Antarctic Terahertz Telescope Project

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1. Introduction

The Antarctic plateau, is the best place for astronomical observations on earth. Because of the low temperature and high altitude, precipitable water vapor (PWV) is very low. Since water vapor is the main cause of the atmospheric absorption, the Antarctica plateau has most transparent sky on earth, especially, for wavelengths of 3 μm to 3 mm. Figure 1 shows the sky transmission at some sites calculated from PWV. The transmission at submm band is much higher in the Antarctic plateau than other sites and the Antarctic plateau is the only site on earth where we can make observations in THz easily. Furthermore, it is also advantage for astronomical observations that the PWV is very stable.

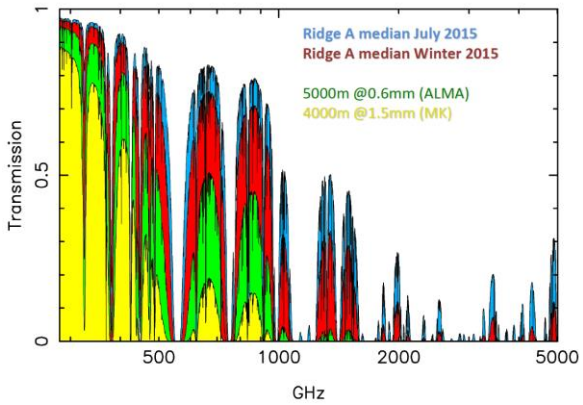

Figure 1. Atmospheric transmission. (Kulesa 2017)

The submm and THz windows of the sky is very important for astronomy, since we can observe many interesting objects through the windows. For example, dark galaxies or submm galaxies are one of the most important targets. They were found by submm observations and are dark in optical observations. Since they are thought to be young distant galaxies obscured by interstellar dust, it is important to know the properties of the dark galaxies for understanding evolution of galaxies. For the purpose, survey of dark galaxies at submm and THz bands is effective and we can estimate the redshift of the distant galaxies with submm and THz data. Furthermore, we can observe various phase of interstellar gas by using various atomic and molecular lines within submm/THz band (e.g., [CI], [NII], and high-*J* CO lines) which can not be observed by other frequency range. They are very important to understand evolution of interstellar medium in galaxies.

As mentioned above, the Antarcic plateau has a very high potential to be the best site for astronomical observations. Therefore, some telescopes have been constructed in Antarctica. For example, the South Pole Telescope is a 10-m telescope for observations of mm band operated by U.S. astronomers. Chinese astronomers installed optical telescopes (AST3) at Kunlun Station in Dome A. Furthermore, they are planning to construct a 5-m THz telescope (DATE5) in Dome A. Antarctic astronomy consortium of Japan is also promoting Antarctic astronomy and planning to construct teraherz telescopes on the Antactic plateau.

2. Antarctic 30-cm telescope

Ishii et al. (2014) developed a 30-cm telescope for observations in Antarctica (Figure 2). A sideband-separating (2SB) receiver based on the ALMA Band 8 mixer unit is installed on the telescope. To demonstrate the excellent condition of Antarctica for astronomy and gain experience of telescope operation in Antarctica, we are planning to transport the telescope to Antarctica. We will conduct a Galactic plane survey in CO(*J*=4-3) and [CI] to investigate evolution of ISM in the Galaxy. The details of the 30-cm telescope project are presented by Seta et al. in this conference.

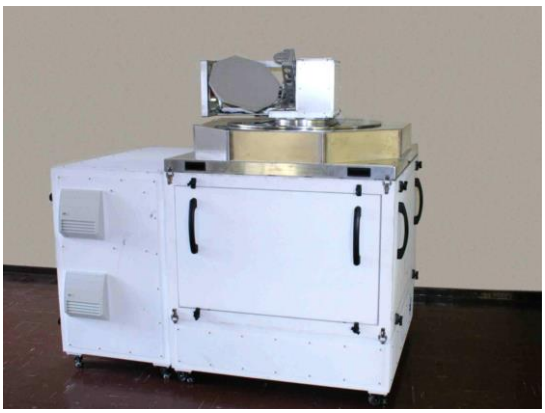

Figure 2. Antarctic 30-cm telescope. (Ishii et al. 2014)

3. Antarctic 10-m Terahertz Telescope

We are planning to construct a 10-m teraherz telescope on the Antactic plateau (Figure 3). The main purpose of the 10-m telescope is survey of the dark galaxies. The specifications of the 10-m telescope is lisetd in table 1. Frequency coverage

is 200 GHz to 1.5 THz. The field of view is about 1 deg which is very important especially for the survey of dark galaxies. We will adopt Ritchey–Chrétien telescope to get such wide-field of view by reducing Comatic aberration. The angular resolution is 5.8" at 1.3THz. We will use two Nasmyth focuses for a MKID camera and heterodyne receivers. We will develop a wide field MKID camera with 20,000 pixels

Table 1. Specifications of Antarctic 10-m terahertz telescope.

Parameter	Value
Diameter	> 10 m
Surface accuracy	< 20 μm
Observation frequency	200 GHz – 1.5 THz
Field of view	~ 1°
Pointing accuracy	~ 0.5"
Power consumption	< 35 kVA

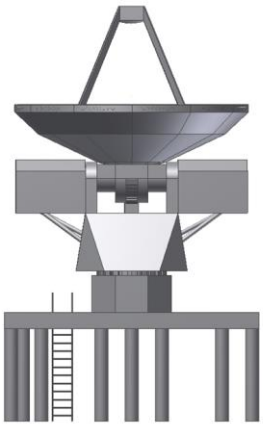

Figure 3. Schematic view of Antarctic 10-m telescope.

which can cover a field of view of 1 deg. The camera consists of 7 modules which can observe three frequency bands, 400GHz, 850GHz and 1.3THz, simultaneously. For line observations, we will develop heterodyne receivers which cover the atmospheric windows, 230 GHz, 450 GHz (e.g., $[CI]^3P_1$-$^3P_0$, CO(J = 4-3)), 800 GHz (e.g., $[CI]^3P_2$-$^3P_1$, CO(J = 7-6)), 1 THz (e.g., CO(J = 8-7)), 1.3THz (e.g., CO(J = 11-10)), and 1.5THz (e.g., [NII]). Because electric power is limited in Antarctica, power consumption should be as low as possible. We will construct the telescope on a raised floor to avoid accumulation of snow. We need de-icing system for the operation under low temperature condition in Antarctica. The candidate site for the construction of the 10-m telescope is Dome Fuji or Dome C.

4. Antarctic 30-m Terahertz Telescope

The sensitivity and angular resolution are essential to observe distant galaxies, detail structures of star forming regions and nearby galaxies, and so on. Therefore, to get much higher sensitivity and angular resolution, we started discussion about construction of a 30-m telescope as a large project following the 10-m telescope. The specifications of the 30-m telescope are listed in table 2. Note that the specifications are very rough estimation at this stage. The candidate of the construction site is Dome Fuji. Since the 30-m telescope is a very large and massive structure, we have to check feasibility of construction and operation of the 30-m telescope at Dome Fuji. We have many issues that we have to investigate and solve for the project. At first, we need to measure weather conditions at the candidate site in Dome Fuji. The information of wind and temperature is very important. We also have to investigate the condition of snow surface and consider how to set the antenna with more than 1000 tons. Furthermore, we have to consider about the method to transport such huge materials. Power supply for the telescope operation is another important issue.

Table 2. Specifications of Antarctic 30-m terahertz telescope.

Parameter	Value
Diameter	30 m
Surface accuracy	< 20 μm
Observation frequency	200 GHz – 1.5 THz
Field of view	~ 1°
Pointing accuracy	~ 0.2"
Power consumption	~ 600 kVA
Weight	~1000 t

5. Summary

The Antarctic plateau is the best site for astronomical observations on earth. Antarctic astronomy consortium is planning to construct terahertz telescopes in the Antarctic plateau. The terahertz telescopes will play an important role for astronomy from Antarctica. The international interest in astronomy from Antarctica is growing rapidly. We hope that Japan can lead such activities, especially THz astronomy from Antarctica.

References

Ishii et al, Development of a 30-cm submillimeter-wave telescope for the operation at Dome Fuji in Antarctica, Proc. SPIE 9145, Ground-based and Airborne Telescopes V, 914535, 2014

Kulesa, SCAR AAA Workshop, 2017