Age of the Universe:
13.7 Billion Years

COSMIC TIMES

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Size of the Universe:
94 Billion Light Years

Faster Walk On The Dark Side

There is fresh evidence for the existence of dark energy, a peculiar entity that is hastening the expansion of the cosmos. Dark energy amazingly comprises almost three-quarters of the universe. It appears to be accelerating the distances between galaxies and working against gravity, but its nature is still unknown.

The new evidence is the discovery of an effect dark energy has on photons of light from the earliest universe. This ancient light began moving across the universe just 380,000 years after the Big Bang, and its initial energy has been shifted into the microwave part of the energy spectrum in the 13 billion years since. We see the light today as what scientists call the cosmic microwave background (CMB) radiation. The detection of an effect in the CMB called Integrated Sachs-Wolfe (ISW) confirms that dark energy had an additional influence on those photons.

ISW was named after Rainer Kurt Sachs and Arthur Michael Wolfe, who first described it in 1967. But its influence on the CMB was recently verified by an international collaboration of researchers: Stephen Boughn (Haverford College) and Robert Crittenden (University of Portsmouth), Charles Bennett's (NASA) WMAP team, and a collaboration of astronomers from the Sloan Digital Sky Survey and the Institut d'Astrophysique de Paris.

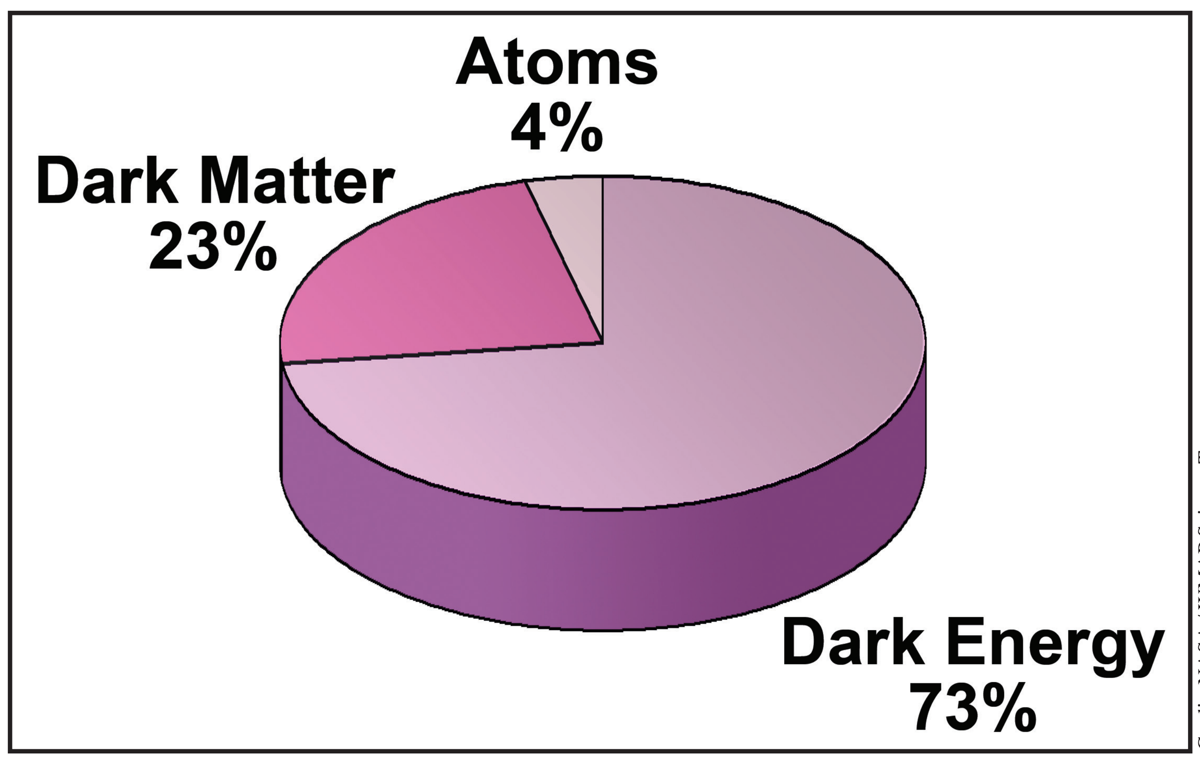
Their conclusions result from efforts to pull together a treasure trove of data, on the large-scale structures of the universe and on light from the newborn universe. The data included observations from visible light, x-ray, radio and microwave telescopes.

Here's how the ISW effect works. Gravity is a property of matter, so matter exists in "gravity wells" in space-time. More matter makes a deeper well. If there is no change in the depth of a well while a photon crosses it, the well has no effect on the photon's energy. But if dark energy stretches out deep wells of gravity into mere shallow dents, then CMB photons crossing the well will change their energy. The recent observations of these subtle changes in the CMB provides further evidence for the existence of dark energy.

This additional evidence is good news to astronomers who first detected a gravity-defying dark energy in 1998. At that time, two teams of astronomers were measuring the retreat of a collection of very distant Type Ia supernovae. These supernovae are created by the explosion of a white dwarf. The teams from the Supernova Cosmology Project at Lawrence Berkeley National Lab and the High-Z Supernova Search had intended to measure the rate at which the universe's expansion was slowing down. Instead, they found that the distance between Earth and these supernovae was growing, and at an increasingly faster rate. Starting about five billion years ago, some unexplained "dark" energy began to overwhelm the force of gravity and push galaxies apart.

The researchers chose to name it dark energy, not to be confused with dark matter, which is another confounding problem in cosmology.

As for what dark energy is, that's anybody's guess right now. While there are at least a half dozen theories, none seem very close to an authoritative answer.



WMAP data reveals that the universe's contents include 4% atoms, the building blocks of stars and planets. Dark matter comprises 23% of the universe. This matter, different from atoms, does not emit or absorb light. It has only been detected indirectly by its gravity. 73% of the universe, is composed of "dark energy", that acts as a sort of an anti-gravity. This energy, distinct from dark matter, is responsible for the present-day acceleration of the universal expansion.

Biggest Mystery: What is Dark Energy?

The further we look into the cosmos, the more puzzled we are. That's the experience of astronomers and astrophysicists now wrestling with the problem of dark energy. This unknown substance dominates the universe, yet is a profound mystery.

There are several theories being proposed to explain dark energy. So far, however, testing these ideas has been very hard to do. The key will be to create a new generation of scientific instruments to search deeper into the cosmos.

At the moment the only way to talk about dark energy is to say what we know it does. It creates more space, new space, pushing galaxies further apart and making the entire universe larger at an increasing clip. Some measurements of distant supernovae in the late 1990s showed us this startling phenomena.

Ironically, there was one big hint that dark energy existed even before astronomers found evidence of it. None other than the great Albert Einstein had factored in an "anti-gravity" effect, which he called the "cosmological constant", into his theory of general relativity to make it work with the static universe that was observed in 1916. After Edwin Hubble discovered in 1929 that the universe was indeed expanding, Einstein and other physicists considered the cosmological constant an annoying fudge factor, without any connection to the real universe.

Later researchers proposed that the cosmological constant represents an underlying background energy. That energy might exert some kind of pressure on the cosmos. Unfortunately, the theory predicts that the energy ought to be 120 orders of magnitude stronger than dark energy appears to be.

Another strong contender for dark energy is something called quintessence. The word is the same as the ancient Greek term for a mysterious fifth element – beyond earth, air, fire and water – which acted in the Moon and stars. Unlike the cosmological constant, the modern theory of quintessence holds that it is some kind of energy field that pushes particles apart. It states that the energy is variable and that it can lessen in strength as it travels through space and time. This concept fits the data available, which suggests that dark energy has only been in the driver's seat for about 5 billion years, so its effect is not constant.

Scientists need to learn much more about dark energy's impact on the universe to test their theories. The only way to do that, of course, is with more data from the heavens.

Journey to Cosmos' Dark Heart

Scientists are gearing up to shed some light on the darkest mystery in the universe: dark energy.

NASA and the US Department of Energy have selected three concept studies for consideration to become their Joint Dark Energy Mission (JDEM). JDEM is slated for launch as early as 2013.

JDEM's goal is to sharpen and double-check the distance measurements to Type Ia supernovae. This, in turn, should reveal critical clues to how fast the universe has expanded at different points in cosmic history.

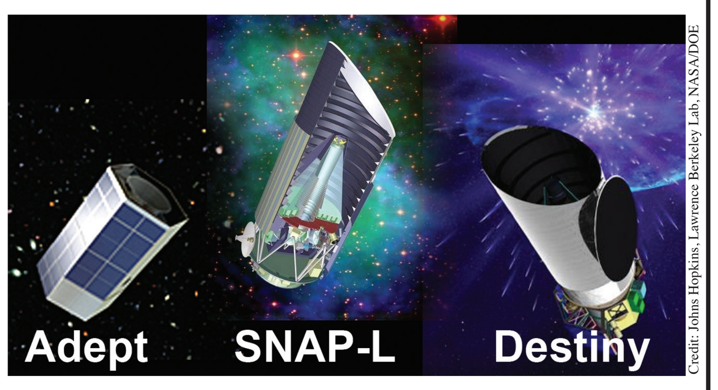
Type Ia's are considered a standard of comparison used to determine the distance to other astronomical objects. By observing a large number of these "standard candle" supernovae in galaxies far and near, researchers hope to find out just how quickly those galaxies are flying away from us.

The three proposed concepts are the Supernova Acceleration Probe (SNAP), the Advanced Dark Energy Physics Telescope (ADEPT), and the Dark Energy Space Telescope (Destiny). Each would look at the supernovae in a different way.

SNAP would use a 1.8-meter optical/infrared telescope with a CCD (charge-coupled device) light detector like those in digital cameras. But with a billion pixels, SNAP's detector beats any handheld camera by a factor of a thousand. SNAP would spot about 2,000 Type Ia supernovae each year over a wide range of distances – about 200 times more supernovae than are now detected each year.

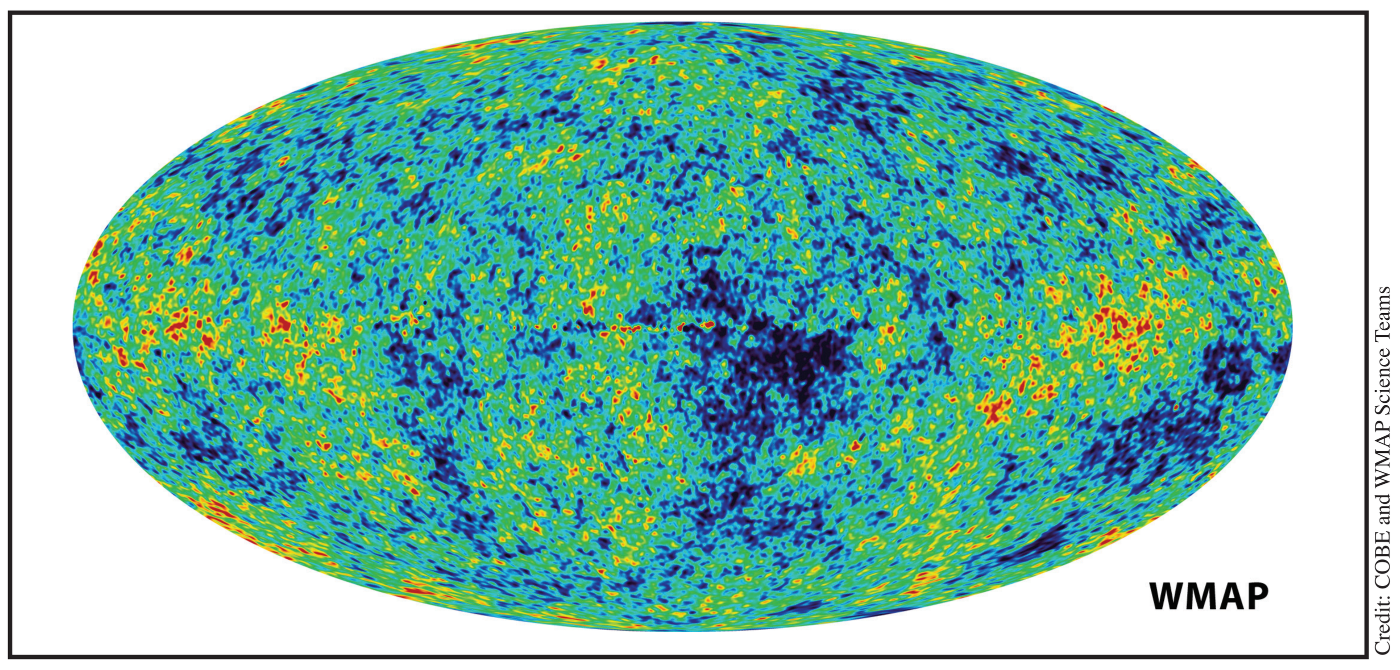
ADEPT would use a 1.1-meter near-infrared telescope to locate 100 million galaxies and 1,000 Type Ia's. Its data would be compared with that of the minute temperature differences in the cosmic microwave background. The mission would reveal how well the earliest (most distant) galaxies match up with the earliest clumps of matter, and how dark energy has altered the distribution since then.

Destiny would have a 1.65-meter near-infrared telescope, designed to detect 3,000 Type Ia supernovae over two years. It would spend an additional year surveying, in detail, 1,000 square-degrees of sky. This would gather new readings on changes in the large-scale distribution of matter in the cosmos since the Big Bang. Both phases of Destiny's mission would improve on the sensitivity of similar ground-based observations by a factor of about 10.



Artist conceptions of the three JDEM missions proposed to refine distances to Type Ia supernovae and shed light on dark energy.

Seeds of Modern Universe



A sky map of the temperature fluctuations in the Cosmic Microwave Background as measured by the Wilkinson Microwave Anisotropy Probe. The dark blue regions are only a few millionths of a degree cooler than the red regions. Astronomers analyzing these fluctuations have determined the percentages of matter and energy in the universe.

Cosmic researchers now have the sharpest focus ever of the universe's early structure. This better view comes in the form of super-sensitive temperature data of the sky-filling cosmic microwave background (CMB) collected by the Wilkinson Microwave Anisotropy Probe (WMAP). The CMB is the afterglow of the Big Bang.

WMAP has vastly improved on the fuzzier, but groundbreaking first image of the CMB unveiled in 1993 from NASA's Cosmic Background Explorer satellite (COBE).

What WMAP has now confirmed are the acoustic "peaks" of the undulating Big Bang shockwaves in the CMB. These were first observed in 1999 and 2000 with ground-based instruments, leading to the conclusion that the geometry of the universe is flat. What that means, among other things, is that on a large scale, parallel lines would stay parallel.

WMAP's measurement of these acoustic peaks give the amount of normal matter and dark matter in the universe. Because WMAP has nailed down the flatness of the universe, astronomers know what the overall matter and energy composition of the universe must be. Knowing the matter composition, they have been able to work out the energy composition. They find normal matter comprises 4% of the universe, dark matter is 23% of the universe, and the energy is 73%. Rather nicely, the energy needed falls right in the range of the amount of gravity-repulsing dark energy discovered by astronomers in 1998.

WMAP has also, for the first time, detected the polarization of light in the CMB across the entire sky. This is important because it helps work out details of what happened during the first split second after the Big Bang. That's when the universe puffed up like a hyperactive lump of bread dough. It's that moment of what astronomers call inflation which allowed for tiny fluctuations in the original Big Bang to translate into huge, but subtle differences in temperature seen in the CMB. And those differences, in turn, are now thought to be the seeds of today's gigantic clusters of galaxies .

Researchers are now comparing and combining the new WMAP data with a range of other cosmic measurements – vast surveys of stars, galaxy clustering, hydrogen gas clouds, supernovae, and others – to uncover a new unified understanding of the universe's past, present and future.

'First Light' Wins Nobel

Astrophysicists John Mather and George Smoot have been awarded the 2006 Nobel Prize in Physics. It was presented for their 1992 discoveries about the cosmic microwave background (CMB), the light from the beginning of the universe as we see it today.

According to the Nobel jury, "These measurements also marked the inception of cosmology as a precise science."

Using data from the space-based Cosmic Background Explorer (COBE), a team led by Mather and Smoot teased out the details of how the universe has cooled. They measured the spectrum of light from this background and found that it matched predictions from the Big Bang theory perfectly. They also found the very subtle variations across the sky in the CMB. Before the discovery of these tiny variations, it was difficult to account for the present structure of the universe, say cosmologists. Later experiments refined the COBE data, but the basis of the discovery comes from this mission.

Dr. John C. Mather at the Nobel Award ceremony, accepting his award from the King of Sweden.

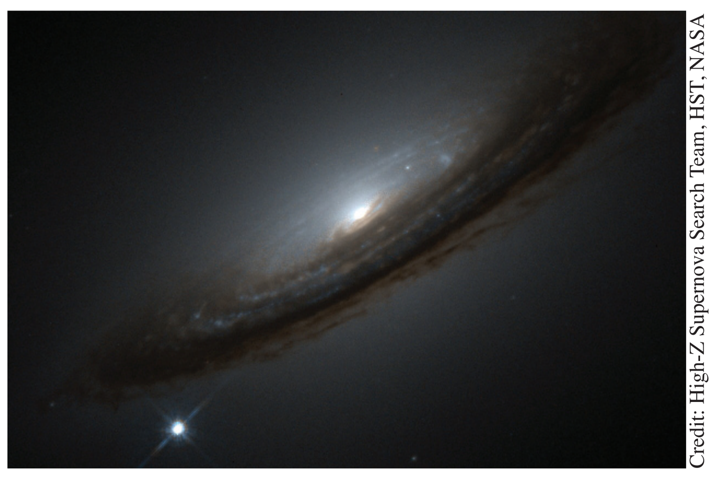
Sorting Out the Dark Stuff

There's some good news and bad news about the cosmos. The bad news is that the normal matter which makes up humans, the Earth and Sun - and everything else we can detect - accounts for just 4 percent of the known universe! The good news is that our tiny little portion of the universe is beginning to get a handle on what makes up the rest of it.

The more abundant matter in the universe – dark matter – doesn't rule either. It makes up just 23 percent of the universe. This is dwarfed by the most prominent entity of all – dark energy, which is 73 percent of the universe. While both are mysterious, and both have been dubbed "dark" because they can't be directly sensed, they are very different beasts.

Dark matter is the universe's "missing mass." It does not appear to interact with normal matter, other than to tug on it with gravity. Dark matter was first proposed in the 1930s by astronomers who discovered that the amount of visible matter known to exist in galaxies wasn't enough to account for their measured gravitational effects. Dark matter is currently thought to be a kind of cold particle that interacts extremely weakly with both atoms and light.

Dark energy, on the other hand, is a stranger animal. It reveals itself only by flinging everything else apart. This peculiar energy is right now creating more space out of nothing and pushing everything in the universe further apart at a faster rate. And that's good news too, if you like privacy.



Supernovae, like the one in the lower left portion of this distant galaxy, were used to determine that the universe's expansion rate is accelerating, leading scientists to propose the existence of dark energy.