# Mapping the Universe

## Unravel the mysteries of dark matter

Quick read
The largest sky survey ever has unveiled dark energy and dark matter. These galactic phenomena make up 96 percent of the universe, and are leading scientists to question long-held beliefs such as Einstein’s theory of relativity.

Los Alamos, a world leader in computing since the beginning of the digital revolution is mounting a major initiative to help unravel the mysteries of dark matter and dark energy, producing the largest sky survey ever.

For most of the 20th century, everything that cosmologists observed in the heavens confirmed the laws of physics we know on Earth. But that’s about to change.

Starting with early observations of galaxy clusters, evidence has accumulated to suggest that the matter in planets, stars, and interstellar gas—ordinary matter made of neutrons, protons, and electrons—is but a small fraction of the matter in the universe. Most of it appears to be cold and dark, to have no electric charge (making it unable to emit or absorb light), and to collide so infrequently with other matter that it never heats up or cools down. This dark matter is invisible to us, but Newton's laws tell us that it must exist to provide the gravitational force that keeps the fastest stars confined within our own galaxy and the fastest galaxies bound into giant clusters.

In 1998, the search for distant supernovae (exploding stars) revealed that the overall expansion of the universe, which began about 14 billion years ago, is not slowing down as it should under the braking power of gravity.

Instead, the expansion appears to be accelerating under the influence of a mysterious force, dubbed dark energy. Over the past eight years, the evidence for dark energy has finally turned the world of physics on its ear. Computer simulations of the dark matter universe, when compared with the latest maps of luminous matter and the latest maps of the cosmic microwave background (the radiation left over from the early universe), indicate that the universe contains an astonishing 74 percent dark energy, 22 percent dark matter, and only 4 percent ordinary matter.

"This is a very stimulating time for physics. Fully 96 percent of the universe seems to be composed of stuff we've never seen directly on Earth!" says Emil Mottola, Los Alamos theorist, who has his own model of dark energy.

Los Alamos National Laboratory is collaborating in a multi-billion-dollar exploration of the deep universe. If they can discover the true nature of dark energy, they will find out whether Einstein's theory of general relativity, the description of the expanding universe that has held for 75 years, needs to be changed in some fundamental way.

Success will depend on coordinating theory, computation, and the many types of observation planned for the future. Lab Director Mike Anastasio has named the problem a Grand Challenge for Los Alamos and the Laboratory is assisting with the Sloan Digital Sky Survey at the Sloan telescope in southern New Mexico.

Dedicated to mapping the universe, the Sloan survey has imaged more than 200 million celestial objects, and its researchers have seen back in time to when the universe was about 5 billion years old and only two-thirds of its present size. The Sloan 2.5-meter-diameter digital telescope records continuously through the night, recording images of a narrow strip of sky the width of the moon as the Earth turns on its axis. The strips are then laid side by side to give a contiguous view of the quarter of the sky visible to the telescope.

Powerful computing capabilities, developed to simulate the performance of nuclear weapons in the U.S. stockpile, can be applied to the problem of simulating the cosmos. "We are also developing a unique statistical approach to minimize uncertainties in the predictions drawn from computer simulations," says Los Alamos scientist Katrin Heitmann. "It allows us to get more accurate results with many fewer simulations and to interpolate to new models of what the universe might look like."
Los Alamos is importing tens of terabytes of imaging and spectroscopic data—the entire Sloan Digital Sky Survey—with the goal of investigating gravitational lenses. A strong lens is a large mass concentration (presumably dominated by a dark matter halo) somewhere along the line of sight between the observer and a distant source that produces multiple images of the same object. Los Alamos scientist Przemek Wozniak is developing a high-speed program specially designed to search for the characteristic signature of multiple images of quasars lensed by galaxy cores to solve the evolution of the universe.
These are heady times in physics, with the biggest questions of all—what is the universe made of and how did it get here—being asked once again.

## The Sloan Digital Sky Survey

The Sloan Digital Sky Survey Telescope  Credit: SDSS Team, Fermilab Visual Media Services

The Sloan Digital Sky Survey (SDSS) is one of the most ambitious, influential surveys in the history of astronomy. Over eight years of operations, SDSS has obtained deep, multi-color images covering more than a quarter of the sky and created three-dimensional maps containing more than 930,000 galaxies and more than 120,000 quasars.
SDSS data have supported fundamental work across an extraordinary range of astronomical disciplines, including the properties of galaxies, the evolution of quasars, the structure and stellar populations of the Milky Way, the dwarf galaxy companions of the Milky Way, asteroids and other small bodies in the solar system, and the large-scale structure and matter and energy contents of the universe.

With its many spiral arms and a bar structure in the center, NGC 5162 resides in the constellation Virgo. Credit: Sloan Digital Sky Survey

An enormous range of scientific investigations by astronomers around the world have been supported by SDSS data, and many discoveries have been made. And, since the final SDSS data sets are only now being analyzed, the list of scientific highlights continues to grow.
The latest phase of SDSS observations involves a program of four new surveys using SDSS facilities, including those used by Los Alamos National Laboratory researchers. These efforts began in July 2008 and will continue through 2014.
Interested in more information about LANL's role in SDSS?
Contact Salman Habib, habib@lanl.gov,
505-667-5265.

## About Our Capabilities, Facilities, and Staff

"Los Alamos National Laboratory plays an indispensable role in building America as a science and technology powerhouse, and our staff are an incredible resource to the nation and the world." Michael Anastasio, Dir.

Solving Complex R&D Problems with Special Blend of Staff, Capabilities and Facilities
Now in its seventh decade, LANL is one of the few laboratories that can bring great breadth of fundamental and discovery science, technology, and engineering rapidly together to create tangible solutions for national security needs.
Our staff, working with partners throughout science and industry, must be able to deliver today's solutions while maintaining the depth of capabilities to deliver the next generation of discoveries.
Los Alamos has demonstrated a cycle of innovation where we have developed world-leading capabilities and facilities in response to urgent, unique missions. Our new discoveries continue to responde to emerging missions.

Being able to integrate and apply our capabilities rapidly to new challenges will be a key advantage in an increasingly competitive landscape.

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Campus for 2020 (consistent with complex transformation)
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Signature facilities