TMT～Thirty Meter Telescope

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About TMT

TMT（Thirty Meter Telescope）is an extremely large optical/infrared telescope with an aperture of 30m, whose construction began in the fall of 2014 atop Mauna Kea on the island of Hawaii and is scheduled for completion in 2022. In comparison to the 8.2m Subaru Telescope, one of few telescopes currently at the forefront of astronomical observation, TMT will have 13 times the light-gathering power and 3.6 times the resolving power, enabling it to perform at an unprecedented level of sensitivity. Utilizing this power to its fullest extent, TMT will aim to search for evidence of life on extrasolar planets and to reveal the identity of astronomical objects in the very early universe.

FIGURE1: CONCEPTUAL IMAGE OF THE THIRTY METER TELESCOPE (TMT) (©NAOJ)

TMT Site

The summit of Mauna Kea, the location for the construction of TMT, was selected after years of monitoring conditions for astronomical observation including seeing, clear night ratio and the level of atmospheric water vapor in five candidate sites in Hawaii, Mexico and Chile. In addition to the low water vapor level, excellent seeing and high clear night ratio, the condition for astronomical observation at Mauna Kea in Hawaii is also particularly outstanding for its low atmospheric turbulence in the upper atmosphere, as atmospheric turbulence can significantly affect the performance of Adaptive Optics. Complementarity with other nearby astronomical facilities such as the Subaru Telescope is another merit which finally led to the selection of Mauna Kea as the site for TMT. The site is located at an elevation of 4012m on Mauna Kea and about 1 km northwest from the Subaru Telescope.

There are currently two extremely large telescopes other than TMT that are under construction – the European Extremely Large Telescope (E-ELT; 39 m) of the European Southern Observatory (ESO) and the Giant Magellan Telescope (GMT; 8.4m x 7) collaborated by USA, Korea and Australia. All three projects are aiming to commence observation in the 2020s. While E-ELT and GMT are located in Chile, a country located in the southern hemisphere, TMT is located in Hawaii, which is in the northern hemisphere, making it suitable for observing the northern sky.

TMT Features: Segmented Primary Mirror and Adaptive Optics

In the history of astronomical observation, telescope aperture has continued to grow larger in order to detect fainter objects. 8-meter class primary mirrors such as the ones of the Subaru Telescope are largest for a single mirror aperture. In order to realize an even larger primary mirror, utilizing a segmented primary mirror composed of multiple mirrors instead of a single large primary mirror is more realistic from both technical and operational perspective. The 30m primary mirror of TMT consists of 492 segment mirrors, each of which is hexagonal in shape and 1.44m in length across corners.

FIGURE2: CONCEPTUAL IMAGE OF THE PRIMARY MIRROR OF TMT (COURTESY TMT INTERNATIONAL OBSERVATORY)

The diffraction limit of TMT and its 30m aperture is 0.01-0.02 arcsec in the near-infrared, which is an order of magnitude greater than that of the Hubble Space Telescope. However, observations from ground-based telescopes are affected by atmospheric turbulence that causes stellar images to be blurred. Even from atop the Mauna Kea summit region, an area known for its stable atmospheric conditions, typical seeing size is about 0.6 arcsec with the observed image blurred to a size dozens of times larger than an image captured at the diffraction limit of TMT. Adaptive Optics technology can be used to cancel out atmospheric blurring to produce diffraction limited images similar to those by a space-based observatory. With this technology, aberration in the optical wavefront is measured with a wavefront sensor and corrected with a deformable mirror in real-time. Adaptive optics, combined with a laser guide star system that creates an artificial star image as a reference point for wavefront, is already in use with the current 8 to 10m class telescopes. NFIRAOS, the first-light adaptive optics system for TMT, adopts a further developed AO concept – Multi-Conjugate Adaptive Optics (MCAO). It will utilize six laser guide stars/wavefront sensors and two deformable mirrors to correct atmospheric turbulence near ground and 11 km above ground. This will enable sharp and clear images to be obtained in a wide field of view.

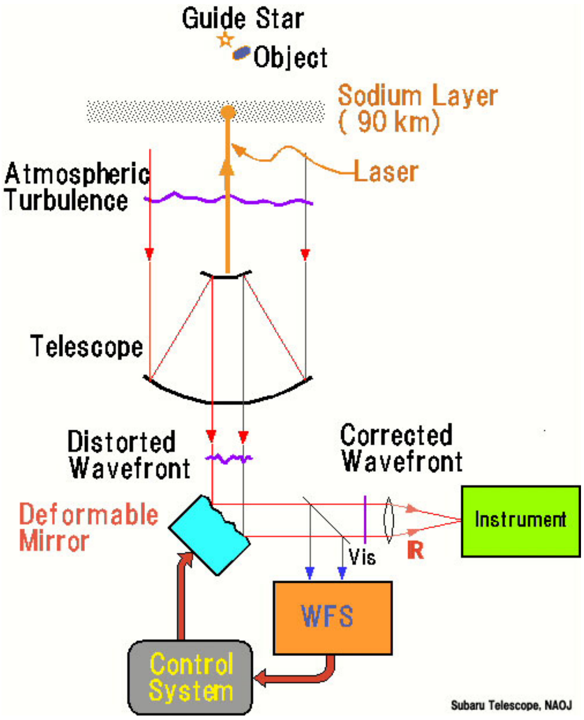

FIGURE3：A SCHEMATIC DIAGRAM OF HOW THE ADAPTIVE OPTICS AND LASER GUIDE STAR SYSTEMS WORK. (©NAOJ)

FIGURE4：AO-IMAGE OF THE GALACTIC CENTER IN INFRARED (RIGHT), CONTRASTED WITH SIMULATED NON-AO IMAGE (LEFT).
（CREDIT:KECK/UCLA GALACTIC CENTER GROUP）

Science case for TMT

TMT will explore the great mysteries of the Universe which are beyond the reach of the current 8 to 10m class telescopes. Here, we introduce two such mysteries.

(1) The first stars and the dawn of the galactic cosmos

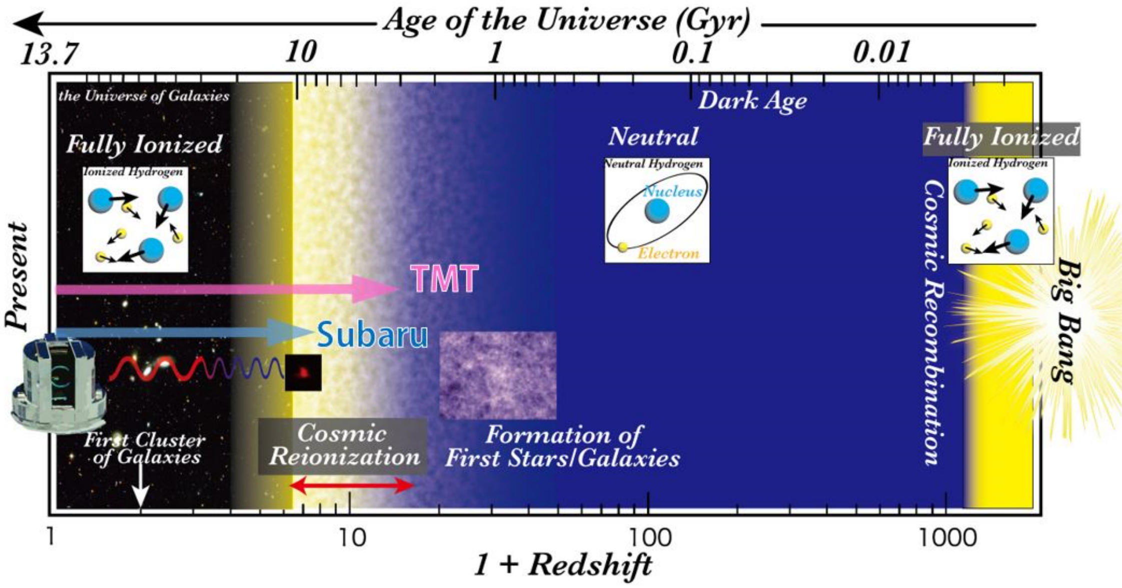

FIGURE5 : COSMIC HISTORY FROM THE BIG BANG TO THE PRESENT (©NAOJ)

It is believed that, until hundreds of millions of years after the birth of the Universe, there were only a few stars and galaxies in the Universe. When and how were the first stars and galaxies born to bring the “cosmic dark age” to a close? The current 8 to 10m class telescopes were successful in discovering galaxies within 700 million years after the Big Bang – a clue to the process of cosmic reionization. TMT will endeavor to observe an even earlier Universe by capturing light from first galaxies and supernova explosion of the first stars. TMT will also uncover the entire history of cosmic reionization by studying objects discovered by the Subaru Telescope in further detail with high-resolution imaging /spectroscopy using adaptive optics.

(2) Search for evidence of life on extrasolar planets

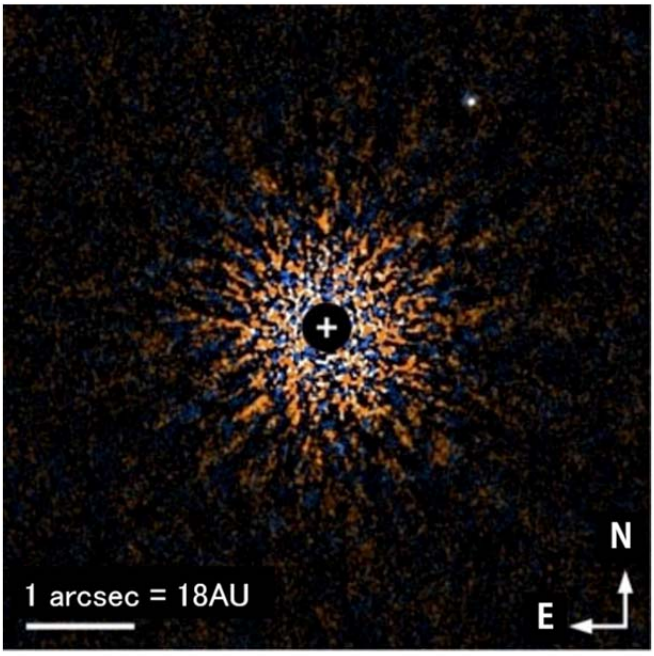

Figure 6 : The least massive exoplanet ever imaged to date, discovered by Subaru Telescope. GJ 504b (upper right) is a Jupiter-size planet whose mass is estimated to be 3 - 5.5 times Jupiter's mass. Coronagraph is used to suppress bright light from the star in the center of the image. (©NAOJ)

Since the first extrasolar planet discovery in 1995, more than 4000 planet candidates have been discovered to date, revealing diversity in planetary systems. Are there any extrasolar planets with existence of life? To answer this question, earthlike planets within the range of distance from a star that would enable water to exist in a liquid state (habitable zone) must be observed. The probability of existence of life is believed to be high if biomarker gasses such as oxygen (i.e., substances which are thought to be formed by vital activity) are detected in the atmosphere of such earthlike planets. To observe the atmospheric composition of earthlike planets, light-gathering and resolving power beyond the reach of the current 8 to 10m class telescopes is needed. TMT will take on this challenge of observing earthlike planets utilizing two methods.

One method is to directly observe a planet reflecting light from its host star to shine. Since closer a planet is to its host star the brighter the reflected light, observation of a planet will require creative solutions such as utilizing extreme adaptive optics to attain higher resolution and stellar coronagraph for contrast enhancement.

The other method, applicable only when a planet has an orbit that crosses directly in front of its host star from the observer's point-of-view, takes advantage of light from the host star transmitting through the planetary atmosphere. Composition of the planetary atmosphere is identified by analyzing the transmitted light. Again, as the ratio of transmitted light to the observed stellar light is extremely low, this method will also require that observation be made with extremely high precision.

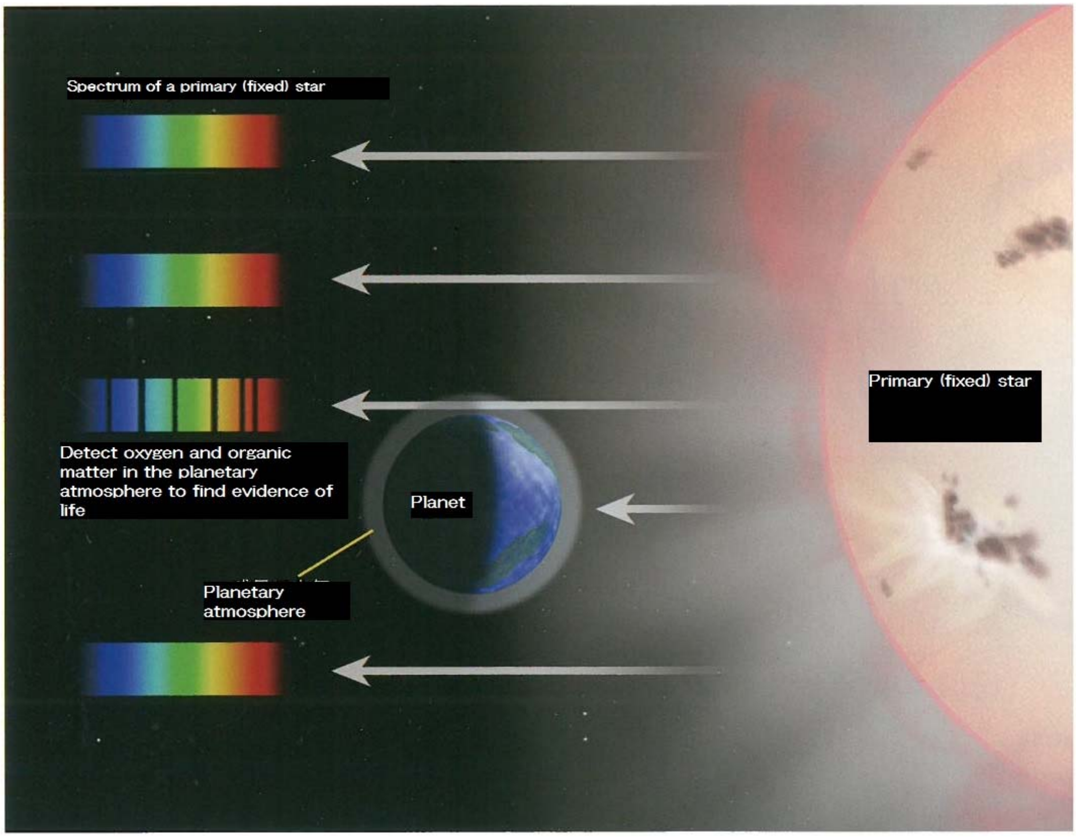

Figure7：An illustration of the concept of observation of transmitted light through planetary atmosphere (©NAOJ)

International Collaboration and Contributions by Japan

The TMT project is driven by international collaboration consisting of five partner countries including Japan, USA, Canada, China, and India. In 2014, financial authorities of the partners in TMT signed agreements laying down the fundamental principles for the construction and operation of TMT and the assignment of contributions to be made by each member country, and paving the way for the TMT International Observatory to be founded as a nonprofit limited liability company. Japan is making significant contributions to the project by taking charge of the design and manufacture of the main telescope structure, production of all of the mirror blanks for the segment mirrors (574 blanks including those for replacement), and performing a portion of the surface polishing of the segment mirrors. Japan also has a significant role in promoting scientific planning for TMT and in developing science instruments for the telescope.

Conclusions

History of astronomy reveals that evolution of the telescope is what allowed us to further expand and deepen our understanding of the universe. Our knowledge of the universe will undoubtedly take a big leap forward in the 2020s with the unveiling of the unprecedented power of TMT.