Scientists are waging a battle to pinpoint the sun's temperature

by David Pesciin The University of Connecticut**Traditions**Alumni Newsletter, Fall 1996

How hot is the center of the sun?

Finding a correct answer to this question has led to one of the most controversial and important issues in science today: the solar neutrino problem.

The solar neutrino problem has become a point of contention in part because of one solution being championed by many scientists would mean a radical shift in fundamental physics. This is the stuff of Nobel Prizes, prestigious appointments to lucrative university chairs and other appointments of the academic acropolis. Curiously, the other solution being offered is somewhat less dramatic, but no less emotional. It states that past measurements of the neutrino have simply not been accurate.

Or, in other words, one side is proclaiming that it is on a genius-level breakthrough while the other side is saying the devil is in the details.

Sitting squarely between the warring parties in this scientific melee is Moshe Gai, a UConn professor of physics. In 1992, Gai pioneered a new measurement method that will help provide a definitive answer to some of those details. At the very least, this solution will give us a better understanding of how the sun and the other stars in the universe work. It could also make or break the solar neutrino problem.

It's a tremendous opportunity for Gai and his team, but one that carries a considerable amount of responsibility, although some would call it pressure. After all, virtually every physicist in the world, including Nobel laureates and internationally renowned researchers, are looking over his shoulder waiting for the results. But Gai has remained cool and detached from the controversy.

"In all honesty I do not have a preference or an opinion on which way this turns out," he says. "I am just trying to get the most accurate measurements possible. I am interested to see what the data reveal, but I do not have a stake in either side. My interest lies in the process, in good science."

Three Decades of Disagreement

The controversy surrounding the solar neutrino problem can be traced back to a fundamental theory about the sun, stars and nuclear fusion developed during this century known as the standard solar model of physics. In the early 1960s, physicists sought to prove the solar model by determining the core temperature of the sun. Among other things, knowing that temperature would give scientists accurate information about the sun's fusion rate, the amount of energy it generates. But since an actual core reading could not be made, scientists needed an indicator. The solar neutrino seemed like a natural candidate.

Solar neutrinos are subatomic particles produced by the constant series of nuclear reactions occurring at the sun's center. They are the only byproducts of the sun's core that actually reach the earth. And they are plentiful. As you read this, about 10 billion solar neutrinos will pass through your body. To get a clear idea about the workings of the solar core, scientists need to measure, within a 5 percent accuracy, how many neutrinos reached a given spot of the earth over a specific period of time.

But counting neutrinos is not easy. They are massless, smaller than protons, and move at the speed of light. Still, scientists devised a method using giant "detectors." These use underground tanks more than 10 stories tall filled with thousands of tons of such liquids as heavy water, carbon tetrachloride (which is also used for dry cleaning) and gallium. These tanks can detect the presence of the rarer, highly energized radioactive neutrinos spun off from solar fusion. The early detectors were able to identify about one such neutrino every three days. The newer facilities are more sensitive and have increased this rate to about one every three hours.

However, in both cases, this number of neutrinos was far less than what the standard model predicted - anywhere from 50 percent to 70 percent less. This meant one of two things: either the standard model of particle physics was wrong and scientists were on the verge of discovering a completely new explanation for fundamental physics in the universe, or the estimated neutrino number was inadequate and needed to be adjusted. The debate over which side is right has raged one for more than 30 years.

But is "raged" the right word? After all this is only a physics problem.

"It's very emotional," Gai says. "People have built their whole careers on this for 30 years. Some are anticipating acclaim and prizes. Former colleagues now don't speak to each other except with insults. The debate is as bitter as any you can think of."

This was the environment that Gai stepped into in 1992 while an associate professor at Yale University. He had a proposal for a new way to measure the elusive radioactive solar neutrinos that hinged on another basic tenet of physics: every reaction can be reversed. Knowing this, Gai reasoned that he could design an experiment where the process for producing the neutrinos went backward, decomposing instead of fusing. The analysis of the break-up would give scientists the information on what it took to create the particle in the first place.

"It was like running a movie in reverse," he says. "Only we would be starting at the end and watching it go back so we could observe what created it."

Some colleagues saw genius in Gai's idea, but, to put it politely, many others thought he was wasting time and money.

"I had people tell me I was crazy and being foolish," he says. "But I said nothing to them. I decided to pursue it and let the data we got show whether my idea was sound or not."

The experiment Gai was proposing required an atomic accelerator, a sophisticated facility that cost tens of millions of dollars to construct. Opportunity was with him, though. The Japanese had just built an atomic accelerator at the Institute of Physical nd Chemical Research of Japan, better known as RIKEN.

Crazy Idea' Accepted

The experiment, which takes weeks to prepare, is over in the blink of an eye, and must be performed many times over to obtain the required level of accuracy.

Gai was able to successfully conduct the experiment at RIKEN. Word spread, and soon the "crazy idea" was accepted as standard.

In 1994, Gai, now at Uconn, presented his results at a major conference in Israel that attracted more than 600 scientists, including three Nobel Prize winners. What he found was that the neutrino number was still at odds with the standard solar model. Gai was then asked by a member of the audience on which side of the solar neutrino problem he stood.

"I stated my interest was only in the accuracy of my measurements," he said. "This produced a tremendous round of applause from the audience. That is something that isn't really done at these conferences. It was very flattering."

Unfortunately, Gai's announcement did nothing to cool the debate. If anything, it heightened the emotions involved. But the debate will soon be coming to a close.

Gai has secured $1.2 million in grants to continue his work and gather more data. This information will be combined with data collected by two new solar neutrino detectors, one in Japan and the other in Canada. These are the most advanced yet, and, according to Gai, will collect the rest of the information needed to end the controversy.

"I fully expect for us to have an answer within the next five years at the very latest," he says. "Perhaps even within two years."

But when they have the answer, what will it really mean?

"Every culture has a story of creation, and this is ours," he says. "Unlike the old stories of creation, though, ours is based in science, not folklore. If we can understand the sun, then we can understand the other stars and perhaps other solar systems, or even how life began here and how it begins elsewhere. It is the most basic of questions, and we are very close to now producing a definitive answer. I think that is very exciting."

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