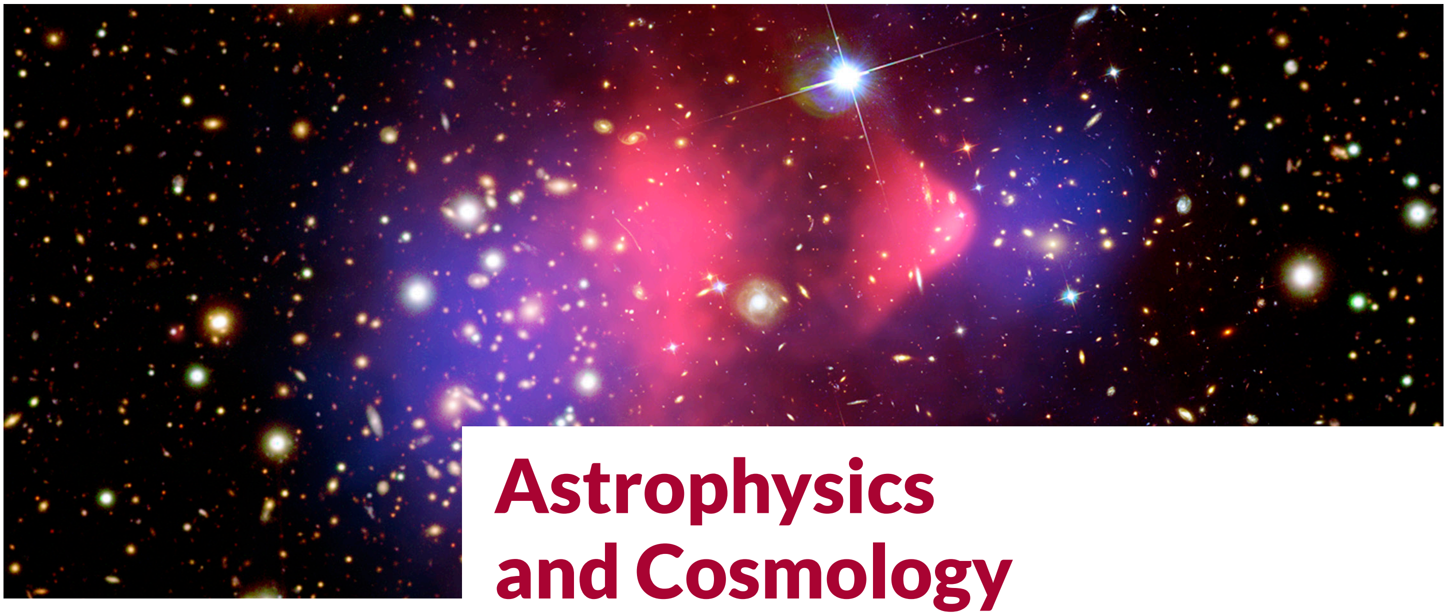


Astrophysics and Cosmology

slac.stanford.edu

To explore the birth of the universe, the formation of stars and galaxies and the fundamental structure of space and time, SLAC researchers develop cutting-edge technologies for sensitive experiments located deep underground, on the Earth's surface and in space.

Top National Priorities

SLAC's astrophysicists and cosmologists pursue research in areas identified as top priorities for U.S. high-energy physics for the next decade. They want to understand our universe – from its smallest constituents to its largest structures. Several of these research topics are also covered by SLAC's particle physics program.

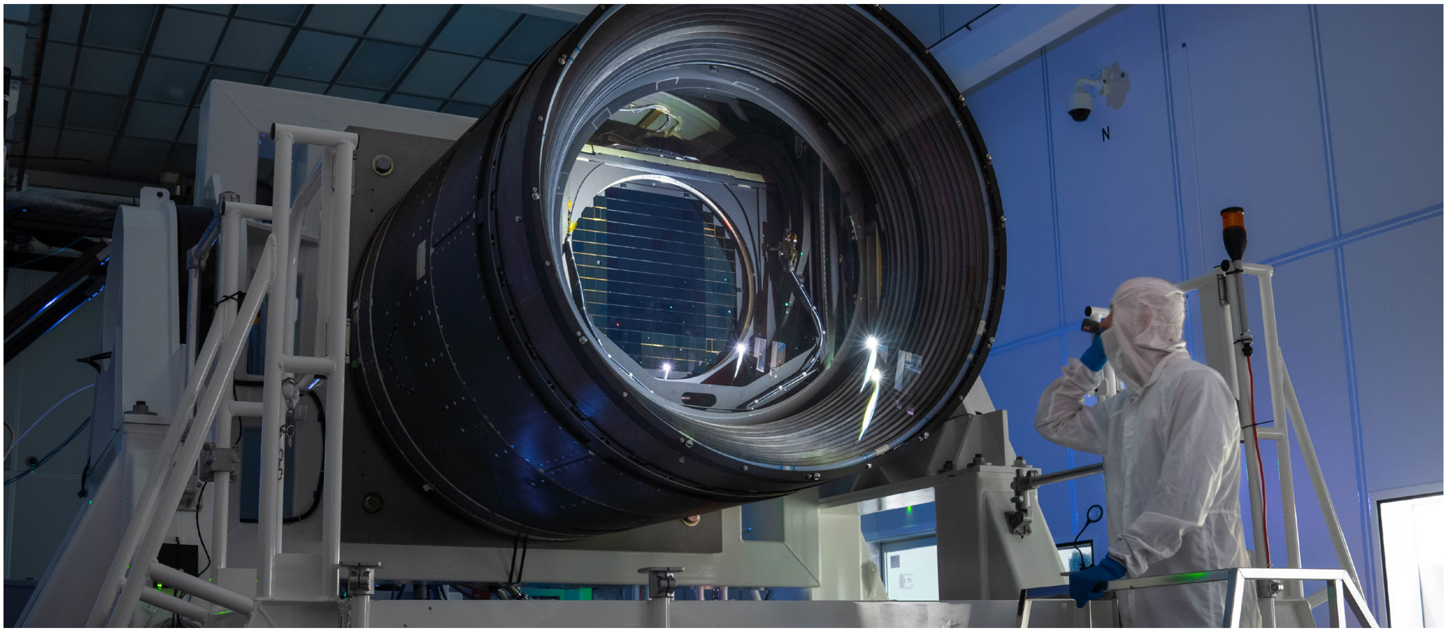
A team at KIPAC put together a prototype of the LUX-ZEPLIN (LZ) dark matter experiment. (Dawn Harmer/SLAC National Accelerator Laboratory)

The Early Universe

Our universe was born 14 billion years ago in the Big Bang and has been expanding ever since. But what exactly happened in those very first moments? Many researchers believe that the infant universe underwent a period of exponential growth, or inflation, when the cosmos was only a trillionth of a trillionth of a trillionth of a second old. Scientists search for signs of inflation in the oldest observable light, which covers today's sky as faint microwave radiation known as the cosmic microwave background (CMB). SLAC researchers are helping to develop next-generation detectors for the CMB-S4 experiment, which will probe inflation's fingerprints in greater detail than ever before.

Dark Matter

One of the biggest mysteries of modern science is dark matter – an invisible form of matter that affects the rotation of galaxies and bends the path of light. Scientists don't know yet what dark matter is made of, but they carry out a number of experiments to find out more. SLAC researchers helped build the LUX-ZEPLIN experiment, which sits deep underground at the Sanford Underground Research Facility in South Dakota and produced its first, world-leading results in 2023. SLAC designed and built the detectors for the underground SuperCDMS-SNOLAB experiment and are pursuing new directions as well, including developing quantum sensors to detect light dark



The 3.2-gigapixel Legacy Survey of Space and Time (LSST) Camera. The camera, built at SLAC, is the size of a small car and weigh more than 3 tons. (Olivier Bonin/ SLAC National Accelerator Laboratory)

matter particles. SLAC researchers also continue to analyze data from the Fermi Gamma-ray Space Telescope, whose main instrument was assembled at SLAC, and are developing new ways to probe dark matter with cosmic surveys.

Dark Energy

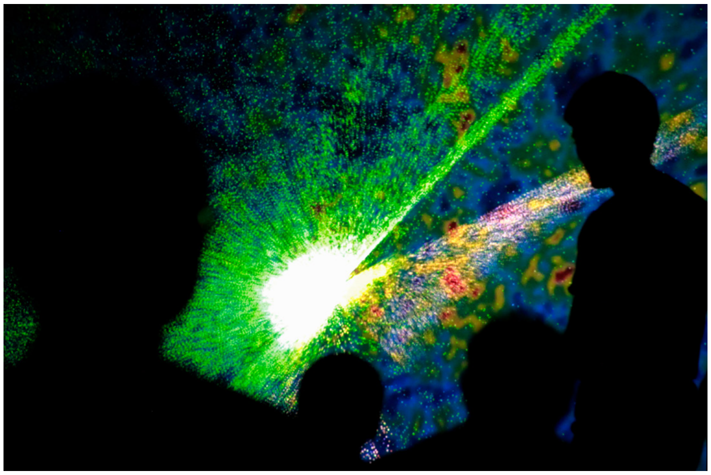
In the late 1990s researchers discovered that instead of slowing down as previously believed, the universe is actually expanding at an ever-increasing rate. But what causes this acceleration, whose unknown driving force is dubbed “dark energy”? Scientists study dark energy by looking at how the distribution of galaxies changes the farther they are out in the universe. This is done in deep astronomical surveys that photograph large portions of the sky in unparalleled detail.

SLAC is taking part in the recently completed Dark Energy Survey (DES), the ongoing Dark Energy Spectroscopic Instrument (DESI) survey, and is completing Vera C. Rubin Observatory’s 3.2-gigapixel Legacy Survey of Space and Time Camera (LSST), which will being taking data in 2025. SLAC will also host the image processing center for the 10-year LSST survey; 20 terabytes of images will be sent to SLAC from Chile each night and analyzed in real time to identify changes in the sky, from asteroids to distant exploding stars.

Putting It All Together: Cosmic Evolution

At the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), researchers from SLAC and Stanford bring the resources of modern computational, observational and theoretical science to bear on our understanding of the universe. They develop theories for the evolution of the cosmos – from the Big Bang to the formation of the first stars and galaxies to the complex structures we observe today – and test them against a wealth of experimental and observational data.

At KIPAC’s Visualization Lab, scientists turn this information into stunningly beautiful full-color, high-definition 3-D videos that help researchers understand their data and inspire and educate the public at planetarium shows.



Left column: A computer simulation visualizes the filaments of dark matter thought to underpin the Universe’s structure of galaxies and galaxy clusters. Visualization by Ralf Kaehler, Oliver Hahn and Tom Abel (KIPAC). Above: Audiences watch a 3-D movie at KIPAC’s Visualization Lab.