Weak sun blamed on WIMPS

There is something wrong with the sun. For almost two decades now, observers have been monitoring the flux of neutrinos from the sun. Consistently, they have recorded significantly fewer neutrinos than the astrophysicists' model of what goes on in the sun leads them to expect. Neutrinos come from the deepest center of the sun so the lack of the expected number says something about conditions there.

What it may say, according to John Faulkner of the University of California at Santa Cruz (UCSC) and Ron Gilliland of the National Center for Atmospheric Research in Boulder, Colo., is that the sun's core is inhabited by WIMPS (Weakly Interacting Massive Particles). WIMP is a generic term; a specific kind of particle that could fill the bill is a hypothetical one known as a photino. However, another argument, recently published, avers that photinos living in the center of the sun could not be responsible for lessening the neutrino flux.

What WIMPS would do, according to Faulkner and Gilliland, is to cool the center of the sun. Being massive (by particle physics standards) WIMPS stay near the center of the sun, orbiting around in there. As weakly interacting particles, they sometimes collide with other objects and carry away some energy (but not too much), which they then give away to regions outward from the core. Thus they cool the core just enough to slow down the thermonuclear fusion reactions that go on there, and that would lessen the flux of neutrinos.

Faulkner and Gilliland got this scenario from a computer model of the sun's evolution that they calculated some years ago, while Gilliland was a graduate student at UCSC. At the time they finished the calculation, they decided not to publish it, Faulkner says, because at the moment there seemed to be good astrophysical arguments against WIMPS. Now those arguments have fallen away and there are some unexplained experimental results from the CERN laboratory in Geneva that could indicate that particles like WIMPS, and specifically photinos, really do exist. So now Faulkner and Gilliland are about to publish their solar model.

Meanwhile, the same experiments at CERN prompted Joseph Silk of the University of California at Berkeley, Keith Olive of the Fermi National Accelerator Laboratory in Batavia, Ill., and Mark Srednicki of the University of California at Santa Barbara to consider photinos as candidates for the unseen or dark matter that astrophysicists believe is plentiful in the universe; which would account for the cohesion of clusters of galaxies and also ensure that the universe has a closed geometry. Their report, in the July 8 PHYSICAL REVIEW LETTERS, indicates that if there are a large number of photinos floating around the cosmos, the sun's gravity would continually draw some of them to its interior. As they orbit there, photinos and antiphotinos would meet at a fairly steady rate and annihilate one another. The result of the annihilation would be high-energy (250 million electron-volt) neutrinos. Thus the sun would have an *extra* flux of neutrinos, and these high-energy neutrinos should be detectable on earth in experiments now running.

While the photinos are moving through the sun, however, Silk, Olive and Srednicki calculate, their cross section or probability for collision with other particles is too low to cool the sun's core significantly. Faulkner and Gilliland calculate that the cross section is large enough. Exactly what you get in such a case depends on what you assume about the behavior of the hypothetical particle. If anyone finds and measures the properties of an actual photino, that might resolve the disagreement.

Photinos are a prediction of the supersymmetry theories, which propose that every particle we now know has an as yet unknown partner. Photinos would be partners to the photons or particles of light. The CERN results may indicate the existence of a squark (partner of a quark) of about 50 billion electron-volts mass. If that is true, it means that photinos of about 4 billion to 10 billion electron-volts are likely to exist. *— D.E. Thomsen*

Earthward on a rocky, chaotic course

The origin of stones that fall from the sky and are recovered as meteorites is a long-standing puzzle. Although many people suspect that the most common type of meteorite comes from the jumble of asteroids found in a wide belt between the planets Jupiter and Mars, until recently no one could adequately explain how any of these rock fragments manage to get into orbits that cross the Earth's path.

The missing ingredient may be the peculiar behavior of trajectories within a "chaotic zone" that appears to coincide with a gap in the distribution of asteroids, says Jack Wisdom of the Massachusetts Institute of Technology. Asteroids that find themselves in this chaotic region may spend as much as a million years within nearly circular orbits. Then suddenly their orbits stretch to become so elliptical that they cross the paths of Mars and Earth and, over the years, get swept up by the planets. This process leaves a gap in the asteroid belt.

In his research, Wisdom focused on the absence of asteroids in a gap about 2.5 times the earth's distance from the sun. Particles found at this distance would complete three orbits around the sun in the time that it takes Jupiter to circle once. Wisdom discovered that Jupiter induces a chaotic zone that accounts for the precise size and shape of the gap. This zone is defined by a range of initial positions and velocities, which commit particles that start with those characteristics to an erratic path.

In the roller derby of the asteroid belt, collisions between chunks of rock continually spray debris in all directions. If any one of these fragments happens to be in the right place and has the right velocity, then its future course becomes essentially unpredictable. In this chaotic regime, two particles with almost identical initial positions and velocities can end up in very different orbits. In the June 27 NATURE, Wisdom calculates that one out of five of these particles ends up on an earth-crossing orbit within 500,000 years.

When Wisdom first presented his idea two years ago, most astronomers were skeptical. "Many people thought that if you had such unusual behavior," says Wisdom, "it must be an artifact of the method rather than its true behavior." For the results described in his NATURE paper, Wisdom found enough computer time to do the necessary calculations using an accepted mathematical technique instead of the unconventional method that initially led to his discovery.

One person who took Wisdom's idea seriously was George W. Wetherill of the Carnegie Institution of Washington (D.C.). Wetherill calculated what the orbits of these meteorites would look like when they hit the earth. The results matched earth-based observations almost exactly. "The most abundant type of meteorite, the ordinary chondrite," says Wetherill, "is indeed derived from the mechanism discovered by Wisdom."

Comments Carl D. Murray of the University of London in England, "The beauty of the mechanism is that it does not involve any complicated procedures that require more than one close approach to another planet."

Other gaps in the asteroid belt also appear to be associated with chaotic behavior. Wisdom is now trying to trace out the boundaries of these chaotic zones more carefully. "If you understand the dynamics," he says, "then you can see to what extent the distribution of the asteroids can be explained. But the real goal is to understand the dynamics well enough to begin looking at the primitive formation of the asteroids."

Wisdom, who has already explored the chaotic behavior of Saturn's satellite Hyperion (SN: 7/23/83, p. 59), is also looking into the possibility of a chaotic zone around Pluto. Says Wisdom, "We're trying to see if we can explain some of why the solar system is the way it is."

— I. Peterson

Science Service, Inc. is collaborating with JSTOR to digitize, preserve, and extend access to *Science News*.
www.jstor.org