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Towards imaging Earth's large-scale structures by directional geoneutrino detection with Ocean Bottom Detector

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Geoneutrinos are electron antineutrinos produced by beta decays of radioactive isotopes within Earth. Their detection provides a unique opportunity to quantify the production of radiogenic heat and its distribution in the planet. Despite their significance, geoneutrinos are challenging to detect due to their weak interactions with matter, which necessitates highly sensitive and specialized detection techniques.

Nevertheness, in 2005, the KamLAND experiment (Japan) became the first to successfully detect geoneutrinos, providing groundbreaking insight into Earth's power. The achievement spurred the development of new methods for studying Earth's structure, bridging neutrino physics with geochemistry and geophysics. The Borexino experiment (Italy) later confirmed the detection of geoneutrino, and ongoing projects such as SNO+ (Canada) and the upcoming JUNO experiment (China) aim to further our understanding of Earth's interior through continued geoneutrino detections.

The detectors mentioned above, however, are all located in thick continental crusts that have a high concentration of radioactive isotopes, which limits our ability to investigate deeper layers of Earth. To address this challenge, a project called Hanohano was proposed in 2005. However, due to various challenges, it was never realized. Building on past efforts, a project called Ocean Bottom Detector (OBD) was proposed in 2019 by Research Center for Neutrino Science, Tohoku University, based on the extensive operational and technical experience gained from KamLAND. It involves placing a liquid scintillator neutrino detector on the ocean floor off the coast of Hawaii, where the oceanic crust is thin and contains fewer radioactive isotopes. This makes the location ideal for directly detecting geoneutrinos from the mantle. To launch this international collaboration, the project is being pursued in active cooperation with institutions such as the University of Hawai'i, Lawrence Livermore National Laboratory (LLNL), and Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Another key challenge is that traditional detection methods lack the angular resolution needed to determine the direction of incoming antineutrinos, making it difficult to confirm whether a detected signal truly originates from Earth's interior. In recent years, several new techniques have been proposed and developed to enable antineutrino detectors to achieve angular resolution. These include gadolinium-doped liquid scintillators, which improve neutron tagging, and segmented detector designs that allow for more precise reconstruction of the interaction vertex.

In this presentation, we explore potential observational results that could be obtained if the OBD is equipped with angular resolution. Such observations could not only provide direct evidence of the directionality of geoneutrinos, but also offer valuable insights into the structure and dynamics of Earth's deep interior, particularly the large low-shear-velocity provinces (LLSVPs). These structures located at the base of the mantle have attracted increasing attention in geoscience because of their important role in mantle convection, plume generation, and thermal evolution of the earth.

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Collaboration you are representing

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