news and views

New source of parity violation

from F. E. Close

FOR some weeks there have been rumours in the high energy physics community that parity violation was being seen in an electron-scattering experiment at Stanford, California. The significance is that electron scattering is the canonical example of an electromagnetic interaction (it is electromagnetism that holds the electrons in the atoms for instance), hence this is a new example of parity violation. The group concerned have now officially announced this to be the case. This result fulfils exactly the predictions of the Weinberg-Salam unified model of the weak and electromagnetic interactions.

The 'parity' involved is a parity between left and right. In a mirror left and right are interchanged: write with your right hand—behind the mirror you see a left-hander. But as left-handers also exist in the real world there is no way of distinguishing from a picture of a left-hander whether he is 'real' or a mirror image. This indistinguishability is called 'parity' conservation.

One of the cultural shocks of our generation was the discovery in 1957 that in the subatomic world one could distinguish right from left absolutely. The key is the weak interaction (the force of nature responsible for radioactivity). Radioactive decays emit neutrinos. These are massless uncharged ghostly particles whose only obvious property is that as they travel through space at the speed of light, they corkscrew. The interesting feature is that they always spin anticlockwise (left-handed corkscrew). Viewed in a mirror one would see a neutrino corkscrewing in a right-handed sense. Such neutrinos do not exist in the real world. Hence the real and mirror worlds can be distinguished. This is the famous violation of parity.

Before this discovery Pauli is supposed to have said that he could not believe that God was a weak left-hander. Afterwards he came to terms with it and said that the mystery was not why he was a weak left-hander but why he was not left-handed everywhere. No evidence for parity violation has ever been found other than in the weak interaction—until this new result.

The facility at Stanford can produce high energy electrons that corkscrew left-handed (like a neutrino) or right-handed. It is because both of these configurations exist for the electron that parity is conserved in electromagnetic interactions whereas parity is violated in neutrino interactions as a result of the absence of right-handed neutrinos.

Now fire these electrons at a proton. It was found that the left-handed electrons have a greater tendency to interact with the proton than do right-handed ones. The left-handed excess is only one event in every 10,000 or so, but this is a large effect within the sensitivity of the experiments. Hence we have a new way of distinguishing the real from the mirror world—there are both left-handed and right-handed electrons, but it is the former that prefer to interact in the real world.

The theoretical significance of this discovery is that it had been correctly predicted both that left-handed should win and by how much. The prediction comes from the Weinberg and Salam unified model of weak and electromagnetic interactions about which much has been written recently (see *News and Views* **264**, 505; 1976; *News and Views* **273**, 98, 706; 1978).

There has been much recent evidence supporting this idea that the weak and electromagnetic interactions are but two faces of the same coin ('unified'). If true this innovation parallels Maxwell's nineteenth century unification of electricity and magnetism into modern electromagnetism. As parity is violated in weak interactions it is not surprising that the unification of the weak with the electromagnetic interaction would cause one to predict that interesting parity violations should be found in processes that are 'electromagnetic'. The Stanford electron scattering is a particular example of such a process and other examples include certain phenomena in atomic physics (see *Nature* **264**, 528; 1976). While experiments in atomic physics are still continuing, we now have the first clear evidence supporting this 'new parity violation' and, moreover, it seems to be precisely as the model predicted.

The source of the parity violation is as follows. In standard electromagnetic theory the electron and proton interact by exchanging photons. This process conserves parity, hence is equally probable for left and right-handed electrons. In standard weak interaction theory neutrinos turn into electrons and interact with protons by exchanging electrically charged W bosons. These are very massive and will be actively searched for at the next generation of accelerators. The left-handedness of the neutrino causes parity to be violated here.

In the unified theory of weak and electromagnetic interactions both of the above naturally occur. In addition, two new types of effect are predicted. In the first of these, neutrinos can remain neutrinos and interact with protons by exchanging a neutral W boson (actually this is called the Z°). This also is very massive and on the list of the searchers. This interaction violates parity because the neutrino is left-handed. Such an interaction (weak neutral current) was first seen in 1973 and seems to violate parity (though some technical assumptions have to be made in order to claim that parity violation has really been seen here).

Just as the theory predicts that a Z° can couple to the (left-handed) neutrino, so it predicts that the Z° can couple to electrons. This is the second effect referred to above.

You may be anticipating that the Z° couples only to left-handed electrons; this is not quite correct. It is the case, however, that it does not couple equally to left and right-handed electrons. The actual preference for the one or the other is expressed in terms of a parameter called the Weinberg argue with a value (deduced from other data) $\sin^2\theta \sim 1/4$.

Hence when an electron scatters from a proton it does so not only by the familiar photon exchange of electromagnetism (equally in right and left-handed modes), but also, albeit rarely, by the Z° exchange contribution ('weak neutral current'). This is predicted to favour left-handed electrons if $\sin^2\theta \sim 1/4$.

It is this observation of the left-handed excess which has provided the first evidence that the neutral current couples to electrons, and the first direct proof that it violates parity. The size and left-handedness of the parity violation seems to point clearly to the Weinberg–Salam model as being the correct model for unifying the weak and electromagnetic interactions. □

F. E. Close is at the Rutherford Laboratory.

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