Geoneutrinos

Using neutrinos to probe Earth's interior

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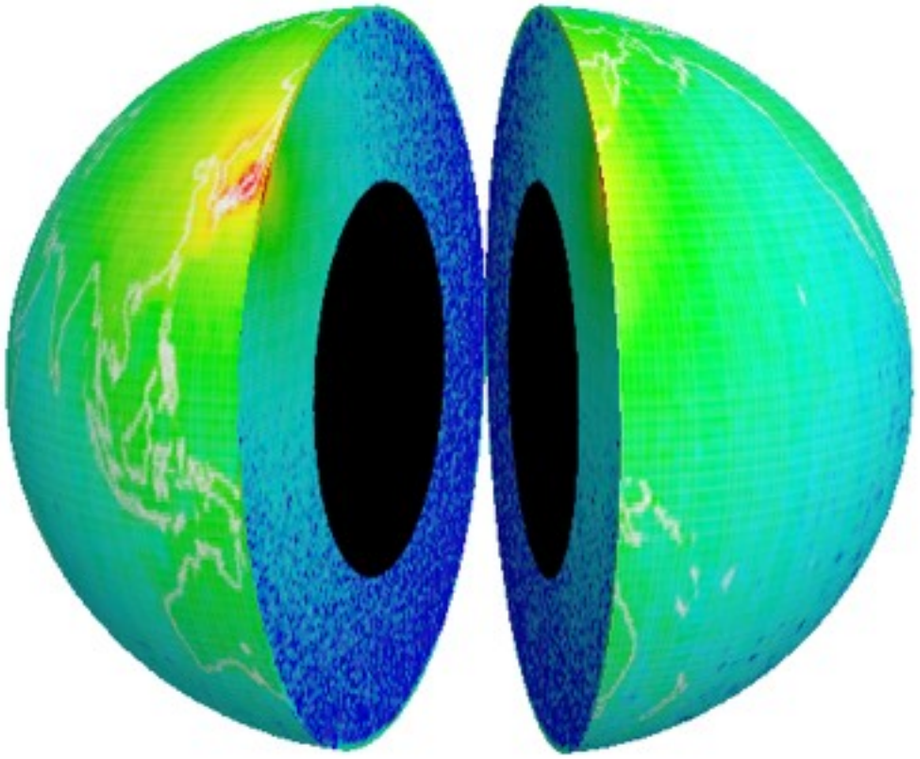
What are geoneutrinos?

- electron antineutrinos
- decay product of Uranium-238, Thorium-232, and Potassium-40

$$^{238}\mathrm{U} \rightarrow ^{206}\mathrm{Pb} + 8\alpha + 8e^- + 6\bar{\nu}_e + 51.7 \quad \mathrm{MeV}$$

$$^{232}\mathrm{Th} \rightarrow ^{208}\mathrm{Pb} + 6\alpha + 4e^- + 4\bar{\nu}_e + 42.7 \quad \mathrm{MeV}$$

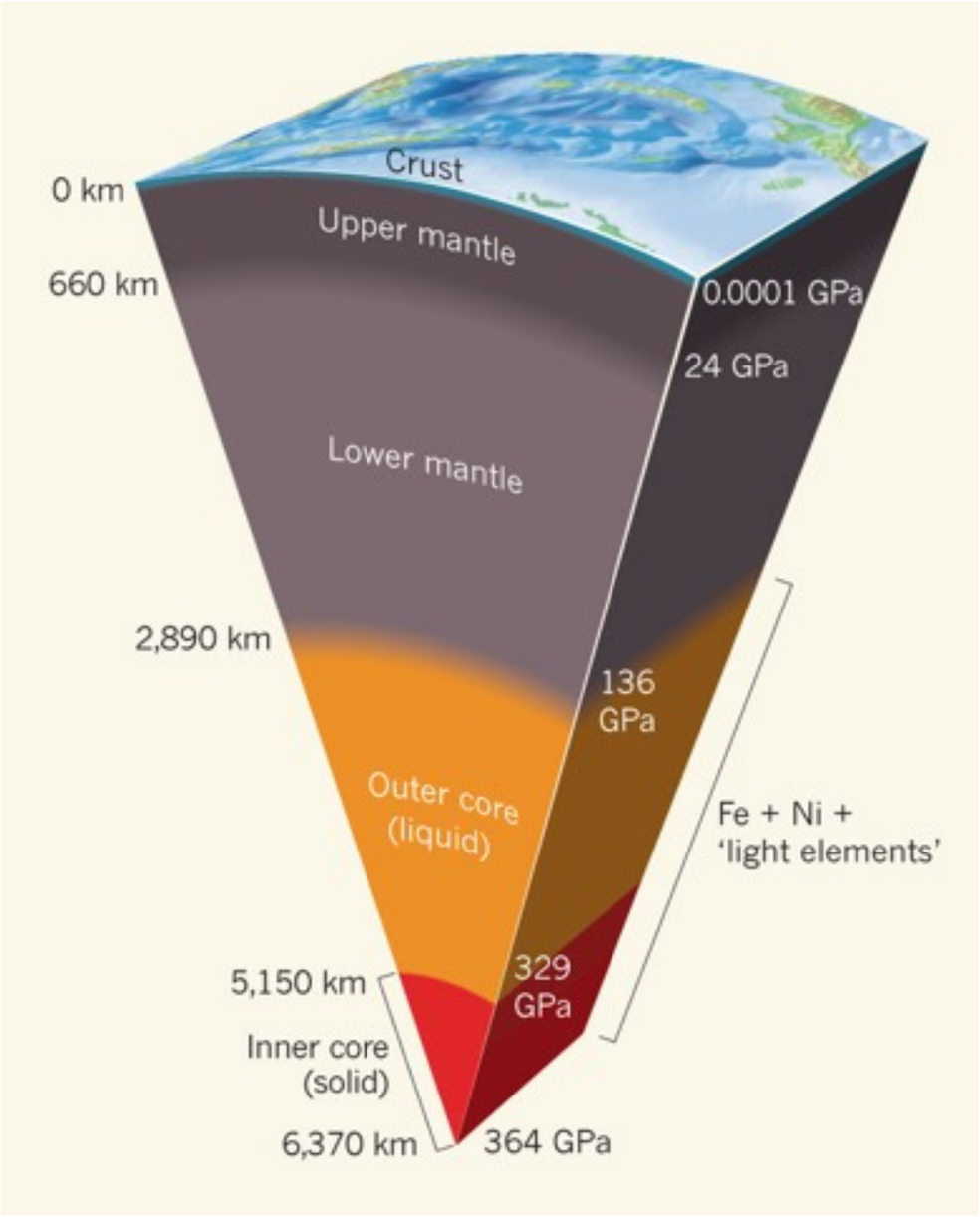
$$^{40}\mathrm{K} \rightarrow ^{40}\mathrm{Ca} + e^- + \bar{\nu}_e + 1.31 \quad \mathrm{MeV}$$



Geoneutrinos detected with KamLAND

Why do we care about geoneutrinos?

- Provide constraints on models of plate tectonics, mantle composition, generation of Earth's magnetic field, abundance of U/Th
- Other methods (upper mantle samples brought to surface through volcanic and tectonic processes) cannot access the lower mantle
- Source of radiated heat (~47 TW): radiogenic heat & primordial heat

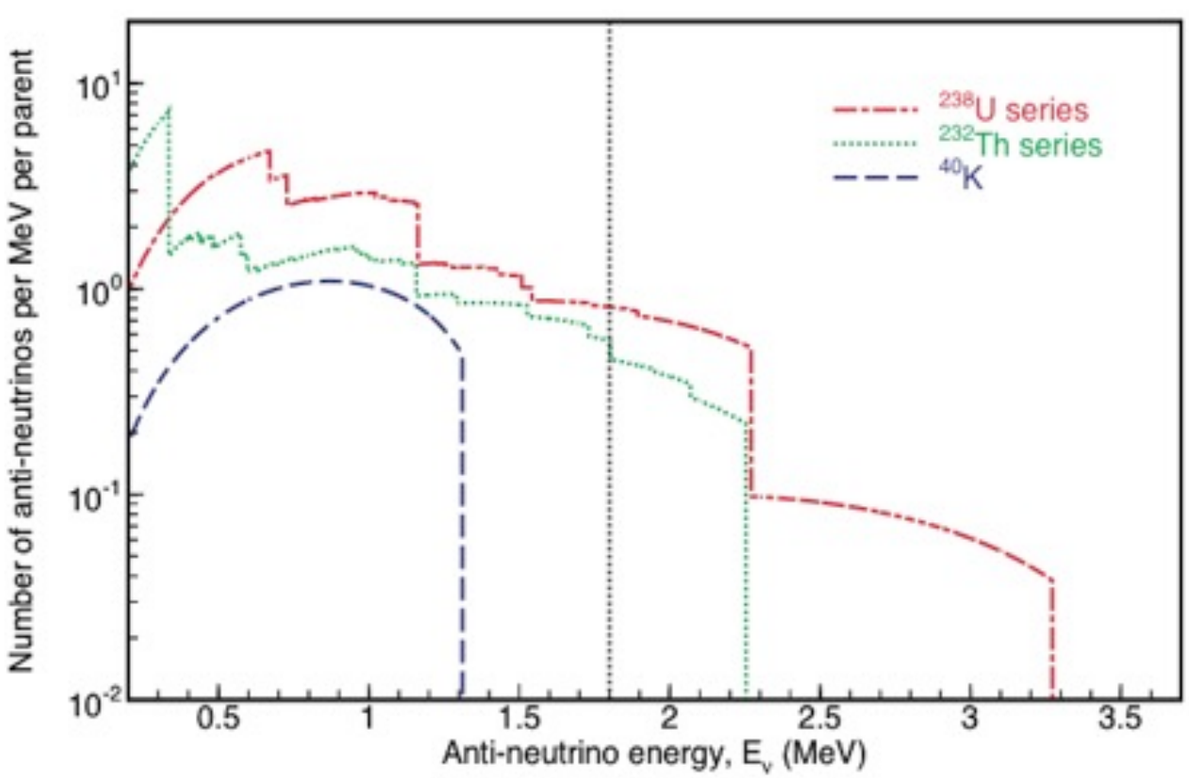


Earth science: probing the core's light elements. Nature, 479 (2011)

Detection Method

- neutrino interacts with proton to produce e+ and n
- e+ annihilates with e- emitting 2 gamma rays
- n captured by p to form deuteron and emits a gamma

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

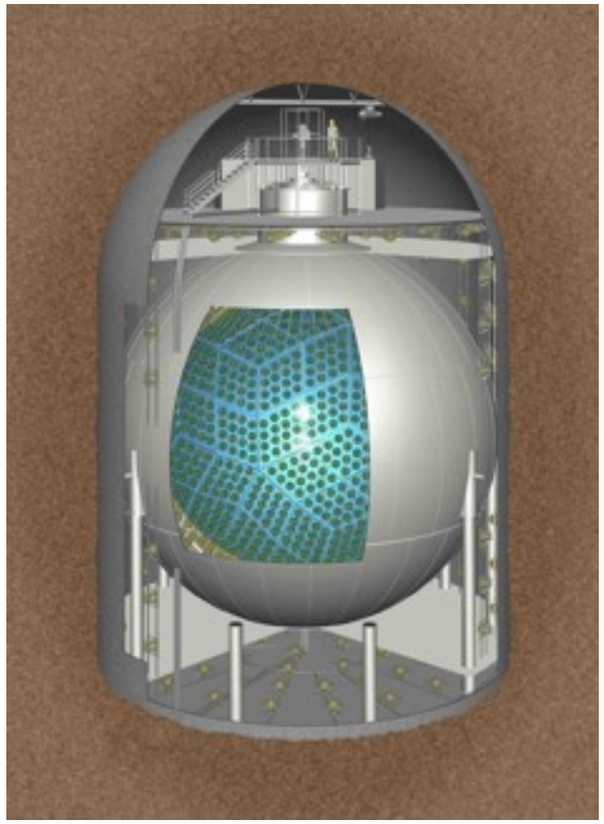


- event defined by two flashes in coincident time (~100μs) and space (<1m)
- threshold energy = 1.804 MeV (geoneutrinos from K-40 cannot be detected)

Geoneutrino Experiments

KamLAND (Japan)

- 1 kiloton detector
- First detection of geoneutrinos (2005)
- Reduced background from reactor shutdowns led to new results (2013) that constrain U/Th radiogenic heat to 11.2 TW



KamLAND detector (LBL)

Borexino detector (NSF)

Borexino (Italy)

- 0.3 kiloton detector
- 14 geoneutrinos of 46 candidates (2013)

Conclusions

- Geoneutrinos are electron neutrinos that originate from Uranium and Thorium decays in Earth's mantle and crust
- Measurements of geoneutrinos provide information used to constrain geological models of plate tectonics, mantle composition, radiogenic heating rates, etc.
- Inverse beta decay allows us to detect geoneutrinos above 1.8 MeV threshold energy (excluding K40 neutrinos)
- KamLAND and Borexino have successfully detected geoneutrinos
- Future experiments include SNO+ (Ontario, Canada), which hopes to measure a higher rate of geoneutrinos with decreased background, and LENA (Low Energy Neutrino Astronomy)

References

- G. Bellini, *et al.*,"Geo-neutrinos," Progress in Particle and Nuclear Physics, **73**, (2013).
- Borexino Collab., "Measurement of geo-neutrinos from 1353 days of Borexino," Physics Letters B, **722**, (2013).
- kamland.stanford.edu/GeoNeutrinos/geoNeutrinos