In Depth

ABC Science

The hunt for dark energy

It's stronger than gravity, thought to make up 75 per cent of the universe and we have no idea how it works. So how are astronomers hoping to crack what's been dubbed the deepest mystery in physics?

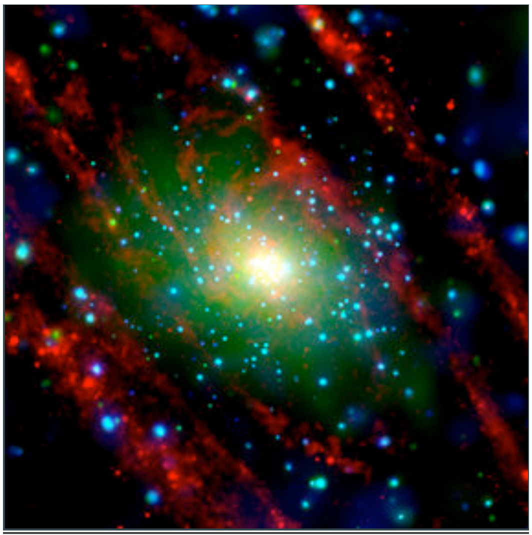
By Carmelo Amalfi

At a mountaintop observatory near Coonabarabran in north-western New South Wales, a team of astronomers are searching for wiggles.

Not the all-singing, all-dancing variety, but the faint imprint of sound waves left in the light patterns of thousands of galaxies formed after the Big Bang nearly 14 billion years ago.

Scientists hope these wiggles will be able to shed some light on what we cannot see — dark energy, a mysterious force thought to have been speeding up the expansion of the universe for the past nine billion years.

Understanding the nature of dark energy from research like this will not only allow us to better understand the distant past, but also the very future of our universe.



Andromeda (pictured) and our own Milky Way galaxy will collapse and form super-galaxies if the expansion of the universe keeps on accelerating. (X-ray: NASA/UMass/Z Li, QD Wang; Infrared: NASA/JPL-Caltech)

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The universe accelerates

In the 1920s, Edwin Hubble noticed the light from distant galaxies moving away from Earth faster than light from galaxies nearby. His observation that the universe was expanding later led to the Big Bang theory.

For the next 70 years after Hubble's discovery, astronomers theorised that the expansion of the universe would slow down over time due to the combined gravitational attraction of the hundreds of billions of galaxies.

Then in 1998 two research groups from Australia and the US realised the opposite had occurred.

While searching for supernovae to measure the rate at which the expansion of the universe was slowing down they found something mysterious had taken over from gravity as the dominant force in the universe between eight and nine billion years ago, and was pushing apart stars and galaxies at near light speeds.

Supernovae are perfect for measuring the expansion of the universe because they emit a known luminosity, or amount of light. By measuring the relative brightness of a supernova you can determine how far away from you it is.

By looking at the colour of the supernova you can also determine its redshift: how much of its light has shifted towards the red end of the spectrum, as the universe expands and its light is stretched as the supernova moves away from you. The relationship between distance and redshift for many supernovae can then tell astronomers whether the expansion of the universe is accelerating or slowing down.

The researchers found the supernovae were dimmer than theorists predicted — so the universe must be speeding up, not slowing down.

"[The discovery was] the equivalent of throwing a ball in the air and having it go into orbit," says astrophysicist Professor Brian Schmidt from the Australian National University, leader of the Australian team. "It's kind of a surprise."

While astronomers still don't know much about the force that is causing this acceleration, they did give

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it a name: dark energy.

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What is dark energy?

Anglo-Australian Observatory director Professor Matthew Colless says dark energy makes up an estimated 75 per cent of the universe.

Dark energy does not emit light so it cannot be observed directly. Instead scientists infer it is there by the effects it has on the expansion of the universe.

Colless, who is also involved in the WiggleZ project, says many theories have arisen over what dark energy is. Albert Einstein started the ball rolling early last century when he was working on his general theory of relativity.

Einstein introduced a 'cosmological constant' into his equations, which allowed for the possibility of a repulsive anti-gravity force to counteract the gravitational pull of matter. It also made his equations fit with the prevailing view of the time that the volume of the universe was static.

When Hubble discovered the universe was expanding, Einstein removed the constant, describing it as his "biggest blunder".

But in 1998, the Australian and American teams realised that Einstein may have been right all along: a 'cosmological constant', or something similar, was responsible for the universe's acceleration.

Schmidt says dark energy is part of space itself.

"You can't disentangle it from space," he explains. "The more space is created, the more dark energy is created. It also pushes away from itself, which works in the opposite direction to gravity."

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Researching the wiggles

Australian scientists hope to test the current theories of dark energy by studying thousands of distant galaxies formed at different times after the Big Bang, particularly galaxies formed about eight to nine billion years ago when dark energy began to dominate gravity.

Andromeda (pictured) and our own Milky Way galaxy will collapse and form super-galaxies if the expansion of the universe keeps accelerating *(Source: X-ray: NASA/UMass/Z Li, QD Wang; Infrared: NASA/JPL-Caltech)*

Using the Anglo-Australian Observatory near Coonabarabran in NSW, the WiggleZ project is measuring wiggles or imprints of sounds waves left in the light patterns of these galaxies.

Billions of years ago, sound waves spread throughout the early universe. As the universe expanded, the distance between the peaks of each wave also increased. Because clusters of galaxies formed on the peaks of these sound waves, the WiggleZ researchers can measure how the spacing between the peaks has changed over time by measuring the distribution of these galaxies.

Scientists first identified wiggles in the cosmic microwave background radiation, or background heat, produced when the universe was only 300,000 years old.

"Our technique involves measuring the [imprints of these sound waves, left behind as wiggles in the light patterns of] about 300,000 galaxies over a very large volume of the universe," says Professor Warrick Couch, a lead investigator on the project.

If they know the distance between the peaks of the sound waves, they can measure how fast the universe has expanded over different eras, and potentially show that something — dark energy — is accelerating this expansion.

Due to be completed by mid-2010, the WiggleZ project is the first survey of its kind that allows astronomers to test different theories of dark energy by looking at much more remote parts of the universe.

The WiggleZ project is only one of a number of dark energy experiments in the works. NASA and the US Department of Energy are planning to launch a US$1 billion-plus Joint Dark Energy Mission in the middle of the next decade, which will hopefully advance our knowledge of matter, space and time.

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Does dark energy even exist?

But not all scientists are convinced that dark energy even exists.

Some question whether the supernovae studied in the 1998 surveys are fainter than first thought, are perhaps closer than they appear or that their dimness is due to other effects.

University of Canterbury physicist Dr David Wiltshire believes most researchers accept dark energy as a theory because scientists since Einstein have used models that are too simple, assume that the universe is homogenous and that laws of physics work the same everywhere.

He argues that the standard model struggles to explain the 'lumpiness' of the universe observed today — clusters of galaxies strung in filaments and great walls around voids 150 million light years across.

There are alternative theories to explain the so-called effects of dark energy such as quantum theories of gravity, or suggestions that the Earth is in the middle of an emptier than normal region of space, and the expansion of the universe is not uniform.

"The field of cosmology developed for decades when there were no good observations, and we are reaping that history now; observations are far in advance of theory," Wiltshire says.

However, WiggleZ project leader Dr Michael Drinkwater does not believe the models are over-simplified: "The basic framework we use leads us to conclude the universe is dominated by dark energy and cold dark matter," he says.

Drinkwater says the standard model of cosmology explains many different observations of the universe, both on large and small scales.

"It would require some extremely unusual results to question the basic model," he says.

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A dark future

While research continues into dark energy, Anglo-Australian Observatory's Colless is confident the mystery will be solved within the next five to 10 years.

"How old is the universe? What will happen to it? We can't answer these questions unless we know what dark energy is," he says.

ANU's Schmidt agrees. He says the night sky will look nothing like it does today if stars and galaxies and everything in between continue to be pushed apart by dark energy at ever increasing speeds.

"If the universe keeps on doing what it is doing, pretty much all the galaxies we see today will be it," he says. "Very few [new] ones will form. The Milky Way and Andromeda galaxies will collapse and form super-galaxies.

"There will still be stars in the sky from our own galaxy but there will be no other galaxy in the sky."

And so the hunt for this mysterious force continues.

Dark matter? Is it the same thing as dark energy?

The atomic matter that makes up stars, planets, trees and animals only accounts for four per cent of the universe. The rest is made up of phenomena that we can't see: dark energy and something else called dark matter.

Scientists know dark matter exists and that it makes up 21 per cent of the universe, but they don't know what it's made of.

The first evidence of dark matter emerged in the 1930s when astronomers discovered that the mass of all the visible material in a cluster of galaxies was far less than the total mass of the cluster.

They described it as exotic particles such as 'weakly interacting massive particles', or WIMPs, because it interacts very weakly with ordinary matter.

Though dark matter cannot be observed directly, its presence is given away by the effect of its own gravity on objects in space, such as in the motion of distant stars and galaxies. It is thought to act like a 'gravitational glue' keeping these stars and galaxies from falling apart.

As it stands, there is at least seven times more gravity in the universe that can be accounted for with atomic matter.

Unlike ordinary matter, dark matter does not reflect or emit light. Nor can it be recreated on Earth.

It is thought to be cold because it is undetectable to infrared and X-ray telescopes. It's possible that it could zip through our bodies every few seconds just as elementary particles like neutrinos from the sun pass through the Earth.

ANU's Schmidt says there is no evidence dark matter and dark energy are linked: "We have two things which do not emit light and are very difficult to pin down because they are not like the stuff we are made up of — atoms."

However astronomers from the Universidade de Sao Paulo in Brazil (http://www.abc.net.au/science/articles/2009/04/02/2533351.htm) believe they may have found a link between dark matter and dark energy.

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