Neutrino Sciences 2005
Neutrino Geophysics
Honolulu, Hawaii,
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Conference Introduction

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University of Hawaii
Welcome!

• Looking forward to unique cross-disciplinary discussions, and personally to learning some geology.

• Interesting new science possibilities bring us together… a joy for many of us.

• Chance to ask those “dumb” questions!
Neutrino Science Blossoming

- Scientific curiosities
  → some applications.
- Probes of inaccessible locations: centers of galaxies, supernovae, sun, earth and nuclear reactors.
New ν Possibilities

• Old (and new) ideas to study geo-nus now verging on realization.

• We perhaps know more about the deep interior of our sun than the earth beneath our feet.

• Can we use neutrinos?
Natural radioactivity of Uranium, Thorium and Potassium produces electron anti-neutrinos.
Electron Anti-neutrino Detection

- Cleanest detection uses inverse beta decay: $\bar{\nu}_e + p \rightarrow n + e^+$ original Reines technique.

- Long distance detectors need unprecedented radio-purity ($<10^{-16}$ contamination)… but already achieved in KamLAND and Borexino, deep underground.

- KamLAND has measured ~200km distant reactors, made first measurement of earth U,Th $\nu$’s, and made first limits on georeactor.
Measure more than just rate?

- Measuring these neutrinos **directions** is VERY difficult now, but some prospects.

- Neutrino oscillations understood:
  Provide **distance** dependent **modulation** of spectrum (statistical), which we can (eventually) exploit at modest ranges, but still not easy.
Locations for Possible Geonu Experiments

Color indicates U/Th neutrino flux; red-green: mostly from crust; blue: mostly mantle/core
Synergy of Multiple Observations

- Need >1 measurement of U/Th in next round.

- Measurements from various continental and ocean locations will reveal mantle + core contribution.

- Within a few years we should be able to report U/Th content of mantle+core to about 20% precision.
What do we know about the earth?


- Sound velocities from seismic data + total mass and moments: infer density profile, but element mix ambiguous.

- Internal heat drives circulation producing continental drift and geomagnetic field.

- Surface heat flow small (compared to solar irradiance) and measurements not well constrained due to model dependence: 30-45TW.

# Overview of Earth Heat

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<thead>
<tr>
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<tbody>
<tr>
<td>Potassium (K)</td>
<td>170</td>
<td>3.7 ± 50%</td>
<td></td>
</tr>
<tr>
<td>Uranium (U)</td>
<td>0.018</td>
<td>10.0 ± 50%</td>
<td></td>
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<tr>
<td>Thorium (Th)</td>
<td>0.065</td>
<td>10.5 ± 50%?</td>
<td></td>
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<tr>
<td>Total Radioactive</td>
<td></td>
<td>24.2 ± 50%?</td>
<td></td>
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<tr>
<td>Other Sources</td>
<td></td>
<td>&lt;10 ?</td>
<td></td>
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<tr>
<td>Geo- Reactor</td>
<td></td>
<td>0-10 ?</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Total Heatflow</td>
<td></td>
<td>30-50</td>
<td>30-45</td>
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*Abundances from John Verhoogen, 1973*
So where are the Radioactive Elements?

- U/Th mixed in mantle, like slag in crust, in core, or some combination?

- If U/Th in core does it burn, breed?

- K seems to be under-abundant on earth: hiding in core?

- We will have much discussion of these issues....
Other Applications of Future Large Low Energy Neutrino Detectors

- Monitoring of nuclear reactors for illicit production of weapons materials.
- Now done up close (10-100m), can be done with present technology to 100km, eventually could make world network.
- Monitor clandestine bomb tests.
- Excellent science… geology to astrophysics: serious earth tomography, detect SN out beyond Virgo Cluster, ….
Reactor Monitoring Requires Enormous Detectors

The Tyranny of Counting Quarks

Size for 25% measurement of reactor flux, no background.
Long Range Future: Other Neutrino Geophysics Possibilities

• Earth tomography using neutrino factories plus giant detectors.

• Maybe also with natural high energy neutrinos.

• Potential to search for oil, measure earth inhomogeneities, measure core properties
Challenge and Outlook

- **Geologists**: tell us what you need to know most & what are the range of possibilities for what we may find. Also, please tell us about potential for unorthodox phenomena, such as the hypothetical geo-reactor.

- **Physicists**: tell us what you can do now, and in a few years. How well can we measure the U/Th content? Can we measure the K content? Can we do radial distributions?

- **All**: What are the larger implications of these measurements for life on earth, and in other circumstances?

- **Outlook**: lots of fun, as we witness here perhaps the birth of a new and important area of science.

*Enjoy the meeting!*