Solar Neutrino Deficit Confirmed?

The long-awaited first results from a new breed of solar neutrino detectors have finally arrived—and they're more striking than anyone imagined. According to collaborators on the Soviet-American Gallium Experiment (SAGE), who reported on their initial 4 months of data at a recent neutrino conference in Geneva,* the apparatus saw no solar neutrinos whatsoever.

If borne out—and the SAGE physicists are still very cautious about that—the results would confirm what astrophysicists have suspected, but have been unable to prove: that the neutrinos created by fusion reactions in the core of the sun are somehow getting lost on their journey to Earth.

"This is the most exciting news I've ever heard in science," exults astrophysicist John Bahcall of the Institute for Advanced Study in Princeton, who has long been one of the leading theorists on solar neutrinos. "If it's true, [these experiments] are telling us something about fundamental physics that we never expected to learn."

Bahcall's enthusiasm is understandable: astronomers and physicists have been awaiting results like these for two decades now, ever since University of Pennsylvania radiochemist Raymond Davis put his pioneering solar neutrino detector down in South Dakota's Homestake gold mine and discovered that the neutrino flux from the sun was only about one-third to one-fourth the flux predicted by standard astrophysical theory. Over the years, researchers have concocted dozens of theories purporting to explain that deficit. But until now, none of those theories could either be proved or disproved, because no one could be sure if the deficit was real. Since Davis' detector is sensitive only to the highest energy solar neutrinos, which are produced by a very rare fusion reaction involving the isotope boron-8, there was always a chance that the theorists had simply been wrong.

Enter SAGE, which has been under construction since the mid-1980s in a mine near the Soviet town of Baksan, and which has the participation of Davis and a number of other U.S. experimenters. Unlike Davis' original detector, which looks for radioactive argon-37 nuclei produced by neutrinos from the sun hitting chlorine-37 nuclei inside a huge tank of chlorine-rich cleaning fluid, SAGE looks for radioactive germanium-71 nuclei produced inside 30 tons of gallium-71.

The difference is that the gallium reaction can be triggered by relatively low-energy neutrinos from the fusion of protons with protons. And since the proton-proton reaction produces the vast majority of the sun's energy, there is no way the calculated neutrino production rate can be off by a factor of 3 or 4; theorists can obtain the flux simply by knowing how bright the sun is. Thus, a low neutrino rate from SAGE would be strong evidence that neutrinos are indeed being waylaid on the way out.

And low it is—although no one really expected to find a rate of *zero*. The SAGE experimenters themselves urge people not to take that number too literally, however. "This is still a fairly fresh experiment," notes SAGE team member Kenneth Lande of the University of Pennsylvania. First, he says, background noise from cosmic rays and such makes it impossible to say that the neutrino flux is really zero. The correct statement is that the signal most probably lies between zero and 70 solar neutrino units (SNUs)—the SNU being a convenient measure of the solar neutrino flux invented by Davis. But that is still well below the rate predicted by standard astrophysical theory, which is 132 SNUs, corresponding to about one germanium-71 nucleus being produced per day.

Second, says Lande, the SAGE result has yet to be confirmed. If similar numbers come out of Gallex, a gallium experiment that should be ready to begin taking data later this year in Italy's Gran Sasso tunnel, then physicists could feel more certain.

Bahcall, however, is already a believer. During his own talk at the Geneva meeting, he presented his own preliminary calculations suggesting that both results are consistent with the "MSW" model, which was already the most popular explanation for the solar neutrino deficit. The MSW model starts by postulating that neutrinos actually have a very tiny mass, in contrast to conventional particle theories that assume they are massless. Then the model shows how certain subtle interactions with ordinary matter in the sun can cause the original neutrinos to "oscillate" and occasionally transform themselves into other types of neutrino that would be invisible to SAGE as well as to Davis' original detector. Knowing the experimental results, says Bahcall, the model then allows you to make a rough prediction: that the mass of the original neutrino—or, more technically, the electron neutrino— is about 0.001 electron volt.

"My attitude is that the Baksan result must be right because it's so pretty," laughs Bahcall. ■ M. MITCHELL WALDROP

*The meeting "Neutrino '90," was held on 11 to 15 June in Geneva, Switzerland.

Glasnost, Greenhouses, and Ice Ages

Glasnost has come to the study of ancient climate. U.S. scientists are finally getting their hands on glacial ice that lay as much as 2 kilometers down in the Antarctic ice cap until Soviet researchers drilled it out in the early 1980s.

For almost a decade, the French were the only foreign researchers with access to those ice samples and the 160,000-year climate records they contain. But at the recent American Geophysical Union meeting in Baltimore, a group from the University of Rhode Island (URI) presented some of the first U.S. analyses of ice from Vostok, the Soviet drill site in central East Antarctica. The new U.S. results add support to the theory that natural greenhouse gases helped the planet break out of the penultimate ice age about 140,000 years ago.

The work was greatly helped by a novel method developed by the URI group for measuring the total volume of glacial ice in the world simply by analyzing a bit of ice that formed at the time. In the past, oceanographers had to go to deep-sea sediments to infer ice volume, but they could get a reading on greenhouse gases only from ice cores. That was a problem for researchers who wanted see whether an increase in greenhouse gases had preceded the first melting of glacial ice. If it did, the enhanced greenhouse could have helped cause the end of the ice age. But the comparison has been tricky because deep-sea and ice records have no common time scale.

Now the ice volume technique developed by marine geochemists Todd Sowers and Michael Bender of URI, in collaboration with colleagues at the University of Grenoble, France, and in the Soviet Union, avoids having to make any ice–deep-sea comparisons. The trick was to find a record in ice that responds to changing ice volume much the way deep-sea sediments do.

The URI group's tie between ice core and sediment core comes in seawater. The isotopic composition of seawater's lighter oxygen—the proportions of oxygen-18 and oxygen-16—varies along with ice volume. That happens because seawater becomes enriched in oxygen-18 when water containing only oxygen-16 preferentially evaporates from the ocean and falls as snow on the ice caps. Microfossils that form sediments pick up these variations in seawater's isotopic composition.