The published data appear not only to confirm the solar neutrino problem, but, taken at face value, imply that the source of the problem lies with the neutrinos. The explicit result quoted is as follows: using units developed for the ^{37}Cl experiment, called solar neutrino units (SNUs), in which 1 SNU= 10^{-36} events per target atom per second, the SAGE collaboration reports, after five uncontaminated observing runs, an interaction rate of 20^{+15}_{-20} ±32 SNU — about three germanium atom decays observed during the course of the experiment. (The uncertainties are statistical and systematic, respectively.)

From this the researchers claim an upper limit of 79 SNU at the 90 per cent confidence level, which is to be compared with rates of 132^{+20}_{-17} or 125±5 SNU (at 99 and 67 per cent confidence respectively) predicted by various standard solar models[5,6]. The upper limit of 79 SNU is particularly intriguing, because it has been argued that this is also precisely the theoretical *lower* limit on the ^{71}Ga event rate, assuming only that the Sun radiates energy as fast as it generates it (so it is in equilibrium), and that the associated neutrinos are unaffected as they make their way to the Earth. Thus, an observation of a rate less than 79 SNU would lay the burden of the solar neutrino problem squarely on the neutrinos themselves. This would provide the first empirical evidence that the standard model of elementary particle physics is incomplete.

What neutrino physics could suppress the flux of electron neutrinos from the Sun? The SAGE result alone cannot easily distinguish between the possibilities so far suggested. The most investigated proposal has to do with the possibility of a mass difference between the electron neutrino and its cousins, the muon and tau neutrinos which are invisible to gallium detectors. If neutrinos have a mass, their mass eigenstates need not be identical to the eigenstates of the weak interaction that creates them, so that as they traverse the solar interior or on their journey to the Earth, electron neutrinos could oscillate into invisible muon or tau types. A mass difference 100 million times smaller than the electron's mass is all that is needed. Masses of this magnitude have been predicted if the three known forces are unified into a single grand unified theory at cosmological energy.

Nonetheless the SAGE result is not yet definitive. This is the first set of results obtained using this technique, and it is based upon only the first five runs, during which time the cumulative total number of events observed by counting events for two ^{71}Ge half-lives after each run was about nine, including backgrounds. Of this total, only two were assigned as signal, compared with 13 predicted by standard solar models. A single extra atom per run in the signal would change the 90 per cent confidence limit by 35 SNU. More important, the experiment has yet to be calibrated with a neutrino source. This is essential to guarantee that the efficiency for detecting ^{71}Ge atoms produced by solar neutrinos is the same as for the natural germanium carrier. In addition it should be noted that the source of the background, which dominates the data and is itself almost as large as the predicted solar signal, is not yet clearly determined. And there are still puzzling experimental data which are not addressed by the SAGE result. In particular, there is an apparent anti-correlation of the event rate in the Homestake ^{37}Cl experiment with the solar cycle which, while statistically significant, is very difficult to understand theoretically. Also, the observation of a 17-kiloelectronvolt neutrino state (see Nelson's News and Views article[7]) would, if correct, make it much more difficult to assign the light masses to two neutrino species necessary for the neutrino oscillations.

Another gallium experiment, the GALLEX experiment, run by a European–US–Israeli collaboration and located in the Gran Sasso underground laboratory in Italy, is currently on line using 30 tons of gallium in the form of gallium chloride. After several frustrating years overcoming and understanding quite complex chemical contamination problems, the researchers have been taking data for five months, and have stated that they will report results after amassing ten months of data — enough to make statistically unambiguous statements. It is prudent to await these GALLEX data, which should be available before a calibration of the SAGE detector is completed, before one proclaims the dawn of a new era. Nevertheless, if GALLEX agrees with SAGE, solar neutrinos will have opened a new window on fundamental physics, and the race will then be on to develop a new generation of solar neutrino detectors capable of exploring the details. □

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DAEDALUS

Counting stars

THE Hubble space telescope was planned to have the highest possible resolution over a narrow field of view. Daedalus's new space-telescope project has the converse ambition. His 'Skygazer' will combine extremely bad resolution with the ultimate field of view. It will look at all the sky all the time.

Ever since Olbers propounded his famous paradox, astronomers and cosmologists have argued about the intrinsic brightness of the night sky. In the visible waveband, an average square degree of sky delivers about 20 femtowatts to a detector 1 centimetre across: perhaps 60,000 photons per second. Such a modest photon flux could easily be counted directly by a photomultiplier or an avalanche photodiode array. A spacecraft carrying forty thousand such detectors in a spherical fly's-eye arrangement would intercept about 2.5 billion photons a second from the whole celestial sphere, and could count them all. Its photometric accuracy would be absolute.

The Skygazer will have to be shielded from the Sun, which would blind any photodetector that glimpsed it (the Hubble telescope has the same problem). It may also need to be screened from the Earth and Moon, and should be launched into the most distant orbit consistent with adequate telemetric and command links. But it will then provide the most accurate sky-brightness information any cosmologist could wish for.

It will also act as a vigilant watchdog for new celestial developments of all kinds. Let a nova start anywhere in the Galaxy, and the Skygazer will spot the rising photon count. Its direction will be that of the photodetector whose count is rising; an Earth-based telescope could then search that region of sky. Variable stars, stellar collisions, flares and many other fascinating astronomical phenomena could be spotted early enough to follow their full evolution.

Some bold cosmological speculations could also be tested. Daedalus would like to find a correlation between the individual photon counts from opposite points of the sky. This would prove that celestial antipodes are the same, so that their light reaches us from two opposite paths round the whole Universe. Similarly, photon correlation between widely separated astronomical objects would show them to be different views of the same thing, doubly imaged by some outrageous gravitational-lens effect. And if the summed sky count is found to be slowly declining year by year, the steady-state theory of the Universe can finally be abandoned. Cosmic darkness will be closing in, and the date of Doomsday will be known. DAVID JONES