Neutrino Astronomy Born in a Supernova

"It's just a neutrino high, just wonderful," says John Bahcall of Princeton (N.J.) University's Institute for Advanced Study.

"For me this is a kind of culmination of 20 years of work," says Alfred Mann of the University of Pennsylvania in Philadelphia.

"We've been waiting 25 years for this," says Frederick W. Reines of the University of California at Irvine.

They are talking about the detection of neutrinos from the supernova 1987A in the Large Magellanic Cloud (SN: 3/14/87, p.165). This appears to be the definitive finding of neutrinos from the supernova. United in the simultaneous detection are the Kamiokande II detector in Kamioka, Japan, and the IMB detector in Fairfax, Ohio, which is operated by the University of California at Irvine, the University of Michigan at Ann Arbor and Brookhaven (N.Y.) National Laboratory.

The discovery is, in Mann's words, an "existence proof" for a new science, neutrino astronomy. It shows that neutrinos can come to earth from distant astronomical events, bringing information about what is happening there.

During the weekend of March 7 and 8, analysis of Kamiokande's data made clear that on Feb. 23, the day the supernova's explosion was first seen, the detector recorded 12 bursts of neutrinos in 13 seconds at 7:35:35 a.m. universal time. Kamiokande II contains 2,000 tons of water, in which neutrinos can strike either electrons or free protons to produce Cherenkov radiation, a kind of light produced when a particle moves at a speed greater than the speed of light in water. Cherenkov radiation comes in cones, and in the case of the neutrino-electron interactions, the cones point back in the direction from which the neutrinos came. Two of the 12 bursts point back toward the supernova.

According to Mann, who is one of a group of U.S. scientists working with Kamiokande II, when the IMB people heard of the discovery they called Kamioka to ask the time of the finding. They then looked in their records and found eight events in a 10-second period at 7:35:41. The difference is within the uncertainties of timing that usually occur in this kind of data.

Unlike those in a previous European report, the energies of these neutrinos seem to be correct. Just after the supernova was noticed and before the neutrino records were found, Bahcall, Arnon Dar of the Technion in Haifa, Israel, and T. Piran of Hebrew University in Jerusalem calculated what Kamiokande II ought to see, they recount in their letter in the March 12 NATURE. When they called him from Japan to tell him of the discovery, Bahcall says, they told him the finding was "miraculously close to our prediction." At first glance, the numbers recorded seem far less than those given in the Bahcall-Dar-Piran paper, but the Japanese observers explain that by saying that the efficiency of their detector must be figured in, and then, they say, the figures agree.

The discovery tells almost immediately things about neutrino physics and complicates the longstanding puzzle over the energy-producing processes in the sun and why they do not produce the neutrinos they are supposed to.

At the beginning of a supernova explosion, the heavy core of the star about to explode collapses somehow under its own weight and forms a neutron star. The collapse crushes atoms, driving electrons into the nuclei where they combine with the protons to make neutrons, so that everything comes out neutrons. This process makes a flux of neutrinos that fly outward. Thus the neutrinos are a probe into the center of the supernova, into the process that makes a neutron star.

Moving at the speed of light, the neutrinos took 150,000 years to get here. That means that if they are in any way subject to radioactive decay, their lifetime still has to be greater than 150,000 years. Mann says this destroys one suggested explanation of the "solar neutrino puzzle."

The thermonuclear fusion processes that produce energy in the sun should produce a certain flux of neutrinos, according to the standard theory. The one experiment that has recorded solar neutrinos, which is directed by Raymond Davis of the University of Pennsylvania and is located in the Homestake mine near Lead, S.D., records about one-third of the expected number.

One suggestion of how to account for the discrepancy is that most of the neutrinos decay into something else on the way from the sun. However, that trip takes only 8 minutes, so if the neutrino's average life is 150,000 years or more, not many can get lost on the way from the sun.

Another suggestion that could solve the solar puzzle in a somewhat roundabout way requires neutrinos to have a very small rest mass. The theory that back around 1930 predicted the existence of neutrinos, as well as the experiment of about 30 years ago that first found them (in which Reines was a participant) and every uncontested experiment since, is consistent with their having zero rest mass, but experimenters keep searching.

If neutrinos have a small rest mass, they will have a small magnetic moment, a small intrinsic magnetism. (The converse is not true, so a zero magnetic moment does not necessarily mean no mass.) In a laboratory experiment reported in the Feb. 16 PHYSICAL REVIEW LETTERS, a group of 29 physicists including Mann set a magnetic-moment limit that is very close to zero. From the supernova data, considering how the galactic magnetic field would affect neutrinos if they had magnetism, Mann says the observers now can make the limit 100,000 times closer to zero.

The main reason the U.S. group is working with Kamiokande II is to instrument it to record solar neutrinos, and, if possible, to help confirm Davis's result and possibly help solve the solar neutrino puzzle. By the end of this year they hope to have some results on that, and if they do, Mann says, they will have performed the "third neutrino astronomy experiment" — Davis's work and supernova 1987A being the first two. Then, he says, "We will have established neutrino astronomy as an infant science if not a fully established one."

Both Mann and Bahcall say they hope for the development of large detectors for a systematic view of the universe. Mann points out that Kamiokande II's observation of supernova neutrinos was something of a fortunate accident: It happened to be operating at the time. He advocates fully staffed detectors that operate 24 hours a day every day. That way they could make systematic surveys for neutrinos from supernovas and other neutrino-producing astronomical events and study the astrophysics and physics those things can teach us. — *D. E. Thomsen*

Pill/cancer: Another look

Women who have used oral contraceptives have a 40 percent lower risk of developing epithelial ovarian cancer than women who have not used the pill, according to a recent analysis of the Cancer and Steroid Hormone Study data collected between 1980 and 1982 by the Centers for Disease Control and the National Institute of Child Health and Human Development. The report, in the March 12 NEW ENGLAND JOURNAL OF MEDICINE, suggests that this protective effect persists for 15 years after a woman stops using the pill, and is present even if pill use lasted only three to six months. Researchers used data from the same study to determine whether or not oral contraceptives cause breast cancer; the most recent conclusions exonerate the pill (SN: 8/16/86, p.100). □