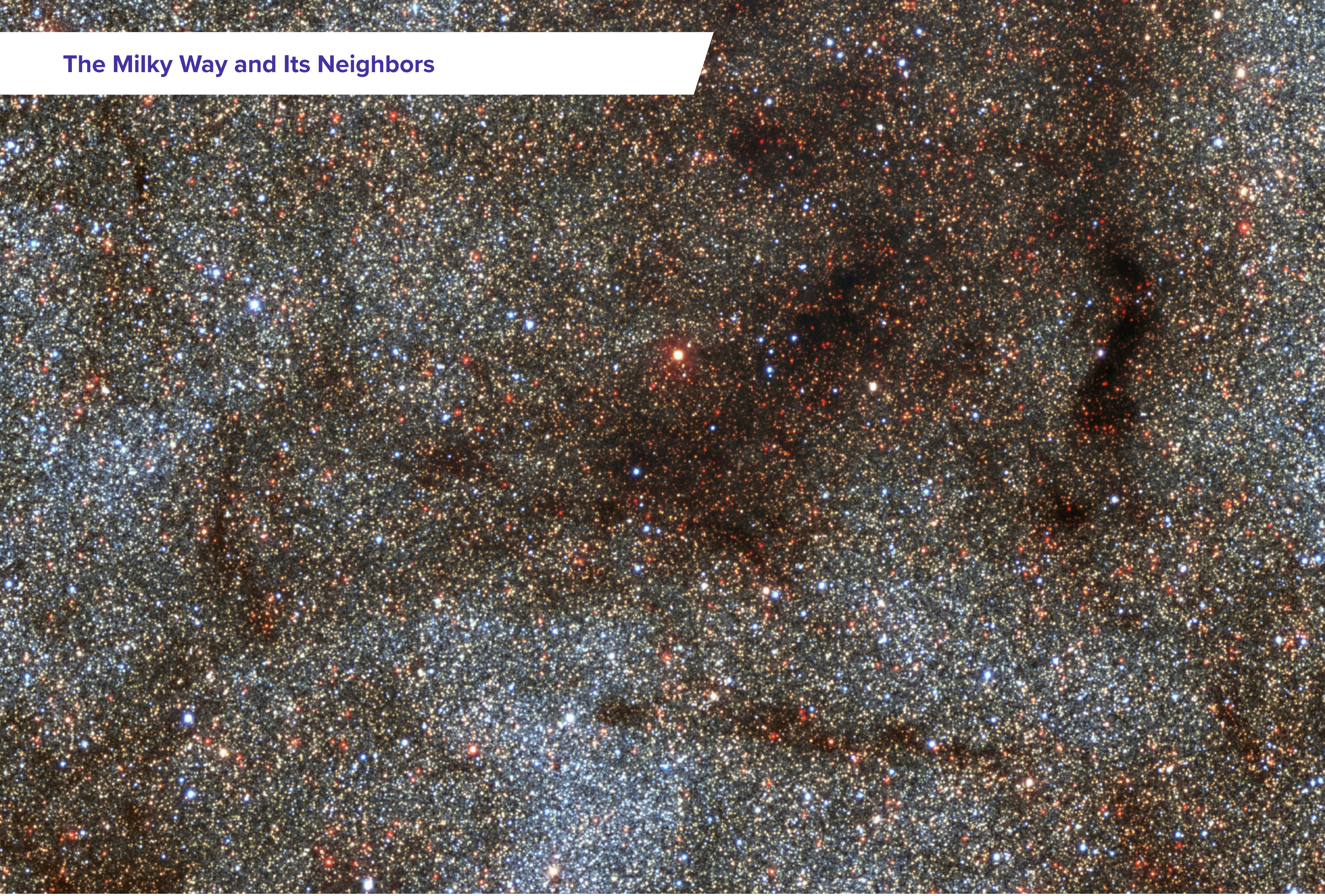
The Milky Way and Its Neighbors

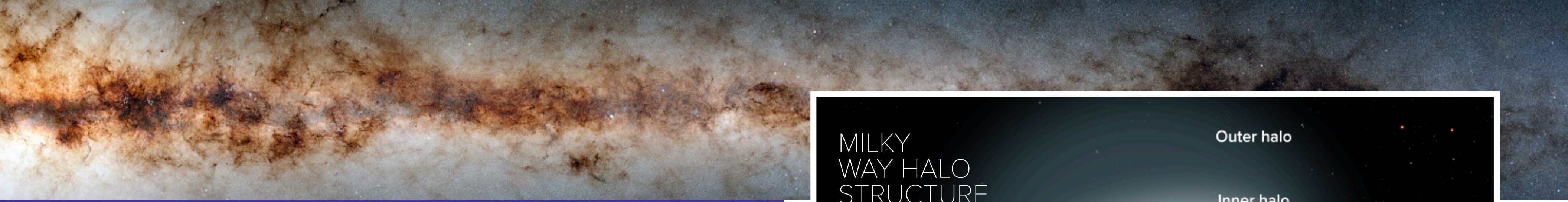


US EXTREMELY LARGE TELESCOPE PROGRAM

TMT THIRTY METER TELESCOPE

NOIR Lab

GIANT MAGELLAN TELESCOPE



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The US Extremely Large Telescope Program (US-ELTP) is a joint endeavor of NSF's 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 help answer profound questions about the structure and evolution of our galaxy, the Milky Way, and its place in the Universe. The wide field of view, high sensitivity, and high resolution of these two extremely large telescopes will enable detailed observations of the faintest stars within our galaxy. These stars are critical to our understanding of the formation of galaxies within our **Local Group** and their evolution over time.

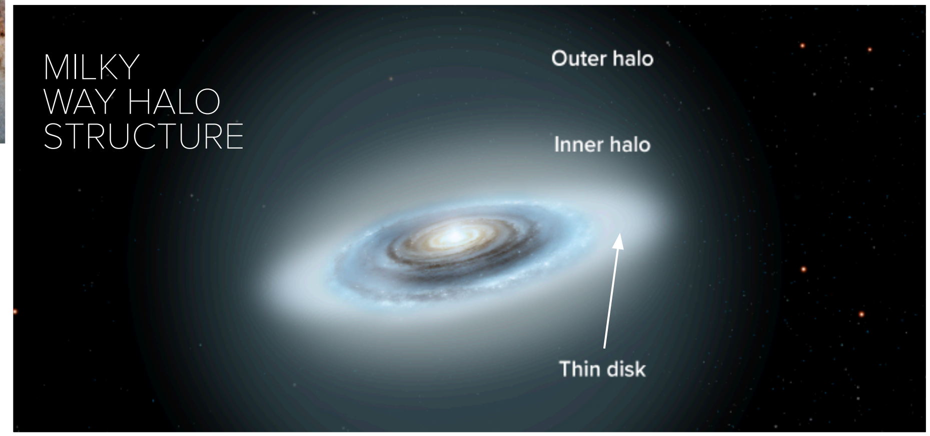
Chemical Evolution of Stars and Galaxies

Determining the detailed chemical composition of the oldest stars in the Milky Way will lead to a better understanding of how stars and galaxies formed in the early Universe. Following the Big Bang, the Universe was composed mainly of hydrogen, a bit of helium, and traces of lithium. As stars began to form and evolve, heavier elements were produced by fusion within their cores. When their fuel for fusion was exhausted, some of the stars produced supernova explosions, dispersing the heavier elements they had created into the surrounding space. The dispersed elements served as seeds, or building blocks, for the next generation of stars. In this way, each generation of stars begins its life from a richer pool of elements than the previous generation. In general, stars that formed later contain more heavier elements than those that were born earlier. Some of the oldest stars in the Milky Way are found in its halo and were formed from the unenriched gas of the early Universe, unpolluted by heavy elements. Further study of these distant and faint stars will shed light on our galaxy's origins.

Stars that contain a small fraction of heavy elements are difficult to study in detail because they tend to be faint and their shortage of heavy elements makes it difficult to measure the tiny bit they do contain. US-ELTP instruments capable of precise, high-resolution **spectroscopy** will be able to make these crucial measurements, taking advantage of the large **apertures** of the extremely large telescopes that vastly increase the detectability of these stars beyond what we can observe today. For example, the Giant Magellan Telescope Consortium Large Earth Finder (G-CLEF) and the Thirty Meter Telescope's planned High-Resolution Optical Spectrometer, HROS, will obtain spectra that enable the detailed chemical analyses of many such stars within the Local Group to provide insight into the initial conditions of star formation and the chemical evolution of the Universe.

Structure of the Milky Way

Living within the Milky Way provides a close-up view of its contents while simultaneously posing a challenge for gathering a complete picture of its structure. Both US-ELTP telescopes will be capable of high sensitivity, multi-object spectroscopy as provided by the Thirty Meter Telescope's Wide-Field Optical Spectrometer (WFOS) and the Giant Magellan Telescope's Multi-object Astronomical and Cosmological Spectrograph (GMACS). These instruments will allow astronomers to classify stars in the outer regions of the Milky Way by their spectra and to determine their



distances, a crucial step in understanding the structure and formation history of the Milky Way. WFOS and GMACS will measure **radial velocities** to calculate the three-dimensional motion of stars to better characterize the shape of the halo and define the total mass of the Milky Way.

Motions within the Local Group

The Local Group has been used as a laboratory for studying many aspects of the history of the Universe. A better understanding of the motions of stars and gas within the Local Group will provide a more detailed picture of the interactions driving galaxy evolution. The resolution that can be achieved by the spectrographs of the US-ELTP telescopes will enable the analysis of the orbital characteristics of all the members of the Local Group. Studies of these motions combined with insight into the chemical composition of the earliest stars will lead to a greater understanding of the formation, evolution, and future of the Local Group.

Vocabulary

Local Group — A cluster of galaxies that includes the Milky Way and other nearby galaxies including Andromeda and the Large and Small Magellanic Clouds
Spectroscopy — The analysis of light emitted, absorbed, or scattered by celestial objects to better understand their composition, temperature, and motion
Aperture — The diameter of the light-collecting mirror of an optical telescope
Radial Velocity — The motion of a star toward or away from an observer

About the Images

Front: This image of a region near the center of the Milky Way galaxy covers 0.5 by 0.25 degrees on the sky (an area about as wide as the full Moon) and reveals over 180,000 stars that are detectable at this depth and wavelength. The image captures a portion of our Milky Way 220 by 110 light-years across. It was taken with the Dark Energy Camera on the Víctor M. Blanco 4-meter Telescope at Cerro Tololo Inter-American Observatory in Chile, a Program of NSF's NOIRLab. *Credit: CTIO/NOIRLab/DOE/NSF/AURA/STScI, W. Clarkson (UM-Dearborn), C. Johnson (STScI), and M. Rich (UCLA)*

Back top: An image of the galactic plane of the Milky Way from the Dark Energy Camera's (DECam) galactic plane survey of a staggering 3.32 billion celestial objects. The DECam was built by the US Department of Energy and operates at Cerro Tololo Inter-American Observatory in Chile, a Program of NSF's NOIRLab. *Credit: DECaPS2/DOE/FNAL/DECam/CTIO/NOIRLab/NSF/AURA*

Back right: An artist's impression of the Milky Way's structure. The halo is a spherical cloud of stars surrounding the overall galaxy. Inner halo stars are closer to the core of the galaxy, whereas outer halo stars extend farther away and tend to be among the oldest in the galaxy. The thin galactic disk is a flattened region made of stars, dust, and gas. *Credit: NOIRLab/AURA/NSF/P. Marenfeld*

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