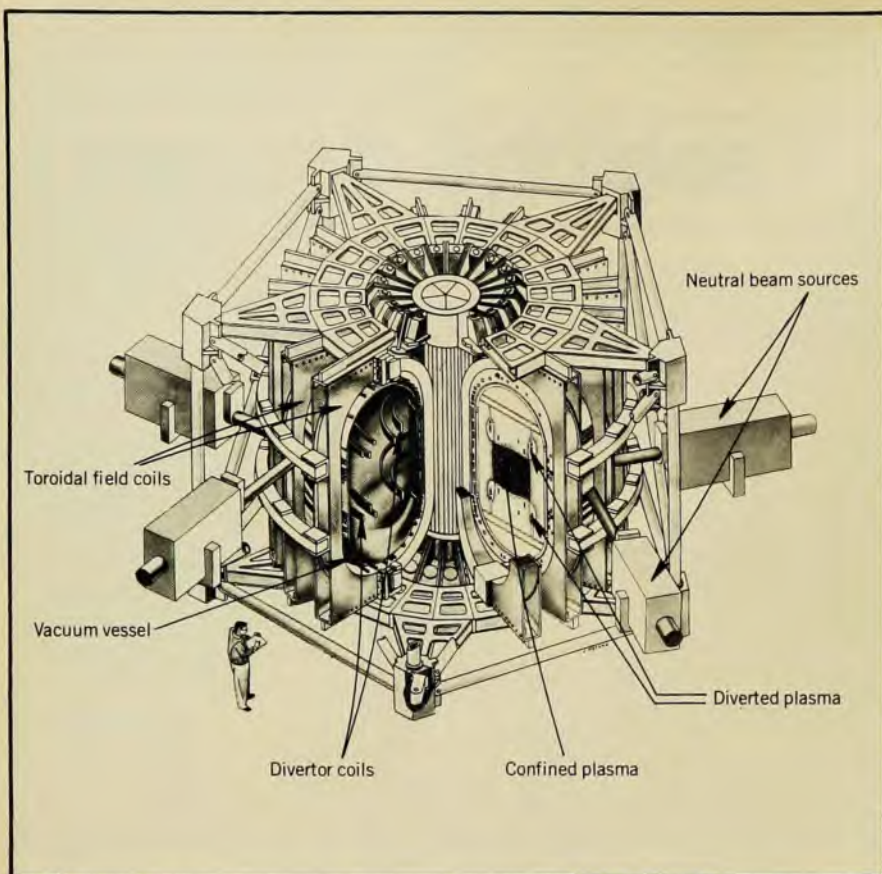




Poloidal Divertor Experiment, under construction at Princeton. Divertor coils inside vacuum vessel provide a poloidal field to direct impurities away from the plasma confinement region.

and into a "burial chamber" outside the confinement area, were first proposed 20 years ago. The Princeton lab tested the concept with their Model-C Stellarator in the last decade; a toroidal divertor, located in asymmetric fashion at a point along the torus's edge, functioned as intended. In the PDX, the plasma is to be confined with magnetic separators and the poloidal divertor field will be axially symmetric to help maintain plasma stability. The plasma size as a function of time will be adjustable, to prevent skin-effect problems associated with the plasma-current buildup.

The PDX will lend itself to another scientific objective as well: to study equilibrium properties of assorted plasma configurations and thereby to determine the optimum plasma cross section for a tokamak. Plasma behavior will be compared for circular and elongated cross sections, which could be D-shaped or even rectangular.

The PDX—proposed in late 1973 and initially funded in FY 1975—represents yet another link in the chain of experimental fusion devices at the Princeton lab, a chain researchers hope will lead to a demonstration fusion-power plant. Princeton's Model-C Stellarator was transformed in 1969 into the ST Tokamak. The PLT followed after the lab's Adiabatic Toroidal Compressor, used to demonstrate that heating by compression

could be employed in a plasma in a tokamak.

Larger than but similar to the PLT will be Princeton's Tokamak Fusion Test Reactor, which will eventually be operated with deuterium-tritium burning. It is scheduled for completion in 1981 at a total estimated cost of \$228 million. Ebasco Services Corp, in association with Grumman Aerospace Corp, recently became Princeton's subcontractor for the building of the TFTR.

—FCB

Neutrino search to go deep undersea?

A group of physicists, oceanographers and oceanographic engineers is studying the possibility of using the oceans to detect neutrinos originating in Earth's atmosphere and beyond. The group, which has organized itself under the acronym DUMAND (Deep Underseas Muon and Neutrino Detector), is now planning a second summer workshop this year.

The detection of extraterrestrial neutrinos—neutrino astronomy—from extragalactic supernovae (10–20 MeV) and from collisions between cosmic-ray protons and intergalactic and galactic gas requires enormous detectors in the megaton range. It is not at all clear that such giant devices can be con-

structed with the required low background or at a reasonable cost, but the DUMAND group considers the prospects sufficiently promising to justify further study.

Chairman of the DUMAND executive committee is Frederick Reines (University of California, Irvine), who, together with Clyde L. Cowan, was the first to observe neutrinos experimentally. Reines remarked that it has been recognized for many years that the extraordinary penetrating power of a neutrino, measured in light years of solid matter, makes it a unique tool for the investigation of stellar interiors as well as providing other information uninhibited by intervening matter.

The first serious foray into low-energy neutrino astronomy was made by Raymond Davis and his collaborators (Brookhaven National Laboratory), whose search for low-energy (about 1 MeV) neutrinos from the Sun has so far yielded negative results. In fact the Davis experiment has underscored our ignorance of stellar interiors, Reines notes, and shows the importance of information one might hope to obtain from neutrino astronomy.

Consideration of expected neutrino fluxes and the strength of the neutrino interaction suggests that one would need a very large detector, possibly in the range 10^6 – 10^9 tons. Economic factors suggest using clean sea water, both as target and detector. (A fast charged particle, secondary to the neutrinos, produces light pulses in the form of Cerenkov radiation, which can be observed with photomultiplier tubes.) Such a large detector would be overwhelmed by ordinary cosmic rays at Earth's surface; thus a deep, underwater location—about 5 km—is under consideration.

At last summer's workshop, held at Western Washington State College in Bellingham, Washington, the group evaluated the possible role of such a deep underwater muon and neutrino detector in high-energy physics in the supra-accelerator region (greater than 10^{12} eV) and the problems associated with the detection of supernovae and other cosmic sources.

Plans are now being formulated for a second summer workshop, which would be directed by executive-committee member Arthur Roberts (Fermi National Accelerator Laboratory). Participants will study the detailed design of a detector in the 1–10 TeV range. They will consider whether or not one can build a photomultiplier collecting apparatus that can detect antineutrinos from a supernova. Another question is whether one can study neutrinos produced in high-energy cosmic-ray proton collisions with interstellar or intergalactic gas and collisions with the 3-K blackbody radiation and distinguish

them from atmospheric background. Other topics will include: oceanographic and marine-engineering problems, preliminary schemes for deploying large photomultiplier tubes, problems with bioluminescence and the transmission of water, and choice of site.

The Navy Underseas Center in San Diego is lending an unmanned submersible to DUMAND. The group is now designing apparatus for optical transmission and bioluminescence measurements to be made at great depths in the ocean.

At the International Cosmic-Ray Conference held in Munich last summer, discussions with physicists from other countries led the DUMAND group to hope that an international collaboration might be possible. For example, some Soviet experimenters have expressed interest in participating in the project.

The DUMAND executive committee consists of Howard Blood (Navy Underseas Center), John Learned (University of Wisconsin), Roberts and Reines (chairman). The steering committee, in addition to the above, consists of Ugo Camerini (University of Wisconsin), Peter Kotzer (Western Washington State College), Clive Lister and Seth Neddermeyer (University of Washington), and David Schramm (University of Chicago). —GBL

X-ray bursts

continued from page 17

P. Conner, and W. D. Evans at Los Alamos had been analyzing data taken by the two Vela 5 satellites during their first 15 months of operation. Vela satellite data had previously been used (PHYSICS TODAY, December 1973, page 17) by Ray Klebesadel, Ian Strong and Roy Olson to discover short gamma-ray bursts. In the new analysis Belian, Conner and Evans found 20 very intense x-ray events, ten of which came from a region in the constellation Norma, which is 30 deg from the galactic center. The most intense of the Norma bursts was about three-quarters the intensity produced by Sco X-1 in its quietest phase. Unfortunately, time resolution was relatively poor. Burst duration was less than about 130 seconds for nine of the events and less than 190 seconds for one. One event was in a position consistent with the source observed by ANS, namely 3U1820-30.

The group sent in an abstract to the December meeting of the American Astronomical Society and subsequently described their results at the Cambridge meeting of the High-Energy Astrophysics Division of the AAS, held late in January.

When the Los Alamos group included weaker events in their analysis, Belian told us, they have a total of over 1000

probable events, bursts or large flares, over the 15-month period. Preliminary sky maps showing the locations of all of these have been prepared and submitted for publication. Belian says that several bursts were probably seen from 3U1820-30, as well as repeated bursts from other unreported sources.

SAS-3 results. The MIT group had observed something unusual in SAS-3 data, soon after its launch last May, but with a detector that has so large a field of view that they could not localize the source. When they heard of the ANS discovery, they examined their complete production data from May, taken when the same source seen by ANS was in the large field of view. They found a sequence of ten bursts that resemble in many details the ANS observations. Furthermore the bursts occurred more or less periodically with a period of about 0.182 days. However, the bursts were not perfectly periodic—they had a jitter of 3.9%. In the sequence of ten observed bursts, one was missing (number four); this burst, if it occurred, would have been blocked by Earth.

The group consists of George W. Clark, Claude R. Canizares, Jesse Jernigan Jr and Fuk Kwok Li (MIT). Coinvestigators on the project are Hale Bradt, Walter H. G. Lewin and Saul A. Rappaport (MIT) and Schnopper.

In May 3U1820-30 had been in a state of relatively low luminosity, compared to its condition when observed by the Uhuru satellite. Similarly, during the September bursts seen by ANS the source had low luminosity. In January the SAS-3 group looked for several days at 3U1820-30 but found no bursts from that source. During that time the source was highly luminous. Thus, Clark believes there is an anticorrelation between intensity and the burst phenomenon. Clark also notes that the two bursts seen by ANS were separated by 2×0.18 days, twice the period observed by SAS-3. At the intermediate time, no ANS observation had been conducted. However in the four-day interval that ANS observed the globular cluster, about 20 minutes exposure was obtained at the expected burst times; no other bursts were seen.

Assuming that the globular cluster is 5 kiloparsec away, the peak luminosity observed with SAS-3 is 2×10^{38} erg/sec. Total positional uncertainty is large compared to the size of the globular cluster itself. The ANS position for the source is within 2 arc minutes by 1 degree, centered on the globular cluster. The SAS-3 position is less certain. However the persistent source 3U1820-30 has been located within 1 arc minute of the center of the globular cluster NGC6624 by the SAS-3 measurements.

By the time the Cambridge conference took place, the three groups were able to compare notes, and theoretical explanations were being proposed (see below).

Newer results. In the next two weeks, SAS-3 explorers "fell into a nest of bursting sources," as Clark put it. While looking at 3U1820-30, one of the detectors saw bursts from another source but one could not tell where the bursts were coming from. Then Lewin looked from a different vantage point and saw several bursts from two more sources. It now appears from further work by Lewin and his associates that there are two separate sources within 1 deg of the galactic center. Most recently he finds two separate sources within 1 deg in the constellation Scorpius. In one of the two sources near the galactic center the bursts have more complex structure—they show multiple peaks.

The SAS-3 group has now reported evidence of periodicities in 25 bursts detected from the two sources near the galactic center. Twelve bursts fit a recurrence period of 0.55 days, and eight a recurrence period of 1.46 days. As in the previous observation, the occurrence times jitter in phase by several percent.

In data taken last summer, SAS-3 workers have found a burst from the constellation Aquila, far from the galactic center. And early in March the detectors found a burst in the constellation Puppis, 17 deg from the galactic plane and from a region that contains no globular clusters.

Clark notes that the x-ray bursts are unlike other transient phenomena. The gamma-ray bursts, for example, are more extended and frequently have additional afterpulses; both their spectra and time structure are different.

Late in February Christine Jones and William Forman (Center for Astrophysics) reported that in Uhuru data from September, 1972 they found an x-ray outburst localized to a region of about 0.5 deg by 10 deg, centered on MX0513-40 in the globular cluster NGC-1851, far from the galactic plane. The burst could have lasted several minutes. It had a decay time, however, of 25 sec.

In March Grindlay and Gursky had begun examining data from the galactic plane obtained by the 5-deg detector on Uhuru. They have found several bursts in the 1972 data from the Norma region, which confirm the Los Alamos results and refine the source position.

On 1 March SAS-3 began seeing bursts from a source in the constellation Scorpius, MXB1730-335, which had been quiet the previous month. Bursts repeat as often as four times a minute. The remarkable thing about them is that the time between two bursts is almost directly proportional to the energy of the first burst. The bigger the earlier burst, the longer one must wait until the next burst. Small bursts, which last a few seconds, are separated by periods of approximately 15 seconds. The biggest bursts, which last as long as 50 seconds, are separated by periods of 5–10 minutes.

The new observations were done by