Revealing the Secrets of the Dark Universe

US EXTREMELY LARGE TELESCOPE PROGRAM

TMT THIRTY METER TELESCOPE

NOIRLab

GIANT MAGELLAN TELESCOPE

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The US Extremely Large Telescope Program (US-ELTP) is a joint endeavor of NSF NOIRLab, the US national center for optical astronomy, and the organizations building two of the next generation of extremely large telescopes, the Giant Magellan Telescope and the Thirty Meter Telescope. This collaboration will lead to revolutionary astronomical discoveries and provide full-sky access to all US astronomers.

The US-ELTP will provide powerful new capabilities to explore some of the fundamental questions about the nature of the Universe.

The matter we think of as "normal" — like the matter that makes up atoms — only accounts for 5% of the matter in the Universe. The rest of the Universe is composed of two mysterious components that we cannot yet explain: dark matter and dark energy.

What Is Dark Matter?
Dark matter, making up about 27% of the Universe, has mass but doesn't give off or reflect detectable light because it does not interact with photons. We can't "see" dark matter, but we can infer its presence through its gravitational influence on the "normal matter" that makes up stars by noting how they move and evolve in the Universe.

What Is Dark Energy?
The remaining 68% of the Universe is dark energy, a phenomenon that causes the Universe to expand at an accelerating rate over time. While the accelerating cosmic expansion is well established by multiple observations, the physical nature of dark energy itself is unknown.

The US-ELTP and the Dark Universe
Observations using the cutting-edge technology of the two US-ELTP telescopes will offer new insights into fundamental properties of dark matter and enable unique measurements of cosmic expansion, unveiling the true nature of dark energy.

Halos of dark matter surrounding galaxies and galaxy clusters provide ideal environments for exploring the nature of dark matter. The existence of these dark halos is evident in the motions of galactic stars and gas, as well as through **gravitational lensing**. This light distortion can magnify background sources and reveal the mass and structure of the "lens" itself, such as a dark matter halo lensing a more distant galaxy.

The gravitational lensing effect can also be used to study dark matter in the smallest galaxies — called **dwarf galaxies.** These galaxies have just enough normal matter in the form of stars that we can see them, but much less than normal galaxies. That means the motion of their stars is dominated by the gravitational influence of dark matter. The sensitivity, resolution, and full-sky coverage of the US-ELTP will allow astronomers to detect the minute three-dimensional motions of stars in dwarf galaxies, allowing them to develop a detailed picture of the distribution of dark matter within these galaxies. That distribution will allow astronomers to understand the nature of dark matter. The sensitivity of the telescopes will also help in finding new dwarf galaxies to study.

In addition to studying dark matter, the US-ELTP will provide multiple new strategies for measuring the expansion rate of the Universe to better understand the nature of dark energy. **Type Ia supernovae** are stellar explosions with a uniform intrinsic brightness no matter where they are observed in the Universe. By comparing their intrinsic brightnesses to their apparent brightnesses,

we can measure supernovae distances, while their spectra can tell us how fast they are moving away from us. In this way, Type Ia supernovae are like "signposts" that help determine the expansion rate at different locations in the Universe. This technique can be applied to gravitationally lensed supernovae, taking advantage of the lensing magnification to find even more distant signposts. By comparing very precise distance measurements with precise measurements of the expansion rate at those locations, we can better understand the underlying physics of dark energy. The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) will discover more Type Ia Supernovae, about 50 per year. Additional new supernovae will come from the large-area surveys of the Euclid and Roman Space Telescopes as well. Studying these new supernovae with the US-ELTP telescopes will be critical for measuring both their distance and the expansion rate at those locations.

Vocabulary
Gravitational Lensing — When light from a distant source passes by a massive object, the trajectory of the photons is warped by the concentrated gravitational field of the foreground object, which can therefore act like a lens, magnifying the brightness of the background source.
Dwarf Galaxies — Small galaxies composed of a few billion stars. By comparison, the Milky Way contains hundreds of billions of stars.
Type Ia Supernova — A well-understood type of stellar explosion that results from a binary star system in which one of the stars is a white dwarf that accretes mass from its companion until it becomes structurally unstable.

About the Images

Front: An image taken with the Dark Energy Camera of the Coma Cluster, a rich group of thousands of galaxies and gas, estimated to contain 90% of dark matter. The Coma Cluster played a major role in providing observational evidence of dark matter. In 1933, astronomer Fritz Zwicky observed that the galaxies in the cluster were moving too fast to be gravitationally bound together by visible matter.*Credit: CTIO/NOIRLab/DOE/NSF/AURA*

Back: An artist's impression of a dark matter halo surrounding a galaxy causing gravitational lensing that distorts the light from background galaxies. Gravitational lensing provides a tool for studying the distribution of both visible and dark matter. *Credit: NOIRLab/NSF/AURA/P. Marenfeld*

For more information, visit us at useltp.org

For classroom activities associated with this lithograph, explore the *Gravitational Lensing* activity featured as part of NOIRLab's *Teen Astronomy Café — To Go!* program and the *Expanding Universe* or *Exploding Stars* investigations featured as part of *Rubin Observatory's* education program.