Solar neutrino mysteries persist

Neutrinos emerge from a variety of reactions between atomic nuclei. As the physics of stars—and particularly the sun—is made up of chains of such reactions, scientists wishing to observe how those reactions proceed have chosen to monitor the flux of neutrinos coming from the sun.

It isn't easy. Neutrinos are the most elusive particles known to physics. From 1971 until last year, the world had only one neutrino observatory, a tank of dry-cleaning fluid deep in the Homestake mine at Lead, S.D., operated under the direction of Raymond Davis of the University of Pennsylvania. That experiment finds, on the average, about one-third of the neutrinos the standard theory of solar physics predicts.

Since early 1987, an apparatus called Kamiokande has been concentrating on solar neutrinos. Located at Kamioka, Japan, it detects neutrinos from somewhat different nuclear solar processes. Its first results indicate only 63 percent of the predicted flux, reported Yoji Tatsuka of the University of Tokyo at last week's meeting of the American Physical Society in Baltimore.

Evidence from Homestake suggests neutrinos may be subject to magnetic effects — a true revolution for accepted neutrino physics. The Homestake results have caused a decade-long scramble among solar theorists to figure out what might be wrong either with the theory of the sun or with standard belief about the behavior of neutrinos. Any new finding about the behavior of neutrinos could have a domino effect in many branches of particle physics. The Davis experiment has been running long enough to have records of two cyclic fluctuations in the solar neutrino flux. One of these is anticorrelated with the 11-year sunspot cycle, with the neutrino readings low when sunspot activity is high and vice versa. The other — the one Davis wanted to stress at the Baltimore meeting — is a fluctuation according to which part of the sun the neutrinos come through.

The sun's rotation axis is inclined about 6° to the ecliptic. Thus, as the earth goes around its orbit, the neutrinos recorded by the Homestake detector come from slightly different parts of the sun. Twice a year, on June 5 and Dec. 5, says Davis, the neutrinos Homestake observes come out through the sun's equatorial region, where the magnetic field is lowest. His group analyzed their data, he says, and found a decrease in the rate.

This finding suggests that magnetic fields affect neutrinos, that they have a magnetic moment or intrinsic magnetism. A theoretical proposal, known as the Mikhaev-Smirnov-Wolfenstein (MSW) effect, in which magnetic interactions change neutrinos from one kind to another, has become a popular explanation for the discrepancy between the theoretical prediction and the observations. Neutrinos come in three varieties—electron neutrinos, muon neutrinos and tau neutrinos — named for the other particles with which they are produced. Put most simply, the MSW theory proposes that interactions with magnetic fields on the way out of the sun change neutrinos from one kind to another. Under certain conditions there is a resonance, which guarantees change for a large number of neutrinos.

The Homestake detector is sensitive only to electron neutrinos. If the nuclear processes in the sun were producing the expected amount of electron neutrinos, but these were being changed to another kind on the way out, that could explain the discrepancy between the Homestake findings and the theoretical prediction.

A neutrino with a magnetic moment causes consternation in particle physics circles. It would mean that neutrinos are subject to electric and magnetic forces, a circumstance not contemplated in traditional neutrino physics. It would require changes in those parts of particle physics in which neutrinos are important. A neutrino with a magnetic moment, and one capable of changing from one kind to another, would also have to have a small rest mass. When the neutrino's existence was postulated more than 50 years ago, it was supposed to have zero rest mass.

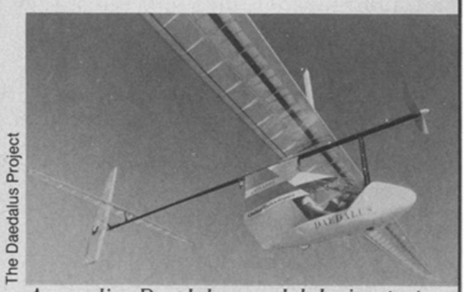
In recent years, some of the attempts to unify all of particle physics have proposed a small rest mass for the neutrino. A few laboratory experiments seeking a neutrino mass have claimed positive results; more have been negative. The question remains highly controversial.

For the solar part of the question, a few new experiments are either planned or in preparation. They will use different detecting substances to get neutrinos of different energies — which come from different nuclear processes — and so check different aspects of solar theory. Two will use gallium: the Gallex experiment, a collaboration of European and American institutions, which will set up 30 tons of gallium in Italy's Gran Sasso tunnel; and a Soviet-U.S. collaboration, which is setting up 60 tons of gallium in a mine entrance at Mt. Amdrychi at Baksan in the Caucasus. The third, a Canadian-U.S. collaboration, will use a tank of heavy water in a mine near Sudbury, Ontario.

— D.E. Thomsen

On a wing and a pedal

Like the mythic figure Daedalus, pilot Kanellos Kanellopoulos escaped Crete on his own power, pedaling his fragile aircraft 74 miles across the Aegean Sea to the shores of the Greek island Santorini. But like Icarus, who attempted the flight with Daedalus, Kanellopoulos ended up in the sea, just yards from his destination. A gust of wind snapped the lightweight aircraft's tail boom, the wings folded and the wreckage gently settled into the surf, forcing the pilot to swim, then wade to shore.



The Daedalus Project

An earlier Daedalus model during test flights this year.

The human-powered aircraft, named Daedalus 88, took only 3 hours and 54 minutes to complete the flight, which began shortly after 7 A.M. on April 23. Assisted by a light tail wind, it flew at an average speed of 18.5 miles per hour about 15 feet above the water. The largely transparent, plastic and carbon-fiber plane weighed only about 70 pounds, despite its 112-foot wingspan.

Kanellopoulos and Daedalus 88 set three records for human-powered flight. They broke the records for the longest straight-line flight and for duration aloft, set in 1979 when Bryan Allen pedaled the Gossamer Albatross 22.5 miles across the English Channel in 2 hours and 49 minutes. The flight also broke the distance record of 37.2 miles set last year by Glenn Tremml in a Daedalus prototype named the Light Eagle (SN: 11/7/87, p.302).

The Daedalus flight went remarkably smoothly, except for the landing. There appeared to be no mechanical malfunctions, and the pilot, a Greek bicycling champion who had been prepared for a flight of up to 6 hours, had plenty of energy to spare when he hit the water.

Original plans for the flight called for a takeoff from a location somewhere along Crete's northwestern coast and a landing on the Greek mainland (SN: 4/12/86, p.229). But both the intended takeoff and landing sites proved inaccessible, forcing a switch to the slightly longer route from the Heraklion military airfield on Crete to Perissa Beach on Santorini's southeast shore. The Daedalus team waited almost a month before the right weather conditions for the flight — a light tail wind, temperatures below 70°F and good visibility — finally came.

— I. Peterson