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WIMPs Offer Solution to Long-standing Solar Mystery, say Astrophysicists

BOULDER --You wouldn't expect that WIMPs could affect anything as powerful as the sun, but astrophysicists at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, and the University of California at Santa Cruz (UCSC) think otherwise. They have found that a smidgen of WIMPs--weakly interacting massive particles--can alter the sun's central conditions, and in doing so could resolve a puzzle that has bedeviled astronomers for years.

The findings have recently become more than just a scientific curiosity because developments in particle physics suggest that WIMPy particles may indeed exist. If so, WIMPs offer an explanation for the shortage of neutrinos coming from the sun, a shortage that has remained a mystery through years of investigation.

UC Santa Cruz Professor of Astronomy and Astrophysics John Faulkner, in collaboration with Ronald Gilliland, an astronomer with NCAR's High Altitude Observatory here, and a UCSC graduate student at the time of the study, created detailed computer models of the sun and demonstrated that a small number of WIMPs effectively lowers the temperature at the sun's center. This in turn inhibits one of the nuclear reactions taking place deep inside the sun, one that is important because it produces the brand of neutrinos that we can detect here on earth.

Neutrinos, so-called "ghost particles," interact so seldom with other matter that they can zip through millions of miles of solid material. Those released by the sun's nuclear reactions stream clean out of the sun and off into space, passing through nearly everything they encounter.

By contrast, photons--particles of light--bounce around inside the sun for millions of years before reaching the sun's surface and escaping to space.

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Astronomers have detected only one third as many solar neutrinos as their theories predict, but it isn't for lack of looking. For almost two decades a special neutrino detector has sat deep in a gold mine in South Dakota, where it is protected from extraneous radiation as it looks for solar neutrinos.

"The solar neutrino telescope acts on Earth as a thermometer for the central temperature of the sun," Faulkner says.

The "telescope" consists of a tank that holds 100,000 gallons of perchlorethylene, a chemical commonly used as a cleaning solvent. When a solar neutrino zaps a perchlorethylene molecule, it causes a chlorine atom to change to argon. Experimenters can later isolate the argon atoms and deduce how many neutrinos have passed through the tank.

The large volume of cleaning fluid guarantees that some of the rarely interacting neutrinos will be nabbed.

Consistently the experiment has spotted fewer neutrinos than are predicted by theories detailing the sun's nuclear reactions. Since those theories are based on well-accepted experimental results and account admirably for the sun's longevity and energy output, astronomers have long been perplexed over why the numbers don't agree.

Over a hundred possible explanations have been thrown at the solar neutrino problem, and nearly all subsequently dismissed. "Many of these explanations have been terrible and in some cases incalculable consequences for other aspects of stellar structure and evolution," says Faulkner.

Nicely enough, WIMPs only affect the very center of the sun and do not carry disastrous consequences for other regions of the sun or for stellar behavior.

As their full name implies, WIMPs interact only weakly with other matter, such as the subatomic particles that exist in dense profusion at the sun's core. WIMPs can travel partway from the sun's center to the outside before banging into another particle and transfering energy to the particle.

WIMPs don't travel too far from the sun's center because gravity confines them, but because they can move fairly freely within their confined sphere, WIMPs offer a means of redistributing energy within the sun, picking up energy in the extreme conditions of temperataure and density at the center and depositing it in a shallower region.

In this manner, WIMPs can smooth out the sharp peak in temperature that computer models indicate exists in the sun's innermost volume. A small swing in temperature greatly affects the nuclear reaction producing the neutrinos that can be detected on Earth. Thus, a very small number of WIMPs can easily reduce the number of those reactions and so reduce the number of neutrinos we expect on Earth, reconciling theory and observation.

Faulkner and Gilliland made these calculations several years ago, and the highlights of their findings appeared in a paper that Faulkner co-authored (Steigman et al., The Astronomical Journal, September 1978). But they didn't publish the details of their solar models because it then seemed unlikely that any particles actually existed with the right properties to be a WIMP. But recently that has turned around.

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Particle physicists, emboldened by findings from the latest particle accelerator experiments, have proposed "supersymmetry theories" and predicted the existence of particles that would match the requirements for WIMPs. In particular, the "photino," the hypothetical, supersymmetric partner to the familiar photon, fits the bill nicely as a potential WIMP.

As well, astronomers at the Center for Astrophysics (CfA) in Cambridge, Massachusetts, recently followed a different, independent approach to the solar neutrino dilemma and arrived at essentially the same conclusions as Faulkner and Gilliland.

Spurred by these developments, Faulkner and Gilliland have submitted their calculations to The Astrophysical Journal for publication. They are also now collaborating with the CfA astronomers to blend the two approaches, combining the best of both into a detailed study of the effects of WIMPs on the sun.

NOTE TO EDITORS: This release is being issued simultaneously by NCAR, a university-based, nonprofit research organization sponsored by the National Science Foundation, and the University of California at Santa Cruz.

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