The Search for Life Beyond Earth

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'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.

Are we alone in the Universe? This question drives astronomers in the hunt for signs of life on planets orbiting distant stars throughout the Galaxy. Investigating the potential for life on other planets goes beyond understanding the formation and origin of our Solar System: it includes studying the formation of planets around other stars and the conditions necessary for hosting life. The US-ELTP's Thirty Meter Telescope and the Giant Magellan Telescope will have advanced capabilities to enable the detection of Earth-size exoplanets in the **habitable zones** around nearby stars and allow astronomers to study their atmospheric compositions in search of **biosignatures** that could suggest a planet is not only **habitable** but also *inhabited*.

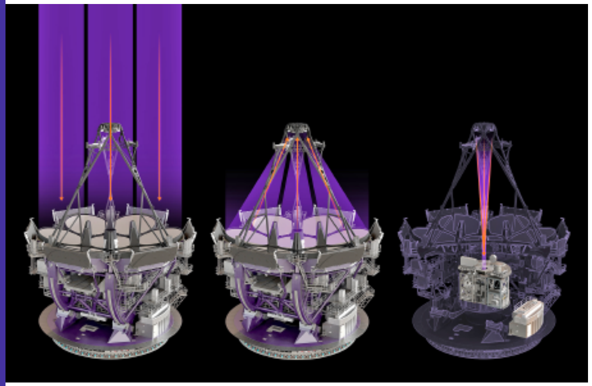
Detecting Exoplanets

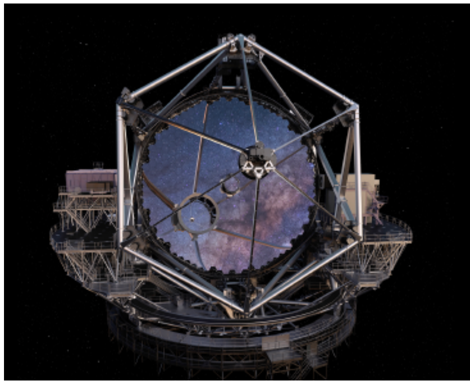
Exoplanets tend to be much fainter than their host stars, making them extremely difficult to detect. The US-ELTP telescopes will use a variety of techniques to discover exoplanets, including high-precision radial velocity measurements and direct imaging. The radial velocity method relies on detecting a change in the host star's velocity caused by the gravitational pull of orbiting planets. This wobble causes the wavelengths of the star's light to alternately become slightly shorter and longer as the star's velocity varies around its planet-induced orbit. Precision instruments capable of detecting these variations, such as the Giant Magellan Telescope's Large Earth Finder (G-CLEF) and the Thirty Meter Telescope's Multi-Objective Diffraction-limited High-resolution Infrared Spectrograph (MODHIS) will enable the radial velocity measurements to detect and characterize Earth-like planets around Sun-like stars within the Milky Way.

The powerful direct-imaging capabilities of the US-ELTP telescopes will allow astronomers to detect exoplanets in the habitable zones around small and faint stars. Direct imaging reveals exoplanets directly by isolating the light of the planet from the otherwise obscuring glare of the host star. Telescopes and instruments involved in direct imaging must have optic capabilities and very fine spatial resolution to be able to separate the planet from its relatively nearby host star. Working in the infrared, where planets are brighter and stars are typically dimmer than in the optical, is also an important factor. Direct imaging is particularly powerful for studying young planets, planets on wide orbits, and non-transiting planets (planets that don't cross the line of sight between us and the host star). Three US-ELTP instruments will enable direct imaging. The Thirty Meter Telescope's Infrared Imaging Spectrograph (IRIS) and planned future Planetary Systems Imager (PSI) will have an angular resolution more than 12 times better than that seen in images from the *Hubble Space Telescope*. Moreover, the Giant Magellan Telescope's extreme Adaptive Optics system (GMagAO-X) will have a resolution of almost 11 times better.

Studying Exoplanet Atmospheres

To understand the conditions for habitability, it is crucial to explore the atmospheres of planets discovered within their habitable zones. One technique the extremely large telescopes will use is called transmission spectroscopy. As an exoplanet transits or moves in front of its host star, starlight will pass through the exoplanet's atmosphere and offer a fingerprint, revealing information about its chemical composition. The Giant Magellan Telescope Near-Infrared Spectrograph (GMTNIRS), G-CLEF, and the Thirty Meter Telescope's Wide Field Optical Spectrograph (WFOS) will use





transmission spectroscopy to measure the atmospheric composition of exoplanets and determine whether biosignatures such as oxygen are present.

With the power of direct imaging minimizing the light of the host star, the spectrum of an exoplanet can be studied in even more detail. This technique is called direct spectroscopy. The Thirty Meter Telescope's MODHIS instrument will use direct and transmission spectroscopy to study the composition and physical characteristics of nearby Earth-like planets while searching for biosignatures from those spectra that could indicate the presence of life.

The unique combination of the very large collecting areas, high-resolution spectroscopy, and adaptive optics of the US-ELTP telescopes will complement exoplanet studies from space with *JWST*, *TESS*, and *PLATO* and will build upon current state-of-the-art exoplanet spectrographs such as MAROON-X and NEID.

Vocabulary

Habitable Zone — The annular orbital region in which a planet must orbit its host star for liquid water to exist and persist on its surface
Habitable Planet — A planet that is able to develop and maintain environments suitable for life to develop
Biosignatures — Measurements that indicate biological activity

About the Images

Front: An artist's impression of space viewed from the surface of an exoplanet. The Thirty Meter Telescope and the Giant Magellan Telescope will be able to find Earth-like planets and search for signs of life. *Credit: NOIRLab/NSF/AURA/P. Marenfeld*

Back left: An illustration showing the path that light will follow from the Giant Magellan Telescope's main aperture, to the secondary mirrors, to the prime focus, and then down to the instruments such as the highlighted G-CLEF. This instrument will measure the masses of Earth-like planets outside of our Solar System and search for biosignatures, such as oxygen, in their atmospheres. *Credit: GMTO Corporation*

Back right: An artistic digital rendering of the Thirty Meter Telescope showing the main telescope and the instruments, located on the two side platforms, that will be used to discover and characterize exoplanets and search for signs of life. Left side: The NFIRAOS adaptive optics system that feeds the sharpest possible images to the IRIS and MODHIS instruments. Right side: The WFOS instrument that will be used to characterize exoplanet atmospheres and search for biosignatures. *Credit: TMT International Observatory*

For more information, visit us at useltp.org

For a classroom activity associated with this lithograph, explore the *Exoplanet Atmospheres* activity featured as part of NSF's NOIRLab's *Teen Astronomy Café — To Go!* program at *https://noirlab.edu/tac-togo/*.