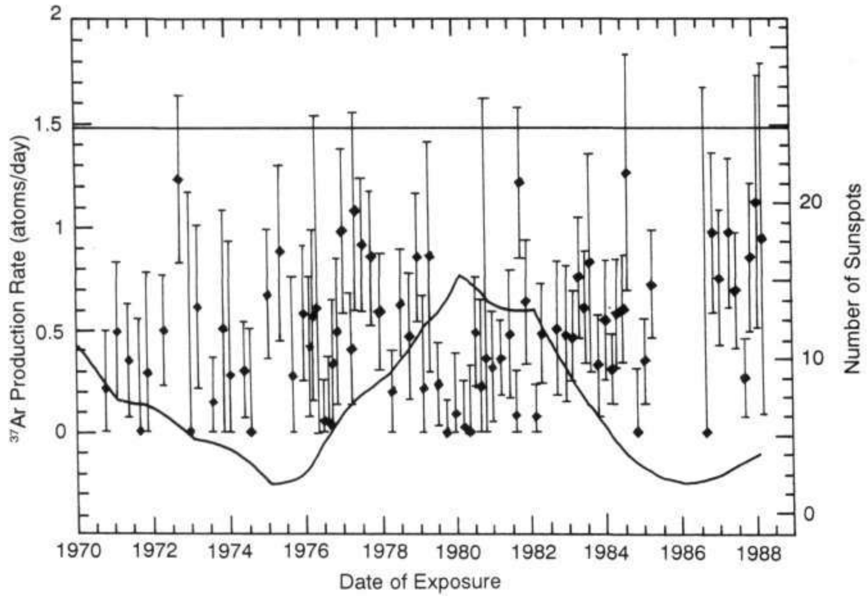
Solar Neutrinos — the Critical Shortfall Still Elusive

Neutrinos have fascinated physicists since they were 'invented' 67 years ago. In B-decay, a nucleus of one element spontaneously changes into the nucleus of a neighbouring element in the periodic table, emitting an electron (or sometimes an anti-electron or 'positron'). To their shock, the scientists found that some energy appeared to vanish in these decays. The solution proposed by Wolfgang Pauli in 1930 was that the missing energy was carried away by a new particle, so ephemeral as to be almost undetectable. In 1955 Clyde Cowan and Fred Reines proved Pauli right by observing the neutrino. The problem facing experimenters is that neutrinos are so difficult to detect. For example, on average, the neutrinos emitted in B-decay can typically traverse 100 light-years thickness of lead unscathed![1]

Life on Earth is made possible by the energy from the Sun. It is believed that it takes about a million years for energy (apart from that carried by neutrinos) supposedly produced by nuclear reactions near the centre of the Sun to make its way to the surface and be radiated. It takes the neutrinos born in those claimed nuclear reactions about 8 minutes to arrive here, so they should tell us what is happening at the centre of the Sun today. This is one of the main reasons why physicists have built large detectors underground — to look for solar neutrinos.

The first experiment by Ray Davis operated for over twenty years in the Homestake mine in South Dakota (USA) measured less than half the expected flux of neutrinos. A large tank was filled with 380,000 litres of dry-cleaning fluid and located in the deep mine to reduce background. The incoming solar neutrinos convert some of the chlorine atoms in the fluid into argon (this is nearly the inverse of 13-decay), so the task of Davis and his team was to measure the number of argon atoms produced. Figure 1 shows the numbers of argon atoms counted by the experiment over 20 years, the count rate falling well short of that expected.[2] They expected an average of 1.5 atoms per day, but only measured an average of about 0.5 atoms per day. Finding one atom of argon in a tank containing over 10^{31} atoms of chlorine is not easy, so it was not surprising that some doubted the Davis result.



The solar neutrino flux measured by Davis and his team over 20 years. The horizontal line at 1.5 atoms per day is the expected rate. The other solid line shows the sunspot rate.

Subsequently another experiment, in the Kamiokande mine in western Japan, used a very different technique and confirmed the Davis result. The team of scientists involved observed the scattering of neutrinos on electrons in a large tank filled with ultra-pure water, the photons produced being detected via amplification of their conversion to a small electric current. This Japanese experiment was also able to follow the Sun as it traversed the sky, much as a telescope can track a star, and it confirmed that the Sun does produce neutrinos but the number detected was again too small.

Both experiments were sensitive to neutrinos with relatively high energy supposedly produced in rare nuclear reactions, whereas the nuclear reactions claimed to produce most solar energy give lower energy neutrinos, which these experiments would not have recorded. Now that has changed, with new experiments sensitive to those crucial low energy neutrinos starting to report results. However, these new experiments are also recording too few neutrinos, in this case about half the expected number.

Understandably, the solar astronomers and physicists remain baffled by this consistent critical shortfall in the neutrinos expected and measured. Since the nuclear reactions they believe are producing the bulk of the solar energy, and hence the bulk of the associated neutrinos, are very well understood, the predictions of the expected neutrino flux here on Earth are very reliable. So why are they not detected in sufficient numbers?

Now the depth of the dilemma has intensified. In its first months of operation, a new neutrino detector with unprecedented sensitivity has confirmed yet again that solar neutrinos are only about half as common as researchers predict when they combine nuclear physics with profiles of the Sun's internal temperature and pressure.[3] The Super-Kamiokande detector, a 50 million litre water tank one kilometre underground in the Kamiokande mine, 'catches' roughly 10 neutrinos daily.

Since the efficiency of the claimed nuclear reaction responsible strongly depends on temperature, astronomers could conceivably explain away the shortfall by positing that the Sun's core is slightly cooler than thought. However, since helioseismology has 'pinned down' the Sun's central temperature (15.6 million degrees Kelvin), this 'out' is no longer viable. Instead, physicists now favour the hypothesis that neutrinos may 'oscillate', spontaneously transmutating between different varieties (electron, muon and tau neutrinos) and thus changing their properties *en route* from the Sun's core to the Earth.[4,5] Allied to this is a recent added twist — the neutrinos may supposedly undergo decay — but this requires abandoning the almost sacrosanct 'relativity principle'.[6] Only further years of experiments will begin to test these attempts at explaining this critical shortfall in the solar neutrinos detected.

So *'after 10 years, no one has yet explained all the data on neutrinos'?* Of course there's one explanation not considered — perhaps the reason for the critical shortfall is that nuclear reactions are not solely responsible for producing the Sun's energy. But such an explanation would be tantamount to an admission that we really don't yet know how the Sun operates, which would clearly be embarrassing. And if we don't understand how our nearest star operates, how can the astronomers be so sure how all the other stars 'evolved' and now operate? As candidly admitted by David Malin, head research scientist at the Anglo-Australian Telescope, in a recent interview on Australian ABC radio, *'How little we really know!'*.[8]

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Galaxy-Quasar 'Connection' Defies Explanation

Astronomers have known for decades about the strange 'connection' between the galaxy NGC4319 and the quasar Markarian 205 (see Figure 1).[1] Without any explanation so far, astronomers are still baffled, and with good reason.

Figure 1 is a reproduction of an isophote image of the galaxy and quasar made by superposing a number of photographic plates taken by Halton Arp using the 200-inch Palomar telescope.[2] The image clearly shows that a luminous 'bridge' connects the two objects which is distinct and well away from any 'pixel [picture element] bleeding'.[3]

So what is baffling about such a clear linkage between this galaxy and its apparently close neighbouring quasar? The 'basic' problem is that the galaxy and the quasar have discordant red-shifts, which according to the standard (Doppler) red-shift interpretation means that the galaxy is receding at a velocity of 1800 km/sec, whereas the quasar is travelling at 21,000 km/sec. Thus, according to the Hubble law, the galaxy is 107 million light years away and the quasar is 12 times further away at 1.2 billion light years! Obviously, this simply cannot be, because the galaxy and the quasar are clearly connected together by a 'bridge', probably of luminous gas filaments. They give every appearance of existing together.

Figure 1. *Isophote image of the galaxy NGC4319 (top) and the quasar Markarian 205 (bottom) clearly showing the 'mystery' luminous bridge connecting them (north is up, east is left).*

Some critics have claimed that the bridge is only an illusion, but Arp and his colleagues have staunchly defended the reality of this connection for many years, and Arp's photography (Figure 1) has documented it. Ignoring this cosmological 'anomaly' won't make it go away! Perhaps red-shifts may not be connected with recession velocities and so may not be a reliable index to distances in an expanding universe after all. These are very fundamental questions to our understanding of the universe. In the words of astronomer William Kaufmann: .

> *'If Arp is correct* [about red-shifts not being distance indicators], *if his observations are confirmed, he will have single-handedly shaken*