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

Ultra-High Energy Universe Revealed by Neutrinos with the IceCube Gen2 Telescope

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Purpose and Background of the Research

● **Neutrinos can pass through anything!**

Neutrinos can reach the Earth from the distant Universe without losing information during their propagation. Neutrino astronomy allows us to observe the deep Universe at high energies, which has been a blind spot for astronomy using telescopes.

● **What do neutrinos reveal about the Universe?**

The Universe, which appears to be completely dark, is filled in reality with invisible background light, the radiation from the past. High-energy light collides with this background light. This means that the Universe has a more prominent blind spot at higher energies. We utilize neutrinos to explore the origin of very high-energy radiation, which is thought to exist in the distant Universe.

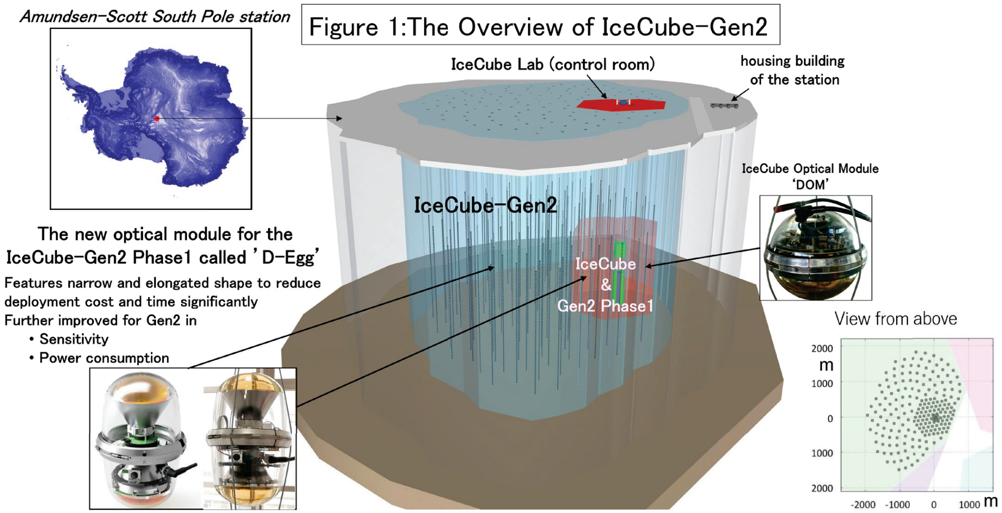
● **How do we observe cosmic neutrinos?**

Observation of cosmic neutrinos requires an instrument with a huge transparent medium. The world's first neutrino telescope, IceCube, which uses one cubic kilometer of Antarctic deep glacier ice, has successfully observed cosmic neutrinos. We could finally start the search for high-energy radiation sources using high-energy neutrinos.

~Our next target~

Ten years of the IceCube observation allows us to point to sources that emit high-energy neutrinos. However, IceCube has not yet identified the sources that produce most of the high-energy neutrinos in the Universe. Now, it is essential to improve the precision of IceCube and to construct the next-generation neutrino telescope IceCube-Gen2.

Figure 1:The Overview of IceCube-Gen2



● **The IceCube-Gen2 Project**

The IceCube-Gen2 detector outlined in Figure 1 represents the next-generation South Pole neutrino telescope, IceCube-Gen2, which will be manufactured as part of this research proposal. Neutrino observation is performed by detection of Cherenkov light. This project increases the detector volume from one cubic kilometer to eight cubic kilometers. The lower right panel in Fig. 1 shows the excavation layout of the IceCube detector. The densely instrumented area is the current IceCube array. The annual detection rate of high-energy cosmic neutrino events will be increased more than five by this expansion.

● **Improved calibration for the IceCube experiment (IceCube-Gen2 Phase-1)**

Before constructing the IceCube-Gen2 detector, the Phase-1 detector array will be deployed. The Phase-1 array aims to reduce the systematic uncertainty of the IceCube, including the optical propagation characteristics in deep glaciers, which is currently the most significant systematic error in the IceCube experiment and limits the accuracy of event reconstruction. The IceCube-Gen2 Phase-1 detector array consists of approximately 700 new photodetectors embedded densely in the center of the current IceCube photodetector array.

Expected Research Achievements

● **Calibration of the ice with the new array**

In Gen2 Phase-1, a variety of artificial light sources, as well as high-performance photodetectors, will be buried together. The light source and detector system, as shown in Figure 2, will allow us to study in detail how Cherenkov radiation propagates through the natural, highly transparent, but impure ice of Antarctica's deep glaciers and to characterize the detector response to lights with different luminosities. The new ice model and detector response characteristics will be incorporated into the simulations to improve the reconstruction accuracy. The improved reconstruction accuracy will allow us to discriminate different neutrino types called flavors. We can determine the current ratios of cosmic neutrinos, which hints at how they are produced.

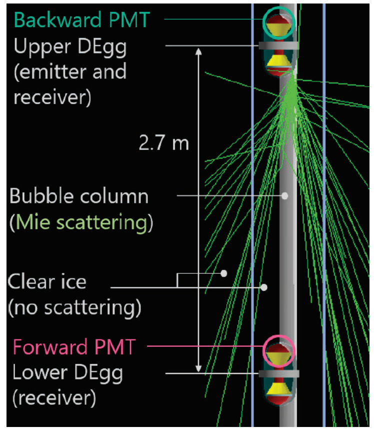


Figure 2 Simulation study of light propagation through the glacier by the LED light source in the D-Egg in the Phase 1 array. Light emitted from the upper D-Egg is observed by the lower D-Egg. The D-Egg that emits the LED light can measure light distributions with high precision, allowing us to observe how light scattering changes at different locations in the array.

● **Production of the Gen2 optical sensors in Japan**

With this research plan, we will start manufacturing the new optical modules for an 8 gigaton capacity Cherenkov Neutrino telescope for a wide energy range of neutrinos. The Japanese group has rich experiences in designing, manufacturing, and testing optical modules. We aim to establish high sensitivity and power-saving design for the Gen2 optical module, as shown in Figure 3.

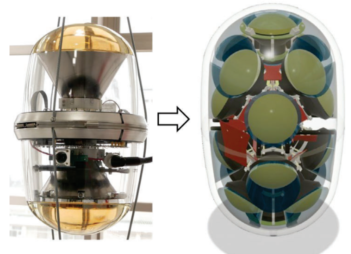


Figure 3 Picture of D-Egg (left) and new photodetector design for Gen2 (right)

Homepage Address, etc.	http://www.icehap.chiba-u.jp/icecube/result.html http://www.icehap.chiba-u.jp https://icecube.wisc.edu/