Constructing the highest astronomical observatory on the Earth

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To achieve the best observational capability in the infrared wavelength from the ground, we are now constructing a 6.5m telescope at the 5640m altitude in northern Chile, which is the world’s highest observatory.

In the modern astronomy, infrared observation is one of the key technique to understand wide range of phenomena in the universe, probing such as formation sites of extra-solar planets, final stages of stellar evolution, massive star-formation activities in distant galaxies, and many more. However, due to absorptions caused by various molecules in the terrestrial atmosphere, the wavelength range in the infrared observable from the ground is limited; this is one of the reasons why various infrared satellites are launched and an airborne telescope is operated. However, such projects require large amount of resources (both financial and technical) and operation period is restricted to short timescale, compared to ground-based telescopes.

As large fraction of the absorption is caused by water vapor in the atmosphere, another way to tackle this problem is to construct a large telescope at a high mountain in a dry area. The University of Tokyo Atacama Observatory project (TAO project, PI : Yuzuru Yoshii), is to construct and operate a 6.5m telescope at the top of Cerro Chajnantor (5640m altitude) located in Atacama desert at northern Chile. Thanks to the dry climate of Atacama where annual precipitation is less than 5mm, and to the high altitude of the site, precipitable water vapor (PWV) is lower than 0.5mm. Figure 2 is a comparison of the transmittance with typical condition of existing major observatories; it can be seen that absorption bands become less prominent and an almost continuous window appears at 0.9–2.5μm, and a number of new windows open beyond 20μm.

Figure 1. The summit of Cerro Chajnantor, where the mini-TAO 1m telescope (a white dome) and ancillary facilities are installed.

Figure 2. Simulated atmospheric transmittance at the summit of Cerro Chajnantor with typical condition of PWV=0.4mm, versus that of a hypothetical observatory at an altitude of 2600m with PWV=3mm.

1 Site Selection and 1m Pathfinder Telescope

Cerro Chajnantor was selected through a survey of satellite data in 2001, carried out in collaboration with Cerro Tololo Inter
American Observatory (CTIO) and European Southern Observatory (ESO). It shows extremely low PWV of 0.7mm, and high clear fraction over 70%. In the following years, we have carried out on-site testing, by installing a weather station to measure the local climate and performing seeing monitor observations, and the results were again promising. However, we need to confirm if the site performance in the infrared is good as we expect through real observations. Therefore, we installed a 1m pathfinder telescope named miniTAO in 2009 (Figure 1), and carried out science observations. Figure 3 is one of the results: they are images of the center of our Galaxy seen in ionized hydrogen Paschen-α (1.875μm) and in emission from warm dust clouds at 30μm, which are almost inaccessible from the other ground-based observatories.

These results clearly demonstrate the high capability of the site for infrared observations, and we are ready to construct the 6.5m telescope. Note that the miniTAO 1m telescope is certified as the highest astronomical observatory on the Earth by Guinness World Records in 2011.

2 6.5m Telescope and Instruments

The TAO 6.5m telescope has three mirrors, a 6.5m primary mirror, a 0.9m secondary mirror, and a tertiary mirror with 1.1m×0.75m elliptical shape. The primary mirror has honeycomb-lightweighted structure, and is fabricated at the Steward Observatory Richard F. Caris Mirror Lab of University of Arizona. The telescope structure is designed by referring to the Magellan 6.5m telescope, and constructed by Nishimura Co., Ltd. Production of major parts are already completed, and they are now being preassembled in a factory in Japan (Figure 4).

The telescope has four foci; two Nasmyth foci located at the elevation axis of the telescope where two facility instruments are installed, and two bent-Cassegrain foci for visitor instruments. The two facility instruments are now under development. One is a near-infrared instrument SWIMS (Simultaneous Wide-field Imager and Multi-object Spectrograph). To make use of the almost continuous atmospheric window in the near-infrared wavelength, it is capable of multi-object spectroscopy with λ/Δλ=1000 from 0.9 to 2.5μm in a single exposure as well as wide-field imaging (Figure 5). SWIMS will be a powerful tool to study formation and evolution of high-redshift galaxies, quasars and transients.

The other is a mid-infrared instrument MIMIZUKU (Mid-Infrared Multi-field Imager for gaZing at the UnKnown Universe), which is capable of imaging and low-resolution spectroscopy from 2 to 38μm (Figure 6). New feature of MIMIZUKU is a “Field Stacker” mechanism, which combines two separated small field of views into one detector area and enables us to observe two objects in a single shot (Figure 4). Thus, we can observe calibration star simultaneously and obtain accurate temporal variation of the brightness of the target, caused by phenomena like dust formation and destruction in forming stars or dying stars.

Development of the both instruments are almost completed. They will be carried into the Subaru 8.2m telescope at Hawaii in 2017 for engineering observations to confirm their on-telescope performances, and then sent to Chile in 2019 for the science

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first-light observations at the 6.5m telescope.

In summary, we are now constructing a 6.5m infrared-optimized telescope at the summit of Cerro Chajnantor (5640m altitude) in northern Chile, which is the highest astronomical observatory on the Earth. Thanks to the high altitude and the extreme dry environment of the site, we can have high transmittance in the infrared wavelength stably.

Production of the telescope and development of the two facility instruments are now almost finished in Japan. We are now planning to start the construction at the summit in 2017, and finish the telescope assembly and see the engineering first light in early 2018.

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The Digitized Sky Survey image shown in Figure 3 was produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The image is based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plate was processed into the present compressed digital form with the permission of these institutions.

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