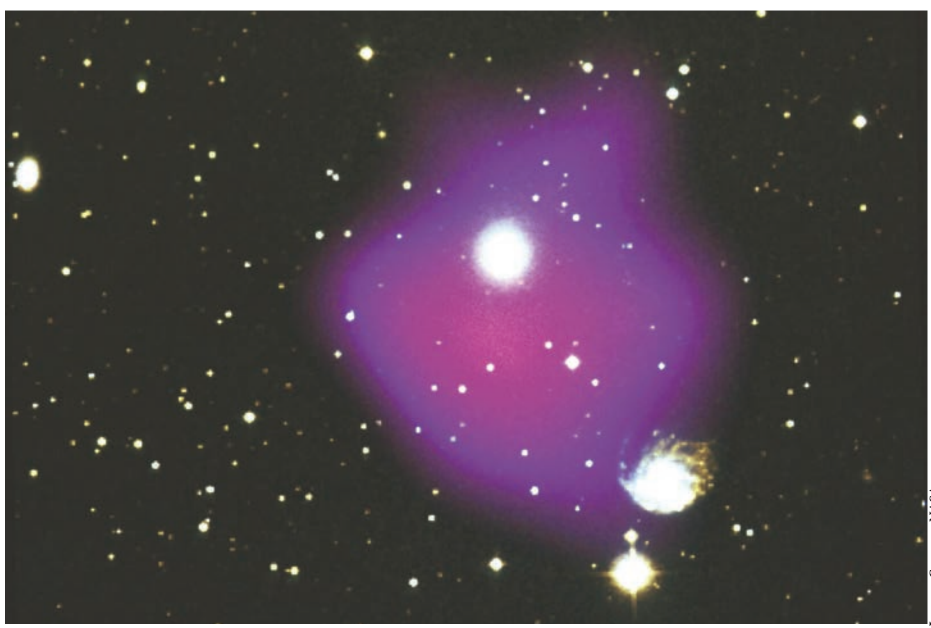


IMAGE CREDIT: NASA

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