*Ultra Deep Field: Photo courtesy of HubbleSite*

## The Early Universe

**13 – 13.7 billion light-years**

TMT will allow astronomers to directly explore the early Universe, from the end of the cosmic dark ages through the formation of the first stars and reionization and into the epoch of galaxy formation. The signatures of the chemically unevolved Population III sources and studies of the resulting chemical enrichment of the young Universe are within reach of the TMT. The epoch of first assembly of matter and stars into proto-galaxies, the first appearance of quasars and the processes of reionization of the intergalactic medium will be observable by the TMT.

TMT also will make important contributions to the study of dark energy by pushing supernovae observations to the highest possible redshifts and measuring the dark energy density as a function of cosmic time.

*Cluster of Diverse Galaxies: Photocourtesy of HubbleSite*

## Distant Galaxies and Clusters

**500 million – 12.5 billion light-years**

In recent years, the important interplay between galaxy evolution and the formation and growth of central black holes has been uncovered. Researchers will be able to use TMT to study supermassive black holes (SMBH) across the entire Hubble sequence and study their demography as a function of environment. TMT observations will also extend dynamical measurements of massive black holes to $z \sim 0.4$ and SMBHs throughout the Universe. TMT is a near-ideal facility to delve deep into the processes that govern galaxy formation and evolution. There are many outstanding questions: Is star formation inherently different in the distant Universe compared to locally? How do galaxies acquire their gas, and how much exchange is there between galaxies and the intergalactic medium? How do energetic processes influence galaxy formation? How does the distribution of dark matter relate to the luminous stars and gas we see?

*Infant Stars in the Small Magellanic Cloud: Photo courtesy of HubbleSite*

## Near-field Cosmology

**10,000 – 500 million light-years**

TMT studies will reveal much about galaxy formation and evolution through observations of the stellar "fossil record." This method has been used to study the stellar content of the Milky Way and other nearby galaxies. With TMT, photometric and spectroscopic studies of resolved stellar populations will be carried out on a larger number of galaxies in the Local Group and beyond, complementing and validating the studies of galaxy formation and evolution at high redshift.

In the last decade, near-infrared observations with first-generation adaptive optics systems on 8- and 10-meter telescopes have revealed exciting details of the Galactic center, including detecting young, massive star clusters and verifying the presence of a supermassive central black hole. The greater sensitivity and spatial resolution of TMT will enable currently unachievable measurements of stellar orbits in the Galactic center. Determining general relativistic effects near a supermassive black hole, placing constraints on dark matter, and understanding star formation in this extreme environment are among the exciting possibilities.

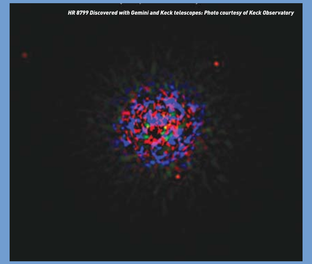
*Star-Forming Region in the Carina Nebula: Photo courtesy of HubbleSite*

## Star and Planet Forming Regions

**500 – 10,000 light-years**

The spatial resolution and sensitivity of TMT will allow individual stars to be resolved even in very crowded fields. In the nearest star-forming regions, mid-IR observations will unveil heavily obscured stars within the densest molecular clouds. This will provide details of the "stellar birthline" in very young clusters and enable studies of the interstellar magnetic field. TMT will also have the spatial resolution to probe the morphologies of protostellar cores as well as highly collimated jets launched from the inner disk. At 10 $\mu$m, TMT will be able to provide images of nearby cores and jets at a resolution of 1.5 AU. At Orion, the equivalent resolution will be ~4.5 AU.

The inner regions of protoplanetary disks are particularly interesting since these are the regions where most planets may form. TMT will be able probe the gaps in protoplanetary disks, revealing the formation of giant planets.



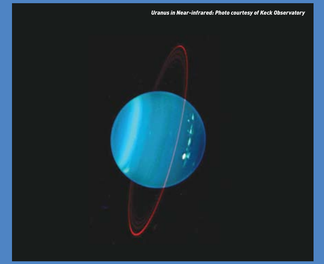
*HR 8799 Discovered with Gemini and Keck telescopes: Photo courtesy of Keck Observatory*

## Exoplanets

**4 – 500 light-years**

Approximately 300 planetary systems have been identified. The vast majority of these have been detected through the periodic motion of the host star due to the gravitational perturbation of orbiting planets. TMT will expand the number of host stars accessible to Doppler spectroscopy by a factor of 30. TMT's hundred-fold increase in sensitivity over current generation telescopes will reduce the necessary observing time for these studies from 1-3 hours to as little as 1.5 minutes.

TMT also will expand the new frontier of directly imaging entire planetary systems. With its large aperture and advanced adaptive optics, TMT will produce images and spectra of Uranus- and Saturn-like planets orbiting nearby stars, image protoplanets forming around young stars, and perhaps even detect the nearest "super-Earth" planets. Current simulations also suggest that TMT would be able to detect the spectral signatures of water, carbon dioxide, and ozone in transiting Earth-like planets. Though not direct biomarkers, these molecules are indicative of planets that could support life.



*Uranus in Near-Infrared: Photo courtesy of Keck Observatory*

## Solar System

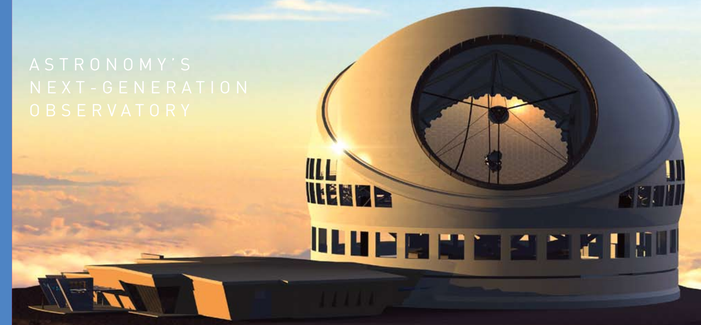
**1 light-year**

TMT will transform our knowledge of the Solar System. With its integrated adaptive optics system, TMT will achieve a resolution of approximately 8 milliarcseconds at a wavelength of 1 $\mu$m, which corresponds to 25 kilometers at the distance of Jupiter. TMT also will be able to obtain spatially resolved spectra to study the atmospheric and surface chemistry of the outer planets and their moons, and monitor these objects for weather, volcanism, and tectonic activity.

Through its unprecedented light-collecting area, TMT will enable new horizons in Kuiper Belt research. These outer reaches contain a vast swarm of small icy bodies that preserve details of the formation of the Solar System and the materials out of which the planets formed. The composition of these bodies is best determined through observations in the near-infrared (1–2.5 $\mu$m) where most important ices have strong absorption features. TMT and its infrared capabilities will provide spectroscopic analysis of potentially thousands of moderately faint Kuiper Belt Objects. Many objects in the one kilometer diameter range will be observable in 15 minutes.

TMT

ASTRONOMY'S
NEXT-GENERATION
OBSERVATORY



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THIRTY METER TELESCOPE

# THIRTY METER TELESCOPE

The Thirty Meter Telescope (TMT) will be the world's most advanced and capable ground-based optical, near-infrared, and mid-infrared observatory. It will integrate the latest innovations in precision control, segmented mirror design, and adaptive optics to correct for the blurring effects of Earth's atmosphere.

The core technology of the TMT will be its 492-segment, 30-meter diameter primary mirror. This remarkable engineering achievement will give the TMT nine times the collecting area of today's largest optical telescopes. It also will enable the TMT to observe objects nine-times fainter than existing 10-meter telescopes in an equal amount of time.

When construction is completed in 2018, the TMT will begin driving new discoveries with other next-generation observatories such as the Atacama Large Millimeter/submillimeter Array and the James Webb Space Telescope.

## QUICK FACTS

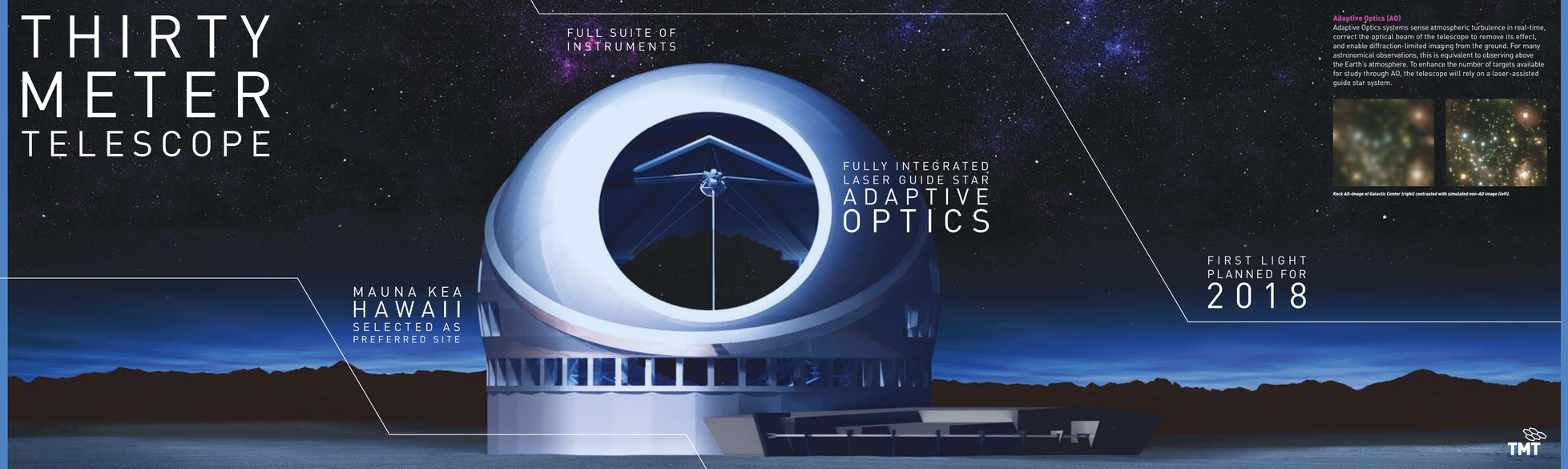
- 30 meter, filled aperture, f1 primary mirror composed of 492, 1.4 meter hexagonal segments
- Wavelength range from the ultraviolet at ~320 nanometers to the mid-infrared at ~30 microns
- Mauna Kea in Hawaii selected as preferred site
- Instruments on large Nasmyth platform, addressed by articulated tertiary mirror
- Rapid acquisition of targets and rapid switching between instruments
- First light instruments include wide-field multi-object spectroscopy from 320 nm to 1 micron, and Adaptive Optics (AO) diffraction-limited imager, integral-field and multi-slit spectroscopy in near-infrared
- Fully integrated Laser Guide Star AO system available at first light
- AO-enabled diffraction-limited angular resolution 3 times better than existing 10-meter telescopes
- Factor of 81 improvement over current generation telescopes in point-source detection with AO
- AO system will have extensive sky coverage, even at the galactic poles

FULL SUITE OF INSTRUMENTS

MAUNA KEA HAWAII SELECTED AS PREFERRED SITE

FULLY INTEGRATED LASER GUIDE STAR ADAPTIVE OPTICS

FIRST LIGHT PLANNED FOR 2018



**Adaptive Optics (AO)**

Adaptive Optics systems sense atmospheric turbulence in real-time, correct the optical beam of the telescope to remove its effect, and enable diffraction-limited imaging from the ground. For many astronomical observations, this is equivalent to observing above the Earth's atmosphere. To enhance the number of targets available for study through AO, the telescope will rely on a laser-assisted guide star system.



*Keck AO-image of Galactic Center (right) contrasted with simulated non-AO image (left).*

**TMT Partner Institutions**

Association of Canadian Universities for Research in Astronomy
California Institute of Technology
University of California

**Collaborating Institution**

National Astronomical Observatory of Japan

**Observer**

National Astronomical Observatories of the Chinese Academy of Sciences

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**TMT Key Science**

- Nature and composition of the Universe
- Formation of the first stars and galaxies
- Evolution of galaxies
- Relationship between black holes and their galaxies
- Formation of stars and planets
- Nature of extra-solar planets
- Presence of life elsewhere in the Universe

**Comprehensive Suite of Adaptive Optics Systems and Instruments**

- Near infrared diffraction-limited Laser Guidestar AO imaging and integral-field spectroscopy
- Near infrared AO-fed multi-slit and high resolution spectroscopy
- Seeing limited, high-resolution spectroscopy and multi-object moderate resolution spectroscopy (0.3–1 $\mu$m)
- Extremely high-contrast (10$^8$ at 1.65 $\mu$m) planet imaging and spectroscopy
- Multiple near infrared integral-field units over a 5 arcminute field of view, with individual AO correction

**Credits**

*Design and typography by SandBox Studio, Chicago; Cover photo-illustration by Todd Mason; Inside photo-illustration by Matthew J. Mew*