GroundBIRD - observation of CMB polarization at large angular scales with a combination of MKID arrays and a high-speed rotating telescope

Main author:

OGURI Shugo

Co-authors:

Choi Jihoon, Korea University

Damayanthi Thushara, RIKEN

Hattori Makoto, Tohoku University

Hazumi Masashi, KEK, SOKENDAI, Kavli IPMU (WPI), UTIAS, The University of Tokyo

Ishitsuka Hikaru, SOKENDAI (The Graduate University for Advanced Studies)

Karatsu Kenichi, National Astronomical Observatory of Japan

Mima Satoru, RIKEN

Minowa Makoto, The University of Tokyo

Nagasaki Taketo, High Energy Accelerator Research Organization (KEK)

Oguri Shugo, Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK)

Otani Chiko, RIKEN

Sekimoto Yutaro, National Astronomical Observatory of Japan

Tajima Osamu, High Energy Accelerator Research Organization (KEK), SOKENDAI

Tomita Nozomu, The University of Tokyo

Won Eunil, Korea University

Yoshida Mitsuhiro, High Energy Accelerator Research Organization (KEK)

Cosmic microwave background radiation (CMB) is an important source of information about the origin of our universe. In particular, large angular scale odd-parity patterns in the CMB polarization, primordial B-modes, are strong evidence for the inflationary universe. GroundBIRD aims to detect them from the ground with novel techniques: high-

speed rotation scan system, cold optics, and microwave kinetic inductance detectors (MKIDs). We plan to start commissioning of the system by observing CMB in Japan in 2015. Then we will deploy the GroundBIRD at the Atacama Desert or Canary Islands for science observations.

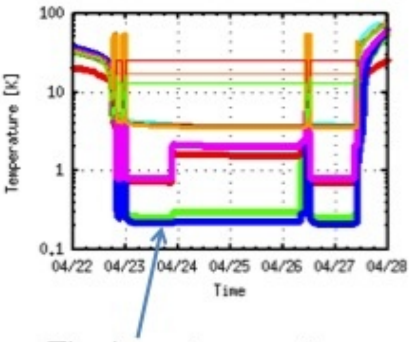
The high-speed rotation scan is realized by the operation of the cryocooler on a rotating table [1,2]. We developed a series of two rotary joints for high-pressure helium gas and electricity lines, which enable connection of helium gas and power supply between the cryocooler on the table and the compressor on the ground. We already achieved cold condition of 0.23 K with a hold time of more than 24 hours under a condition of continuous rotation at 20 rpm. Scan strategy of most ground-based experiments is periodic left-right motion along the azimuth direction. The scan frequency is limited by the mechanical specifications. On the other hand, our rotation scan results in continuous high-speed pointing motion without any deceleration. It allows us a significant expansion of multipole range at $6 < l < 300$ while mitigating the effect of 1/f noise.

We hold two mirrors in the cryostat at 4K. This condition mitigates a radiation noise from the mirror surfaces. To sustain the mirrors and other cold structures (total weight: 100 kg) on a base structure at 300 K, we select truss configuration of carbon fiber reinforced plastic (C-FRP) tubes. These tubes have high thermal insulating property as well as mechanical toughness. The diameter of the aperture window is 30 cm. In shielding from thermal radiation from the aperture, a combination of metal mesh filters (QMC Instruments Ltd.) and radio-transform multi-layer insulations (RT-MLI [3]) is applied. The RT-MLI is a novel thermal radiation blocker. They consist of a set of stacked formed-polystyrene layers. The layers are transparent to radio waves but block infrared radiation. No thermal link is necessary for RT-MLI and the performance of cooling does not vary with the aperture size. This is because its cooling mechanism is radiative cooling similar to conventional MLI, i.e., the mechanism is different from an active cooling from the filter edge. We recently achieved to maintain the mirrors at 3.4 K on the optical configuration. We also achieved 0.21 K temperature for Helium sorption cooler in the same condition.

Microwave Kinetic Inductance Detector (MKID) is chosen for the focal plane detector array of GroundBIRD. MKID has an advantage on its scalability because of frequency-division multiplexing readout, and the number of readout lines can be kept small. It means the thermal conduction along the lines is also small. In addition to that, the fast time response (order of 100 us) of MKID is well-matched with our high-speed scan. Based on tests of MKIDs on the rotation condition, we established the strategy to shield Geo-magnetic field's effect. We plan to observe at 220 GHz (112 pixels) for an understanding of dust emission as well as at 145 GHz (312 pixels) for CMB. Commissioning of our detector with our telescope on the optical condition is currently underway.

In this conference, we will present our status, achievements, and prospects of the GroundBIRD experiment.

[1] S. Oguri, J. Choi, M. Kawai, and O. Tajima, Rev. Sci. Instrum., 84, 055116, (2013).
[2] S. Oguri, H. Ishitsuka, J. Choi, M. Kawai, and O. Tajima, Rev. Sci. Instrum., 85, 086101, (2014).
[3] J. Choi, H. Ishitsuka, S. Mima, S. Oguri, K. Takahashi, O. Tajima, Rev. Sci. Instrum., 84, 114502, (2013).



The base temperature at 0.21K achieved.