

# what

COULD DARK ENERGY BE?

# why

DARK ENERGY IS IMPORTANT

# how

DARK ENERGY WAS DISCOVERED

Every now and then  
in science,  
a discovery comes along  
that is so contrary to expectations that  
it changes the way we think  
about the cosmos.

**Two teams announced such a finding in 1998. In direct contrast to what scientists thought, the universe's expansion is speeding up.**

Imagine the universe as a balloon, with galaxies painted on its surface. As air is pumped into the balloon, the balloon expands, and the galaxies move away from one another. Ever since Edwin Hubble discovered in 1929 that the universe is expanding, scientists assumed that the gravity of galaxies would slow down cosmic expansion, as if air is pumped into the balloon at a slower and slower rate. Instead, the two teams in 1998 discovered that cosmic expansion is accelerating, as if the balloon's size is growing at a faster and faster rate.

**What form of energy is acting against gravity and causing the universe's expansion to accelerate?**

Scientists have concocted dozens of ideas, but we don't know which one, if any, is correct. Physicist Michael Turner coined the term "dark energy" to describe this mysterious phenomenon. Dark energy, combined with dark matter, seem to be the dominant components of the universe. NASA, in partnership with the U.S. Department of Energy, is planning the Joint Dark Energy Mission (JDEM) to crack this profound mystery.

## Joint Dark Energy Mission (JDEM)

The JDEM mission will be jointly funded and developed by NASA and the U.S. Department of Energy. The spacecraft will make precise measurements of how the universe's expansion rate has changed with time, which will yield vital clues about which ideas are consistent with observations, and which ones can be thrown out.

JDEM will also represent a partnership between astronomers and physicists. The project will be managed at NASA's Goddard Space Flight Center, in Greenbelt, Maryland. Goddard played a major role in building and managing Hubble and WMAP, and it has many experts in dark energy. Launch is scheduled for approximately 2015.



**For more information, please visit:**

<http://universe.nasa.gov/science/darkenergy.html>

<http://universe.nasa.gov/program/probes/jdem.html>

NASAMESA, The Hubble Key Project Team, and The High-Z Supernova Search Team

Cover: Sloan Digital Sky

[www.nasa.gov](http://www.nasa.gov)



Quest  
for Dark  
Energy



# DARK ENERGY WAS DISCOVERED how

Two competing teams of astronomers announced the accelerating universe in 1998. The groups, known as the Supernova Cosmology Project and the High-Z Supernova Search team, used the same method. They observed distant star explosions known as Type Ia supernovae. These cataclysms occur when dense stars known as white dwarfs blow themselves to smithereens. Type Ia supernovae are special because they all explode with nearly the same luminosity, so astronomers can use them as "standard candles." Measuring the apparent brightness of a Type Ia supernova gives astronomers a direct measure of its distance.



NASA/ESA, The Hubble Key Project Team, and The High-Z Supernova Search Team

By painstakingly observing Type Ia supernovae at different distances from Earth, and by seeing how their light has been "stretched out" by cosmic expansion, the teams calculated how the universe's expansion has changed over time. The two teams made most of their observations with ground-based telescopes. They also used NASA's Hubble Space Telescope (HST) to improve the accuracy of their measurements. Since 1998, completely independent studies with NASA's Chandra X-ray Observatory and Wilkinson Microwave Anisotropy Probe (WMAP) have confirmed the initial findings: **we live in a universe whose expansion is accelerating.**

# why DARK ENERGY IS IMPORTANT

Whatever it is, **modern astronomical measurements show that about 72% of the total energy in the universe is dark energy.** The rest consists of dark matter (23%) and the familiar atomic matter that makes up our bodies (4.6%). Not knowing the nature of dark energy would be akin to an alien scientist trying to understand Earth's surface without knowing the nature of water. Scientists cannot claim to understand the universe at its deepest level if they can't explain its dominant form of energy. Unlocking the mysteries of dark energy will have profound implications for both physics and astronomy.

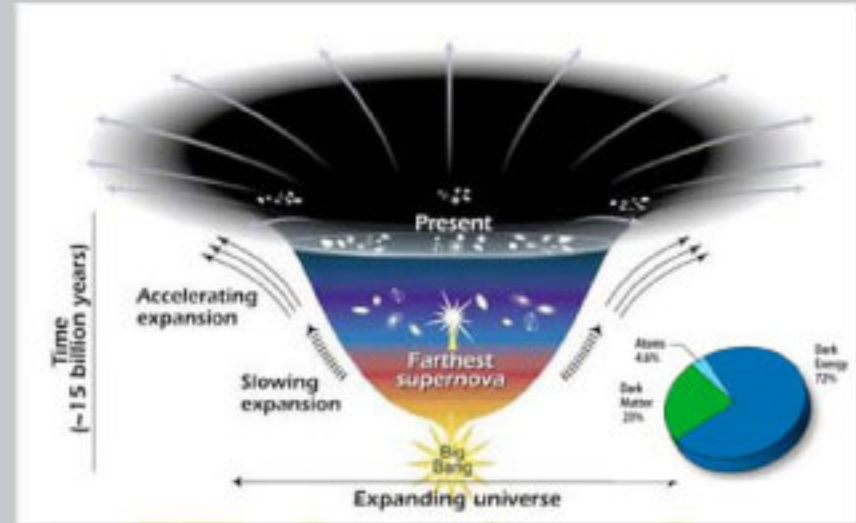


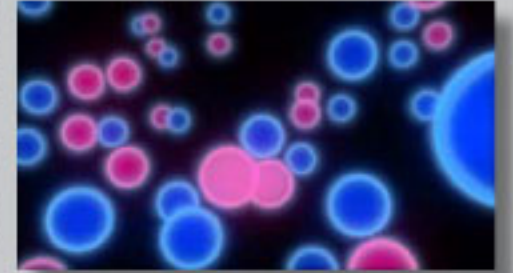
Illustration: NASA/STS/Olm Feld, Fred Hecht, NASA/WMAP Science Team

This diagram shows how the universe's expansion rate has changed over the past 13.7 billion years. The curve changes noticeably about 5 billion years ago, when cosmic expansion began to accelerate. Scientists attribute the accelerated expansion to dark energy, but they don't know what dark energy actually is.

Perhaps more important, **dark energy controls the fate of the universe.** In some theories, dark energy will cause the universe to accelerate forever, eventually spreading out galaxies so thinly that our cosmos will be a dark, cold, and lonely realm. In other theories, dark energy could reverse its properties in the distant future, causing the universe to collapse back upon itself in a "big crunch."

# what COULD DARK ENERGY BE?

Unlike some mysteries, where nobody has any idea how to solve it, the problem with dark energy is that scientists have developed too many possible solutions. It's possible that one of their ideas is correct, but so far the scientific community has not settled on a single explanation. Here are four of the leading contenders:



This illustration depicts the simmering quantum vacuum where particles and antiparticles pop in and out of existence, living on borrowed time and borrowed energy.

- 1 The Energy of Empty Space**  
Scientists have known for decades that even supposedly "empty" space could have energy. The energy contained in this vacuum, known as the cosmological constant, could be providing the oomph that is pushing galaxies apart from one another at an ever-faster rate.
- 2 Modified Gravity**  
Our theory of gravity, based on the laws of Newton and Einstein, is very well tested on the scale of the solar system. But perhaps over very large distances, such as those across the cosmos, our understanding breaks down. A new law of gravity may naturally explain why cosmic expansion is speeding up.
- 3 A Dynamical Energy Field**  
Some theorists think that an invisible energy field known as quintessence pervades our universe, and that the nature of this field varies with time. At the moment, quintessence is causing cosmic acceleration. But in the future, it may reverse itself, leading to a big crunch.
- 4 Extra Dimensions**  
The influence of unseen extra dimensions of the universe predicted by superstring theory.