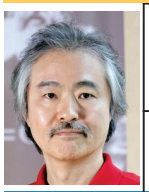
【Grant-in-Aid for Scientific Research (S)】

Mysterious Accelerating Expansions of the Universe - Solving the Problems with Advanced Cosmic Microwave Background Telescopes -



Principal Investigator	High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Professor HAZUMI Masashi　　Researcher Number:20263197
Project Information	Project Number : 22H04945　　Project Period (FY) : 2022-2026 Keywords : Birth of the universe, Accelerating expansion of the universe, Cosmic microwave background, Superconducting detectors

Purpose and Background of the Research

●Outline of the Research

Observations have confirmed that our universe is expanding with time. However, the discovery in 1998 that the rate of expansion is now accelerating came as a great surprise. The Nobel Prizes in Physics in 2006, 2011, and 2019 were awarded for these discoveries. Gravity is only attractive and has been thought to only act to decelerate the universe's expansion. Why the universe's expansion accelerates is thus a mystery and shakes the foundation of physics. With signs of a once-in-a-century revolution in physics, the POLARBEAR-2 telescope, which was developed under the leadership of the Principal Investigator of this research and started operation in 2019 in Atacama, Chile, is the only instrument in the world that can simultaneously approach the two mysteries of the acceleration in the early universe and the current universe. We will improve our instrument and conduct long-term observations until 2026 to be the first in the world to show new observation results of the CMB polarisations and to elucidate the mystery of the accelerating expansions of the universe.

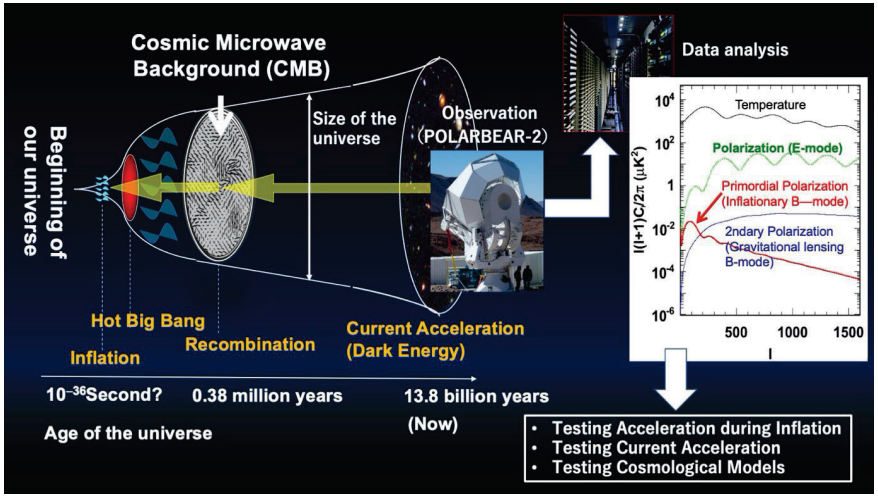


Figure 1. Outline of the Research

●What do we observe?

In this study, we observe the cosmic microwave background (CMB), the oldest light that filled the entire universe about 380,000 years after the birth of the universe. After 13.8 billion years since then, the CMB is arriving on the earth now. It contains not only a wealth of information about when the universe was a fireball after the Big Bang but also definitive information about the inflation before the hot Big Bang. Furthermore, it has unique information about the current accelerated expansion, making it ideal for solving modern physics' greatest mysteries: the universe's accelerated expansions.

●Observation Instruments

The instruments in this study are the Simons Array telescope in Atacama, Chile, and the POLARBEAR-2 detector system mounted on it. The Simons Array telescope is a "big but quick" telescope with a primary mirror with an effective diameter of 2.5 meters. It is a unique instrument that allows simultaneous exploration of accelerations in the early universe and the present. The POLARBEAR-2 detector system was developed under the leadership of this study's PI with support from the 2015-2019 Scientific Transformation Area (A) "Accelerating Universe" project, and observations started in 2019.

Figure 2. Pictures of the instruments (Left: Simons Array telescopes, Right: POLARBEAR-2 detector system.)

Expected Research Achievements

●Objectives during the Study Period

(1) Conduct long-term observations with POLARBEAR-2 to obtain high-precision data on the CMB.

(2) Improve the accuracy of measurements on the expansion speed of the current universe. That will allow us to determine, in particular, whether the accelerations in the present and past universe are constant or changing.

(3) Search for "signals from the universe before the hot Big Bang," as the inflation theory predicts, and explore what new physics lies behind inflation.

(4) In addition to the objectives described above, conduct various cosmological data analyses and publish papers on the results of the observations. Improve the measurement accuracy of standard cosmological parameters important for describing the universe. Explore also physics beyond the standard cosmology.

●Expected Research Outcomes

The most significant possible outcome is the discovery of the "signals from the universe before the hot Big Bang" predicted by the inflation theory. For example, assuming one of the leading inflation models (called the natural inflation model), we can expect to find it with more than 99.9999% certainty (degree of significance) through the observation of POLARBEAR-2. In this case, the correctness of the model can be checked even more rigorously by combining it with another cosmological parameter that POLARBEAR-2 can observe. If the results of the checks indicate that the model is incorrect, this could be an unexpected significant discovery. Another primary expected result is that the acceleration of the current expansion will be found to be time-varying. If this can be proven by combining the results of this project with other cosmological observations, it will undoubtedly usher in a new era of cosmology. The current standard cosmology will then be interpreted as an approximation of a more fundamental theory, and closer and more observationally-supported progress in particle theory and cosmology will occur. In addition to the above, physics beyond the standard cosmology can be explored in various ways, which will certainly advance cosmology.

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