THE HANOHANO NEUTRINO DETECTOR AND ONGOING R&D

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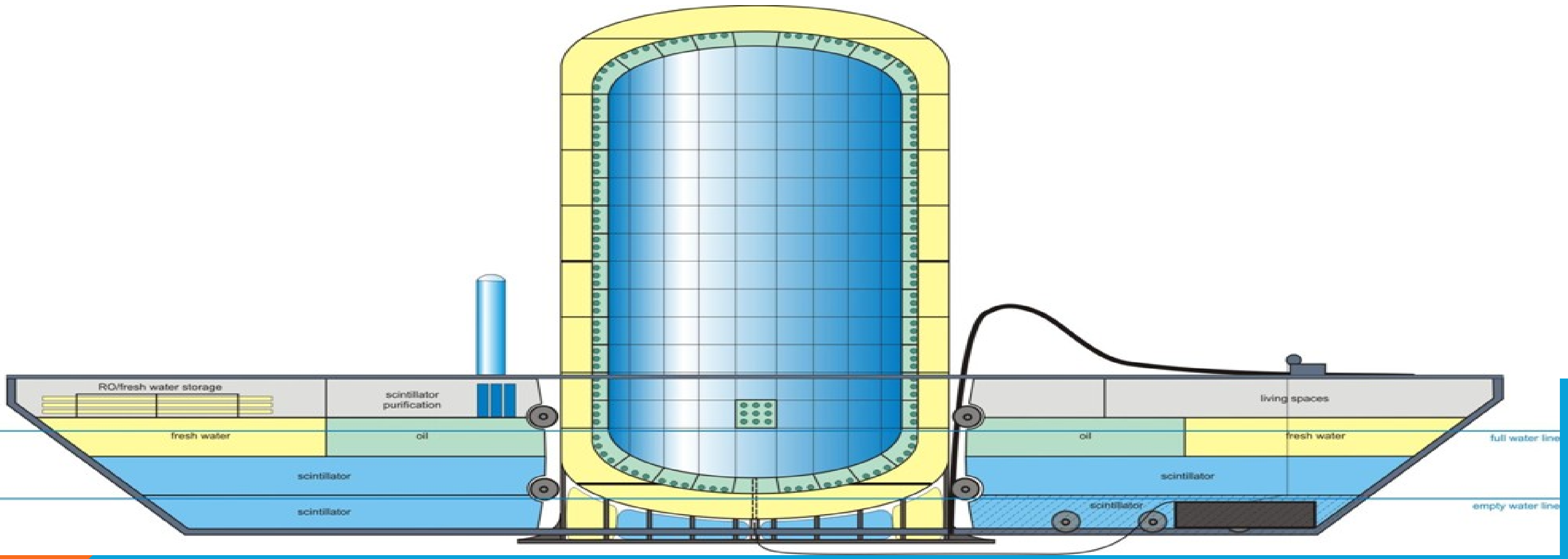
The Hanohano neutrino detector is a deep sea module that can be submerged to the ocean floor far away from surface radiation. Its Physics goals are the study of geo-neutrinos to probe the isotope source of the 45 TW of heat driving all of geodynamic processes in the earth, enhanced studies of neutrino oscillation from reactors through variable distance observations, and as an observatory for astro-physical neutrino sources. Nuclear surveillance of unknown nuclear reactors can be a key mission for a mobile neutrino detector that is also under consideration. The Hanohano detector details will be presented and a summary of the ongoing research and development at the University of Hawaii for neutrino direction detection development reviewed.

GOALS

- **Build a portable detector**
  - A portable detector can be used for long range nuclear proliferation monitoring
- **Take measurements of the unknown mixing angle theta 13**
  - Could help explain the neutrino mass hierarchy
- **Find the neutrino flux from the Earth's mantle from Uranium and Thorium decay**
  - The power output due to these decays does not match the measured power output
  - Some scientists in the Geological community hypothesize that there is a nuclear reactor at the center of the Earth

The Detector

- **The detector is a 10 kiloton liquid scintillation detector that will be positioned offshore by 50 km**
    - This will weed out the background neutrinos from reactor complexes since the detector will be submerged and sitting on the sea floor
- **The detector will use traditional photomultiplier tubes (PMT)**
    - Must be strong enough to withstand a very high pressure



WHAT IS A GEONEUTRINO?

Table from Fiorentini et all

Table 1
The main properties of geo-neutrinos.

Decay	Q [MeV]	$\tau_{1/2}$ [10^9 yr]	$E_{\max}$ [MeV]	ϵ_H [W/Kg]	$\epsilon_{\bar{\nu}}$ [$\mathrm{kg}^{-1}\mathrm{s}^{-1}$]
$^{238}\mathrm{U} \rightarrow {}^{206}\mathrm{Pb} + 8\,{}^4\mathrm{He} + 6e + 6\bar{\nu}$	51.7	4.47	3.26	0.95×10^{-4}	7.41×10^{7}
$^{232}\mathrm{Th} \rightarrow {}^{208}\mathrm{Pb} + 6\,{}^4\mathrm{He} + 4e + 4\bar{\nu}$	42.7	14.0	2.25	0.27×10^{-4}	1.63×10^{7}
$^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + e + \bar{\nu}$	1.32	1.28	1.31	0.36×10^{-8}	2.69×10^{4}

PORTABILITY

- **With sufficient positioning, the neutrino detector can be used for nuclear reconnaissance**
  - Further research into neutrino energies may also yield clues of energy of nuclear explosions
  - Must be able to fit through the locks of the Volgagrad Seaway

http://www.dusharm.com/content/view/21/2/

MIXING ANGLE Θ_{13}

- Θ_{13} is the smallest undetermined angle in the 3 flavor neutrino mixing scenario (Dalnoki-Varess)
  - θ_{13} might help in determining the mass of the neutrinos
  - It might also help in determining if any of the masses are degenerate (Gouvêa)

EARTH'S HEAT SOURCE

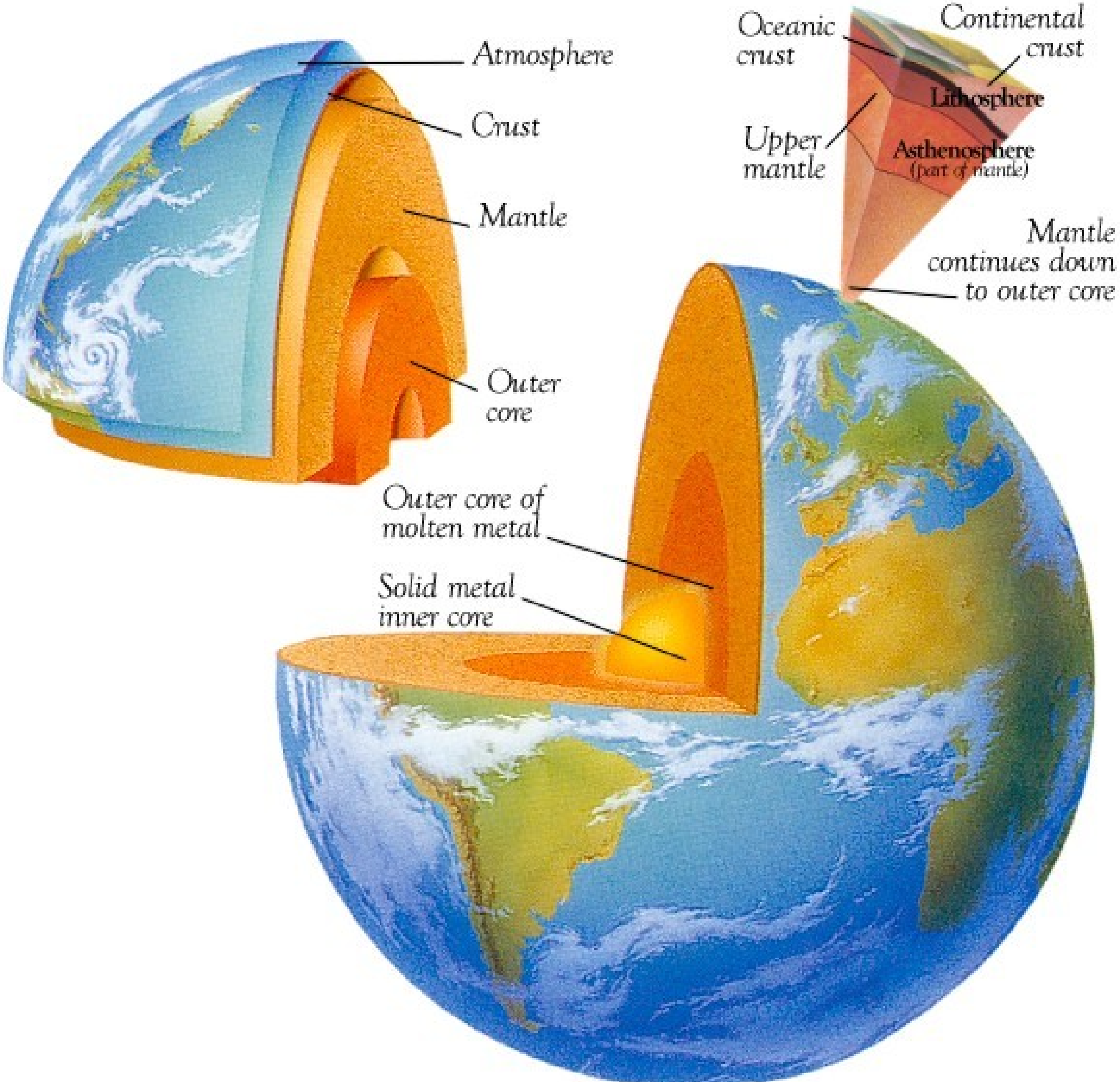
- **The current theory is that the terrestrial heat comes from the Uranium -238, Thorium-232 and Potassium-40 decay**
  - But the predicted power of the earth and the actual power values of the Earth do not match up
- **Generally, the heat flux from the earth is about 60 mW/m^2. (Fioritini et al)**
  - If you integrate over the entire Earth you get between 30-45 TW. (Fioritini et al)
- **Radioactivity could account for 60 to 100% of Earth's heat output**
  - But if you add the past radiogenic heat output, the tidal friction, and the gravitational energy then the values shoot way over 100% of Earth's heat output (Fioritini et al)

NUCLEAR REACTOR?

- **Some Geologists and Geophysicists are hypothesizing that there is a nuclear reactor at the center of the earth**
  - There is evidence in the past of a nuclear reactor on Earth
    - In 1972 a Uranium ore seam in a mine located in western Africa showed signs of being a natural nuclear reactor (Herndon)
- **Other planets too could have nuclear reactors**
  - Jupiter radiates about twice as much energy as it receives (Smith)
    - If there is a nuclear reactor at the core of every planet (with magnetic field) then this could help explain this energy discrepancy

HANOHANO'S DETECTOR

- Would be more than an order of magnitude larger than KamLAND's detector (Dye et al)
- The continental crust contains a much higher concentration of Uranium and Thorium so a site, like the Hawaii abyssal plain, is chosen for the detector
  - This way the detector should only pick up geoneutrinos coming from the core and mantle



http://www.solcomhouse.com/images/struct.jpg

EXPECTED BACKGROUND (DYE ET AL)

- ^{9}Li produced by cosmic rays
- Fast neutrons from cosmic rays passing near the detector
- α decay of ^{210}Po followed by $C(\alpha,n)^{16}O$ in the scintillating oil
- Accidental or random coincidences
- Anti-neutrinos from commercial nuclear reactors
- Anti-neutrinos from a hypothetical georeactor

EXPECTED EVENTS (DYE ET AL)

	Events $(10\ kT\text{-}y)^{-1}$		
	SNO+	**Borexino**	**Hanohano**
^{9}Li	0 ± 0	3 ± 1	3 ± 1
^{210}Po	8 ± 2	8 ± 2	8 ± 2
Accidental	42 ± 1	42 ± 1	42 ± 1
Reactor	528 ± 21	295 ± 12	12 ± 1
Crust Geo-νs	368 ± 74	279 ± 56	31 ± 6
Background	946 ± 77	627 ± 57	96 ± 7
Mantle	79	79	79
Total ($N \pm \sqrt{N}$)	1025 ± 32	706 ± 27	175 ± 13
Expected Signal	79 ± 109	79 ± 84	79 ± 20

GEOREACTOR – 38 EVENTS/ TW_T/10KT-Y

Figure from Dye et al

Geo-reactor Background	Rate $(10\ kT\text{-}y)^{-1}$
^{9}Li (4 km)	4 ± 1
^{210}Po	1 ± 1
Accidentals	1 ± 0
Commercial Reactors	24 ± 1
Total Background	**30 ± 2**
Geo-reactor Signal	**38/TW_t**

CONCLUSION

- The HANOHANO project may help in finding the mixing angle θ_{13}
- The detector's schematics can be utilized for the monitoring nuclear proliferation
- The project aims to get to the bottom ☺ of the Earth's mystery of the missing power
- Questions?