

# Another Neutrino Deficit Still a Challenge

In the world of particle physics, the specialists recognise more than one type of neutrino that presents them with challenges. There is the well known shortfall in the amount of solar neutrinos that should be reaching us here on Earth (see Figure 1), assuming that the solar astronomers are correct in their speculations as to how the Sun 'burns'.<sup>1</sup> Now we are told that the deficit in the relative number of neutrinos found in cosmic rays

*'threatens cherished conservation laws, and calls into question the completeness of the Standard Model of particle physics,'*<sup>2</sup>

How is this so? A wide range of experimental results in particle physics can be explained by the postulate that there are conservation laws for three different classes of fundamental particle — the laws of conservation of electron number, muon number and tau number.<sup>2</sup> Known collectively as the laws of lepton-number conservation, these laws make very similar, very simple statements about what sorts of particle interactions do or do not occur.

For example, electrons are assigned an electron number of +1, and their antiparticles, positrons, are

assigned an electron number of -1. Electron neutrinos have an electron number of +1, and the corresponding antineutrinos an electron number of -1. All other particles have an electron number of 0. In any and every reaction observed, the sum of all the particles' electron numbers in the initial state is equal to that in the final state. The laws of muon and tau number conservation follow exactly the same pattern.

The idea that electron and muon numbers are separately conserved was postulated back in 1958 to explain why certain types of particle decay. It has since been tested in a variety of ways and is now embedded in the so-called Standard Model of particle physics. These laws of lepton-number conservation greatly resemble, in their formulation and use, the dozens of atom-number conservation laws - one for each type of chemical element — in allowed chemical reactions. These laws are what defeat alchemy, and they have served chemistry well; but nuclear physics has shown that they are only approximate.

Now these conservation laws look like falling altogether. At a conference last December, the SuperKamiokande

research group in Japan reported an anomaly in their observations of neutrino interactions that could conceivably throw the fundamental physics research community into turmoil.<sup>2</sup> The SuperKamiokande instrument is a 'modern wonder of the world' — 50,000 m<sup>3</sup> of purified water like a huge aquarium, surrounded by giant photomultiplier tubes which detect miniscule flashes from high-energy neutrino interactions, all hundred of metres underground in an abandoned Japanese mine.

Although the details are complicated, a great deal is known experimentally about cosmic-ray showers, and essentially all the basic underlying processes have been carefully studied.<sup>2</sup> As a result, physicists have estimated the ratio of muon neutrinos to electron neutrinos with considerable confidence — it is close to 2:1. But the experimenters at SuperKamiokande have found far fewer muon neutrinos and antineutrinos than were predicted, while the observed muon to electron neutrinos ratio is about 1:1.

The particle physicists are puzzled by this contradiction between their theoretical estimates and experimental results. The most interesting possibility that has so far been suggested is that neutrinos of one type may 'oscillate' into neutrinos of another type, but this would mean the laws on the conservation of lepton numbers are violated. This idea of neutrino oscillations was first proposed back in 1958,<sup>2</sup> and has also recently been resurrected to 'explain' the solar neutrino deficit that has been painfully obvious for more than two decades.<sup>1</sup> And the depth of their dilemma is intensified by the realisation that the question of whether neutrino oscillations occur is closely connected to the unanswered question of whether neutrinos have mass. A so-called 'off-diagonal' mass of the order of 10<sup>2</sup> electron volts has been suggested (needed to quantify the

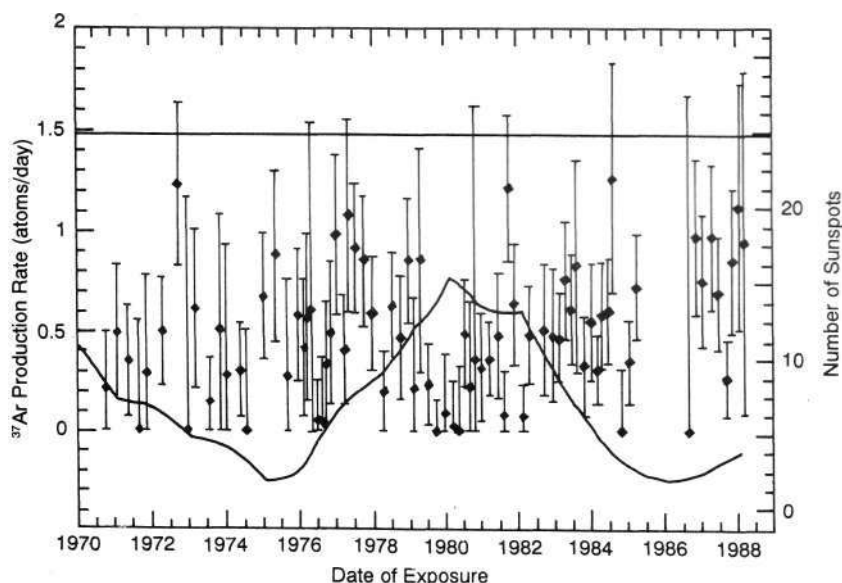


Figure 1. The solar neutrino flux measured over 10-20 years. The horizontal line at 1.5 atoms per day is the expected rate. The other solid line shows the sunspot rate.

observed effect), but this is over a million times smaller than the mass of the electron, which itself is by far the smallest mass appearing in the Standard Model!

Most theoretical physicists would welcome such tiny, non-zero, neutrino masses as an encouraging sign that their ambitious ideas may be on the right track, so they are anxiously awaiting additional observations by the SuperKamiokande team in the coming months. These will either sharpen or compromise the now recognised anomaly in cosmic-ray neutrinos. They are hoping for decisive

observations that the 'lost' muon neutrinos still exist in another form. But that would probably be the downfall of the separate laws of lepton-number conservation.

Once again, it seems that the more we learn, the more questions there are that remain unanswered. Man's quest to describe and explain what matter consists of, and what holds it together, only in terms of what can be seen in 'Nature', will always be unending because of rebellion against our Creator and refusal to recognise and submit to His pre-eminence, authority and power.

'For by him were all things created ... all things were created by him, and for him:

And he is before all things, and by him all things consist [hold together].'  
(Colossians 1:16,17)

REFERENCES

1. Snelling, A. A., 1997. Solar neutrinos — the critical shortfall still elusive. *CEN Tech. J.*, 11(3):253-254.
2. Wilczek, E, 1998. Particle physics: neutrino deficit challenges conservation laws. *Nature*, 391:123-124.

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## The Planet That May Be There, After All!

Planet hunters are breathing a sigh of relief— it is again possible that there might be a planet orbiting the star 51 Pegasi. In the last three years there have been claims of up to eight planets having been discovered orbiting around distant stars, and the one associated with 51 Pegasi was the first and leading candidate (see Figure 1).<sup>1,2</sup> There had been much speculation that just as our star, the Sun, has planets orbiting it, then other stars should also have associated planetary systems. So recent 'discoveries' were not unexpected.

It was in 1995 that Mayor and Queloz of the Geneva Observatory reported that 51 Pegasi is wobbling from the gravitational pull of an orbiting planet.<sup>3,4</sup> The announcement caught the scientific world off guard, not only because it was the first planet found around a Sun-like star, but because the orbital period of 4.2 days implied that it is 20 times closer to its star than the Earth is to the Sun (see

Figure 1). Such extreme proximity for a Jupiter-mass planet (or any planet) was unanticipated by conventional (evolutionary) theories of planet formation.

However, early last year at the University of Western Ontario, Gray issued a serious challenge, asserting that his evidence showed that the slow 'jitters' (periodic changes) in the star's spectrum which had been thought to result from a planet's periodic tug were actually due to the pulsation of the star's gases.<sup>4-6</sup>

Since then other astronomers have searched for the alleged pulsation, but failed to find it. One team, led by Brown of the High Altitude Observatory in Boulder, Colorado, used a telescope on Mount Hopkins in Arizona to obtain high quality spectra of 51 Pegasi. If the star were pulsating, the shapes of its spectral lines should vary. But they remained constant. Now Gray has retracted his challenge, reporting the absence of

pulsations in the star's spectra based on further observations he has made with his original apparatus.<sup>7</sup> And concurrently, Hatzes and co-workers made about 120 measurements of several of 51 Pegasi's absorption lines at more than twice Gray's spectral resolution and have reported seeing no changes in the line shapes (see Figure 2).<sup>8</sup>

Because his original 39 noisy data points were scattered over seven years, Gray (and others) now emphasise that there was roughly a one-in-300 chance that a spurious 4.23-day signal might show up by chance.<sup>5,7</sup> And that appears to be what happened. *7 have to conclude that nature played a dirty trick on him [Gray]*, said Brown.

The heat has now come out of the debate over the 51 Pegasi planet as this technical disagreement has faded. But some of the protagonists have expressed dissatisfaction that Gray's original paper was not thorough enough in its statistical treatment and used less than equivocal language about the spectral-line variations.

*'But those critics'*, says Marcy, as astronomer at both the University of California at Berkeley and San Francisco State University, *'may occasionally forget that competition and human emotion have always provided fuel for the*

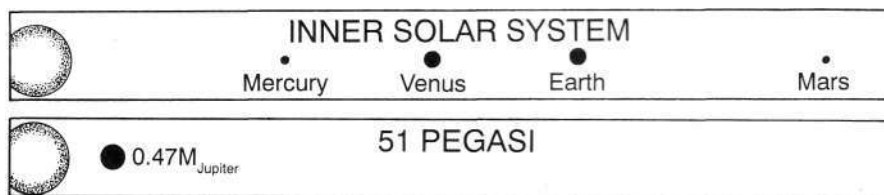


Figure 1. The star-hugging planet, of almost half Jupiter's mass, inferred from a wobble in the spectrum of star 51 Pegasi, compared with the planets of the inner Solar System.