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Probing Earth's interior with neutrino oscillation tomography

The measurement of the energies and directions of atmospheric neutrinos traversing the Earth, combined with particle identification, will first answer the question of whether the neutrino mass ordering is normal or inverted. In the longer term, as neutrino telescopes currently operating (IceCube), partially completed (KM3NeT/ORCA), or under construction (Hyper-Kamiokande, DUNE) accumulate data, neutrino tomography holds the potential to complement classical geophysical and geochemical techniques for probing the Earth's deep interior. In this contribution, we focus on neutrino oscillation tomography, which relies on detecting variations in neutrino oscillation patterns caused by changes in the matter density and proton-to-nucleon ratio along the neutrino trajectories. This novel method offers a promising approach to addressing open questions regarding the Earth's internal density distribution and chemical composition.

We present the sensitivity of neutrino oscillation tomography to the aforementioned properties of individual Earth layers, assuming a spherically symmetric Earth model. Our objective is to identify the depth ranges that can be most effectively studied using this technique. To quantify the constraints that neutrino oscillation tomography can provide on the Earth's structure, we first derive the sensitivity to the planet's composition and density using an ideal neutrino detector. We then incorporate the response of next-generation neutrino telescopes. Our results show that while an ideal detector would be most sensitive to the outer core, realistic detectors with lower resolution but large detection volumes exhibit greater sensitivity to shallower depths. Finally, we investigate the conditions required for next-generation neutrino telescopes to discern possible compositional and mass anomalies currently debated within the geoscience community.

Authors: MITTELSTAEDT, Eric (University of Idaho); GOOS, Isabel (APC); COELHO, Joao (CNRS / APC - Paris); FUJI, Nobuaki (IPGP/UPC); PESTES, Rebekah (APC/IPGP); DURAND, Stephanie (LGL-TPE); VAN ELEWYCK, Véronique; DENIZ, Yael (University of Idaho)

Presenter: GOOS, Isabel (APC)

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