Geoneutrino Flux From Earth's Mantle And Its Detectability

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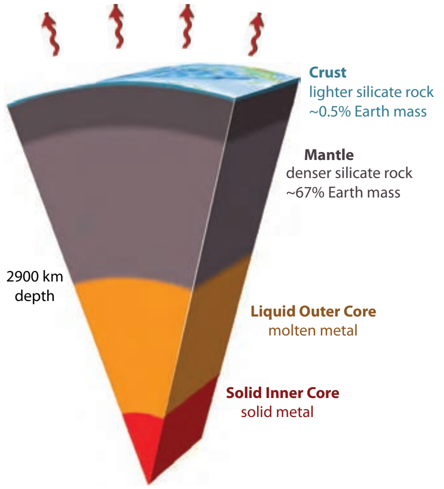
1. Earth Structure And Present-Day Energy Budget

Earth loses heat at a rate of **46±3 TW** [1],
which includes **heating by long-lived radioactivity** (^{238}U, ^{232}Th, ^{40}K),
and **primordial heat** remnant after accretion and core–mantle differentiation.

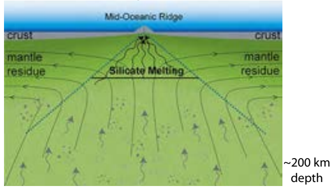


Radioactivity in the highly enriched **crust accounts for 8±1 TW** [2].

Most likely **no U or Th in the core**.

Average mantle abundances implied by different estimates of silicate Earth bulk composition account for **1 to 28 TW** of radiogenic heating [3]:
"Cosmochemical" mantle: 3±2 TW
"Geochemical" mantle: 12±4 TW
"Geophysical" mantle: 25±3 TW

Compositional estimates for **shallow mantle**, based on analysis of basalts erupted at mid-oceanic ridges, suggest heterogeneity in mantle composition for some average mantle estimates.



We use three shallow mantle compositional estimates,
"low", "medium" and "high" in terms of U+Th abundances [3].

Fundamental unanswered questions:

- How much radioactivity is there in Earth's mantle?
  OR more broadly: What is Earth made of?
- How is mantle radioactivity spatially distributed?
  Is the mantle compositionally uniform? layered? 3-D compositional structures?

Crucial for understanding the power available for mantle convection & plate tectonics, Earth's thermal history, planetary accretion.

2. Geoneutrinos

Electron anti-neutrinos emitted in β-decays of natural radionuclides.

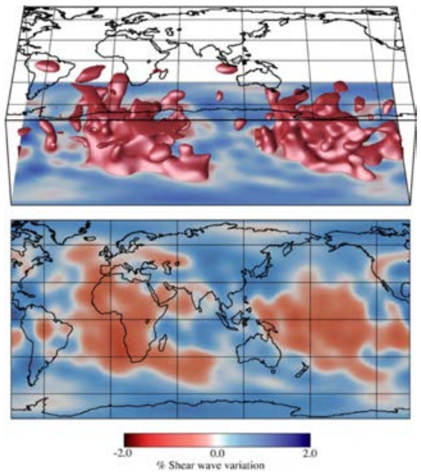
The higher energy geoneutrinos from ^{238}U and ^{232}Th decay chains detectable using inverse beta decay reaction: **direct assessment of mantle radioactivity!**

To-date detections: **KamLAND** [4, 5] & **Borexino** [6]

Combined analysis assuming site-independent mantle flux yields mantle signal of **23±10 TNU** [7]

3. Seismic Image of the Mantle

Shear-wave seismic speed anomaly
relative to a spherically symmetric seismic speed model
(seismic model S20RTS [8], figure from [9])



Two anomalous structures in deep mantle, below Pacific and below Africa

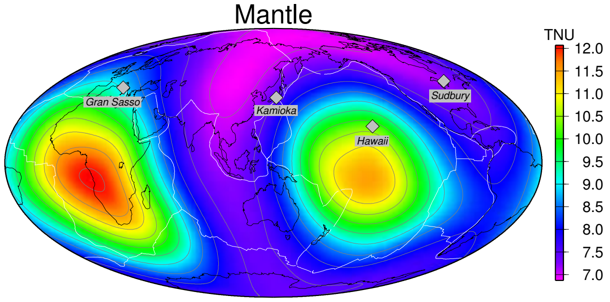
can reflect **temperature anomaly** and/or **compositional difference**

4. Geoneutrino Flux Predictions (^{238}U + ^{232}Th)

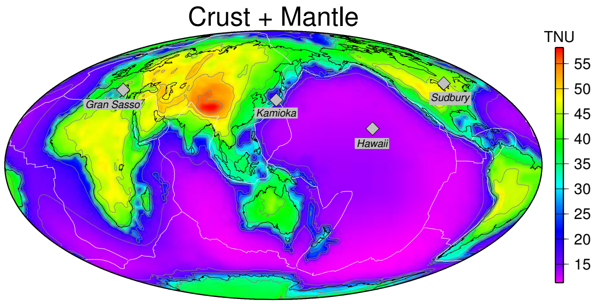
Assumption: seismically imaged deep-mantle structures (section 3) can be compositionally distinct from ambient mantle.

Concentrations of U & Th calculated from available estimates for average mantle and shallow mantle (section 1).

Result for "geochemical mantle" and "medium U+Th" shallow mantle:

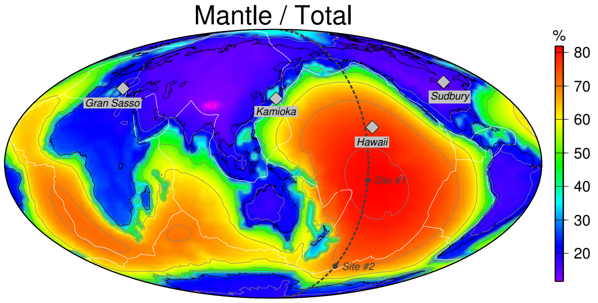


Lateral variation in mantle flux

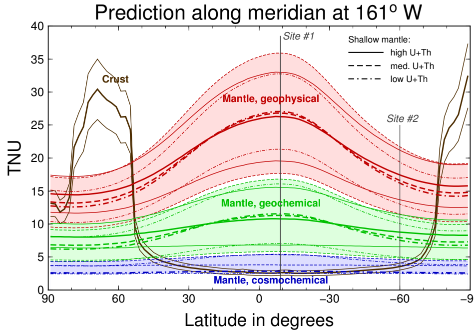


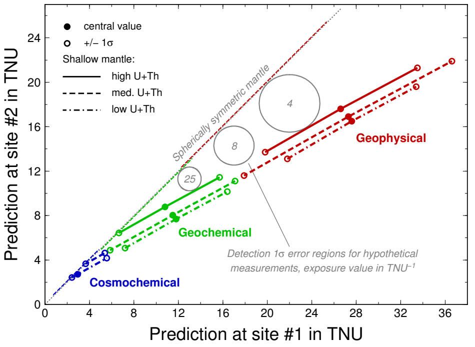
Geoneutrino signal dominated by continental crust

5. Detectability of Mantle Flux



Two detection sites in Pacific basin proposed to benefit from:
- **high mantle-to-crust signal ratio**
- **large lateral variation of predicted flux**





Summary

- Model of geoneutrino emission from Earth's mantle, constrained by geophysics and geochemistry.
- Plausible compositional estimates result in mantle flux patterns ranging from low-amplitude spatially uniform to high-amplitude laterally variable.
- Predicted lateral variation in mantle flux is resolvable for "geophysical" mantle and the high-abundance end of "geochemical" mantle by a two-site measurement in the Pacific.

References

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