# Astrophysics in the Abyss

***Hovering quietly nearly 5 kilometers under the sea, DUMAND will watch and wait for ghostly particles coming from the most violent regions of the universe***

*Kona Coast, Hawaii*—HERE ON THE ARID western shore of the Big Island, where the land is a vast jumble of lava fields and the beaches are small pockets of sand, a swimmer can stand chest deep in the waves and look straight down at his feet as if there were nothing but air in the way. The tourist brochures have it right: the waters of Kona are among the purest and clearest in the world—a fact that has led a consortium* of physicists from the United States, Europe, and Japan to choose the crystalline depths off the coast here for a unique experiment. They want to use the ocean itself as a telescope for cosmic neutrinos.

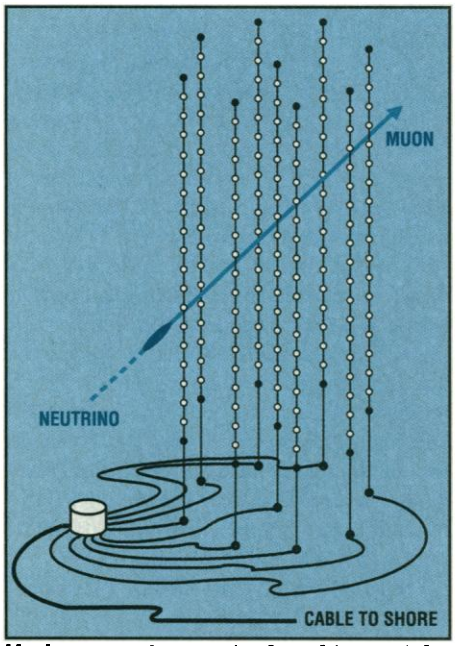
It won't be easy. Neutrinos are ghostly subatomic particles so feeble in their interaction with ordinary matter that they can happily pass through Earth without stopping. In fact, they have almost never been observed outside the controlled environment of the big accelerator laboratories such as Fermilab in the United States and CERN in Europe. And yet, as the product of thermonuclear reactions deep inside stars, supernovas, and other such violent events, neutrinos presumably carry a wealth of astrophysical information about places that ordinary telescopes can't reach.

The Deep Undersea Muon and Neutrino Detector, or DUMAND as the Hawaii project is known, will go after the most energetic of these cosmic neutrinos—the kind that are thought to be coming out of young pulsars, far-off "active" galaxies, and the center of our own galaxy. If all goes well and DUMAND becomes fully operational as planned in 1993, it should shed new light on exactly what's happening in the violent environs of these objects. In doing so it would also search for totally new particle phenomena taking place at energies and densities that far exceed anything conceivable in a terrestrial laboratory.

And best of all, it should accomplish all this for what the Department of Energy considers small change: less than $10 million, of which half will be contributed by DUMAND's Japanese and German collaborators. Indeed, the comparatively low cost of the project seems to have been a major factor last year when a subpanel of the department's High Energy Physics Advisory Panel recommended that DUMAND be given the go-ahead—while nixing two other cosmic ray projects that were more expensive.

The idea of using the ocean as a detector actually goes back to the 1960s, says University of Hawaii physicist Victor Stenger, one of the principals on the DUMAND team. "And people started taking it seriously back in the mid-1970s."

By then, he explains, astronomers realized that neutrinos are even more common in the universe than photons, if only because the Big Bang left a sea of very low energy neutrinos that permeate every corner of the cosmos. But as the DUMAND idea took shape over the years, its proponents came to realize that their best bet lay in the search for neutrinos with the very highest energies, above about 1 trillion electron volts. These are the kind of neutrinos thought to be generated in the cores of active galaxies such as Centaurus A, where a multimillion solar mass black hole appears to be swallowing stars and gas wholesale, or in the environs of a compact binary such as Cygnus X-3, where a tiny, incredibly dense neutron star is siphoning matter from a normal companion star and drawing it down to its surface with thermonuclear force.




**Undersea octagon.** *Anchored in an eight-sided array, the detectors rise upward.*

Although such high-energy neutrinos are quite rare, they would make up for their scarcity by having a much higher probability of interacting with ordinary matter once they reached Earth, Stenger says. Furthermore, he says, such a reaction would produce a high-energy muon: an unstable, electron-like particle that would release a burst of bluish Cerenkov radiation as it passed through matter at nearly the speed of light.

DUMAND's job will be to watch for this Cerenkov radiation in the deep ocean, says Stenger. To accomplish this feat, the DUMAND physicists plan to deploy 216 sensitive photodetectors on the abyssal ocean floor some 30 kilometers off the Kona coast and some 4800 meters down. The individual detectors will be encased in nitrogen-filled, clear plastic spheres about the size of beach balls, and then strung out in groups of 24 along nine separate cables. The cables, in turn, will be anchored to the ocean floor in an octagonal pattern the size of a football field, with one cable in the middle, and will rise vertically for 230 meters. Floats at the top of each cable will hold it upright.

By watching which detectors respond to a passing muon, the DUMAND scientists will be able to calculate its trajectory and thus determine its point of origin in the sky. The maximum angular resolution of the undersea telescope should be about 1°, or twice the diameter of the full moon.

A successful observation is by no means guaranteed, concedes Hawaii's Vincent Peterson, another of the DUMAND principals. The telescope will have to pick up at least ten muon events per year from any given 1° patch of sky for DUMAND scientists to be sure they have a significant neutrino source and not just a few background pulses from non-neutrino cosmic rays. And yet the estimated rates for plausible neutrino sources range from just one event per year to 1000 per year. "So this is the minimum array that has any chance of detecting these sources," says Peterson.

In any case, the team is now gearing up for deployment. In the fall of 1991 they plan to lay a fiber optic data cable from shore to a junction box on the bottom. In the summer of 1992 they plan to put three detector strings down for testing. And in the summer of 1993, if all goes well, they plan to deploy the remaining six.

And from there? "If we *do* detect something we'll immediately propose to increase the size of the array," laughs Peterson. "That's the beauty of DUMAND—you've got the whole ocean to expand into."

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*The members include the universities of Hawaii, California (Irvine), and Wisconsin (Madison), Vanderbilt University, the California Institute of Technology, and the Scripps Institution for Oceanography in the United States; the University of Tokyo, Japan; the universities of Aachen and Kiel in Germany; and the University of Bern in Switzerland.