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A reference Earth model for geoneutrinos

HUANG, Yu[2] ; MANTOVANI, Fabio[1*] ; RUDNICK, Roberta L.[2] ; MCDONOUGH, William F.[2]

[1]University of Ferrara - INFN of Ferrara - Italy, [2]University of Maryland, College Park, MD, USA

Geoneutrino data from the KamLAND and Borexino experiments provide insights into Earth's energetics and global radiogenic heat production. In 2014, SNO+ will begin to collect data; the era of the exploration of our planet through geoneutrinos is definitely open.

Detection of geoneutrinos provides quantitative information about the total amounts of U and Th in the Earth and their distribution within the different reservoirs (crust, mantle and possibly core). One of the greatest potentials of geoneutrino is to discriminate among the different models for the bulk composition of the Earth, which are based on cosmochemical arguments and geochemical and geophysical observations. In order to determine the U and Th concentration of the deep Earth from the geoneutrino signal, the regional and crustal contribution to the geoneutrino flux needs to be determined from detailed geological studies.

We developed a geophysically based, three-dimensional global reference model for the abundances and distributions of U and Th in a Bulk Silicate Earth (BSE) model. The structure and composition of the outermost portion of the Earth, the crust and underlying lithospheric mantle, are detailed in the reference model; this portion of the Earth has the greatest influence on the geoneutrino fluxes. The structure of the crust is based on 1^{o} x1^{o} surface map of the Earth discriminating layers of sediments, upper, middle and lower crust. For the first time three geophysical global crustal models based on reflection and refraction seismic body wave (CRUST 2.0), surface wave dispersion (CUB 2.0), and gravimetric anomalies (GEMMA) are studied with the aim to estimate the contribution of geophysical uncertainties to the reference crustal model.

On the base of new compilations of geochemical data for sediments, oceanic and continental crust, we estimate the expected geoneutrino signal and its uncertainties for the crust of the Earth. Evaluating the U and Th abundances and their uncertainties in middle and lower crust are a focus of this model, along with using seismic velocity data to determine the lithological nature of these layers. The fraction of felsic and mafic rocks in the deep portions of the continental crust has been estimated by comparing the velocities of longitudinal and transverse seismic waves reported in the crustal model with the laboratory values obtained for ultrasonic velocities of different rock types.

An updated xenolithic peridotite database is used to represent the average composition of continental lithospheric mantle. The geoneutrino signal from this reservoir is calculated for the first time and it exceeds that from the oceanic crust at all three existing detectors.

Geoneutrino signal at Earth's surface is calculated in TNU (Terrestrial Neutrino Unit) (see figure) and Monte Carlo simulation is used to track the asymmetrical uncertainties of different crustal inputs. The combination of the global crust model, detailed local crust models, and the measured signal for each detector provides the critical inputs needed to assess the global mantle signal and its uncertainty. Thus, the mantle signal at each detector and its uncertainty can be independently combined to place limits on acceptable models for the mantle's radiogenic power.

Keywords: geoneutrino flux, heat producing element, radiogenic heat power, reference crustal model, deep crust composition, bulk silicate Earth composition