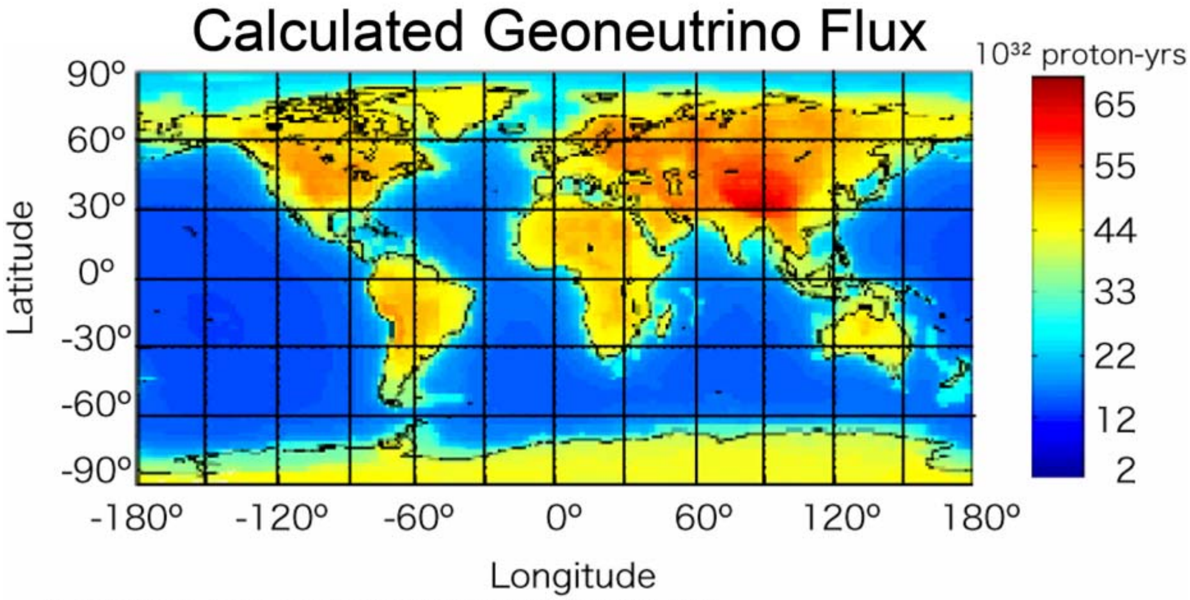
The Doanow meeting

DOANOW- Deep Ocean Anti-Neutrino Observatory Workshop- at the University of Hawaii on March 23-25, 2007

Last week in Hawaii earth scientists and particle physicists gathered to discuss detection of antineutrinos generated inside the earth and in nuclear reactors. The attendees examined how one can better understand the earth's geoneutrino signal, which is produced by radioactive decay of K, Th and U. In July 2005, particle physicists demonstrated that it is possible to detect geoneutrinos and thus establish limits on the amount of radioactive energy in our planet (*Araki et al: Vol 436|28 July 2005|doi:10.1038/nature03980*). Last week's meeting was aimed at enhancing communication between the two disciplines in order to gain mutual appreciation of the constraints on the distribution of earth's K, Th and U afforded by earth science and the new area of geoneutrino detection. The initial results from an antineutrino detector in Japan (KamLAND) are consistent with the abundances of Th and U in the earth determined by earth scientists and the energy output from the decay of these elements, at 16 TW (terawatts, 16 million million watts). (K geoneutrinos cannot be detected at present due to the significant background in this region of the spectrum.) The initial measurement is also broadly consistent with a chondritic Th/U value for the earth, a fundamental assumption used by geochemists to model planetary compositions. However, the upper energy limit (60 TW at the 3 sigma limit) determined by the experiment exceeds the earth's surface heat flow by a factor of 1.5 and thus does not yet constrain models usefully.



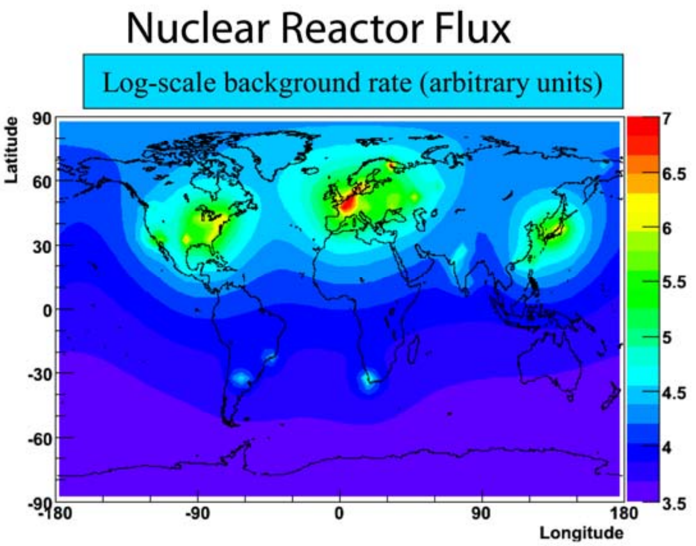
G. Fiorentini, M. Lissia, F. Mantovani, and R. Vannucci, hep-ph/0401085

Nevertheless, the future is bright for several scientific communities. The first detector to be used in this way was intentionally placed near nuclear reactors in order to characterize antineutrino oscillation parameters and sense fluctuations in reactor power output. Consequently, the reactor signal overwhelmed the geoneutrino signal. New detectors are being developed, deployed and positioned in locations that have significantly smaller contributions from nuclear reactors, and thus will provide fundamental information to both the earth science and astrophysical communities. Particle physicists are moving forward; as they continue to count geoneutrinos they are improving signal to background levels. With more counts, the uncertainty on the radioactive energy budget of the earth will shrink and the precision on the determined Th/U ratio of the planet will improve. Measurement uncertainties of 10% or better are possible with planned and proposed new detectors, and achievable on time scales of four years of counting.

What does this mean for the earth sciences? Geoneutrino detectors will be sited on continental crust of different ages, including ancient cratons. The Sudbury Neutrino Observatory (SNO), one of the two original labs involved in solving the solar neutrino problem, is presently being converted to SNO+ (Sudbury antiNeutrino Observatory Plus).

This 1000 ton detector is sited in the Superior province of the North American craton and represents an optimal location for understanding the distribution of heat-producing elements in the ancient cores of continents. Here, the antineutrino signal will be dominated by the crustal component at about the 80% level. This experiment will provide data on the bulk composition of the continents and place limits on competing models of the continental crust's composition. The BOREXINO detector, situated in central Italy (and hence somewhat removed from the reactor-bright regions of France), will begin taking data later this year. This detector will accumulate a geoneutrino signal from a younger continental region and surrounding Mediterranean basin, thus receiving a greater proportion of its signal from the mantle.

Hawaiian particle physicists are proposing a 10,000 ton, portable geoneutrino detector that is deployable in the ocean. This detector, called HANOHANO, would provide a means to examine the geoneutrino signal coming from deep within the earth, far removed from the continents and nuclear reactors. Thanks to the capability of multiple deployments, this detector would provide the exciting possibility of obtaining signals from different positions on the globe.



Ultimately, these different instruments will allow earth scientists to test various models for vertical and lateral heterogeneities in the distribution of Th and U in the earth. Moreover, well-positioned detector deployments will yield unparalleled constraints on the composition of the continents and the earth.

Insights from geoneutrinos will also bring resolution to competing models of the nature of the earth's interior. Decades of research on the state of convection in the mantle have assumed wide-ranging values of the Urey ratio, the proportion of radioactive energy output to the total energy output of the planet. Geochemists have deduced a Urey ratio of ~0.4, whereas geophysicists construct mantle convection models using Urey ratios ranging from 0.3 to 1.0. In addition, geoneutrino data coupled with local heat-flow data will be used to evaluate models of bulk continental crustal composition. Competing models differ by almost a factor of two in their concentrations of K, Th and U, with some models critically dependant on heat flow data.

Beyond detecting antineutrinos, particle physicists described future experiments with neutrinos and antineutrinos that are only a decade or so away from implementation, including using neutrino beams to probe the depths of the earth. Differences in dispersion of neutrino beams penetrating the earth come from variations in the electron-density number for different layers of the planet. The earth's core, composed of high-density metal, has a markedly higher electron number than the silicate shells of the earth. Likewise, there is a marked contrast in electron number for the inner and outer core. Measurement of neutrino dispersion in these layers would yield significant improvements in our knowledge of the absolute radius of the core and appreciably improve the precision of global seismological models. Such beam studies could also determine the limits in the amount of hydrogen in the core.

The range of experiments underway and those just over the horizon will directly interrogate the interior of the earth in exciting and unparalleled ways; these new tools will essentially provide new ways of "traveling" to the center of the earth. ■

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