present a similar map. They used Lepore DNA restriction fragments to discriminate between β and δ globin containing fragments, and a short 3′ specific β-globin cDNA to orient restriction fragments. They have also obtained evidence for intervening sequences of about 1,000 bases in β, δ and Lepore-globin genes.

The next targets for both these groups, and others, are obviously the β^0 and β^+-thalassemic DNAs, and the γ-globin genes, and the results will be awaited with great interest. ☐

Deep-sea neutrinos

from David Eichler

THE Deep Underwater Muon and Neutrino Detector (DUMAND) is one of the most ambitious experiments ever conceived. As presently seen, it will consist of thousands of photomultiplier tubes and perhaps some hydrophones distributed over a cubic kilometre of seawater, more than six kilometres below the ocean surface. This is deep enough so that from most angles, neutrinos are the only high-energy particles that can reach the detector. The array will measure the energy and direction of the hadronic showers and muon tracks that are generated by interacting neutrinos. Nature produces neutrinos of extraordinary energies, in cosmic ray interactions with the Earth's atmosphere, for example, and with DUMAND, physicists plan to study interactions at energies much higher than can be attained in man-made accelerators.

Besides its use to study high-energy interactions, DUMAND, by virtue of its excellent angular resolution, will be an excellent neutrino telescope. In September, a group of physicists and astronomers gathered at the Scrips Oceanographic Institute in La Jolla, California, to discuss what sort of astrophysical systems might produce enough high-energy neutrinos to be detected by DUMAND. High-energy neutrinos are produced when high-energy protons bombard ambient material. It has been noted (for example, Eichler *Astrophys. J.* **222,** 1109; 1978; Berezinsky & Prilutsky *Astrofizike Pis'ma* **3,** 152; 1977) that such high-energy collisions may occur at significant rates in quasars, active galactic nuclei, binary systems and young supernova shells that contain pulsars, and supernovae that go off inside interstellar clouds. In all these systems high-energy particles are produced in a medium of considerable ambient density and high-energy collisions are inevitable. Thus, there is at least a good chance that such systems could be seen with DUMAND.

Much can be learned about potential high-energy neutrino sources from gamma-ray astronomy, since gamma rays are produced in the same collisions that produce high-energy neutrinos. Gamma-ray astronomer T. Weekes (Harvard/Smithsonian) spoke about the very high energy gamma-ray detections of Cyg X3, widely held to be a pulsar in a binary system, and the active galaxy Cen A. These observations are significant because if these gamma rays are generated in high-energy proton collisions then the associated neutrino emission from these objects would be detectable. C. Fichtel and F. Stecker (both of Goddard Space Flight Center) pointed out that present limits on γ-ray intensities imply that any steep spectrum source that is optically thin to gamma rays cannot be a very strong source of high-energy neutrinos, although it may still be marginally detectable by DUMAND.

The most distant, mysterious processes that generate high-energy neutrinos may be the explosions that occur in the centres of active galaxies and quasars. As noted by J. Scott (University of Maryland) and coworkers, most of the neutrino production that is hypothesised to occur in these explosions may take place during the first few hours, when the ejected material is most dense, and most opaque to photons. Since these explosions, as observed at radio wavelengths, typically last a year or so, DUMAND may serve as an 'eye' that will alert astronomers to new explosions.

In marked contrast to quasars, the closest, most familiar, and—in the eyes of many—most amusing source of high-energy neutrinos may be the Sun. Galactic cosmic rays bombard the Sun's atmosphere in the same way as they do the Earth's, producing high-energy neutrinos. However, they are produced in the Sun's atmosphere much more effiicently. This is because the Sun's atmosphere, being more tenuous, allows most of the relevant high energy mesons to decay into neutrinos, whereas most of them would first be degraded by collisions in the Earth's atmosphere. Thus, the disk of the Sun stands out above the atmospheric background of the Earth in high energy neutrinos. Estimates of the count rate are still uncertain—they depend, for one thing, on the extent to which the Sun shields itself from high energy cosmic rays with strong, large scale, closed magnetic field lines—but they do indicate a strong possibility for seeing the Sun with DUMAND.

There is much uncertainty intrinsic to astrophysical speculation. Despite the uncertainty in extrapolating high energy physics to energy ranges that have not yet been investigated, one conclusion at least can be drawn from the High Energy Neutrino Workshop. As well as an instrument for doing high energy physics with atmospherically generated neutrinos, DUMAND will be a sufficiently powerful neutrino telescope to study a wide variety of astrophysical systems. Certainly the history of astronomy has been that whenever a new window has been opened, be it in radio, X-ray or gamma-ray astronomy, no matter how radical it seemed at first, there have always been new phenomena seen through it. Astronomers and physicists are hopeful this trend will continue into high energy neutrino astronomy.

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Photochemical conversion of solar energy

from Anthony Harriman

THE energy crisis of the early 1970s has stimulated considerable growth in solar energy research. Practical means for collection and storage of sunlight offer a great challenge to the scientist; the areas for possible development are virtually unlimited. Many of the latest advances in the application of photochemistry to solar energy research were reported at a recent meeting in Cambridge.*

The photochemical production of a useful chemical fuel is, in many respects, closely allied to the natural photosynthetic process of higher plants. The natural process reduces CO_2 to carbohydrate whilst oxidising H_2O to O_2 but most laboratory models are concerned solely with production of H_2. G. Porter (Royal Institution) stressed two important points that are valid for all models. First, the cost of conventional power sources is about $\$1$/Watt whilst the incident solar energy is roughly 250 Watt m^{-2}. Hence, for a model operating at a 10% conversion efficiency, it is necessary that the total cost of energy output be about $\$25/m^2$. Therefore the model must provide a fuel from a cheap reagent such as water and it must be catalytic with respect to all other reagents. Second, if H_2O is the consumable reagent then its oxidation product must be O_2. Formation of any other product means that production of the fuel will always be

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*2nd International Conference on the Photochemical Conversion and Storage of Solar Energy, Cambridge, 10–12 August, 1978.

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