God has still not shown His hand

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The letters C and P stand for 'charge conjugation' and 'parity' respectively. One of the beautiful consequences of merging quantum mechanics and relativity is the perfect symmetry between particles and antiparticles carrying opposite charge, theoretically predicted by P. A. M. Dirac. One can imagine a charge mirror 'C' which interchanges particles and antiparticles. The theory says that the universe should be symmetric under reflection in this 'C' mirror. The existence of antimatter has been experimentally verified in particle accelerators where it is produced with matter in equal proportions in conditions simulating the hot, dense conditions of the early universe. However, antimatter is not seen in normal conditions prevailing in the universe. This is just as well because whenever matter and antimatter meet, they annihilate one another. Luckily for us all, all planets, stars, galaxies and nebulae seem to be made entirely of matter: the universe we observe is not C-symmetric. So the question that arises is: where has all the antimatter that must have been produced in the very early stages of the universe gone?

The universe was also believed to be left–right symmetric by physicists. A reflection in an ordinary mirror interchanges left and right. The belief was that the fundamental forces of nature are all symmetric under reflections in a mirror, i.e. the mirror images of all fundamental processes occur as frequently as the processes themselves. This is called conservation of parity (P). In the early fifties T. D. Lee and C. N. Yang had carefully analysed weak-interaction processes and concluded that there was no clear experimental evidence for parity conservation in weak processes. They suggested an experiment involving the angular distribution of beta rays emitted by polarized cobalt-60 nuclei (placed in a magnetic field) to verify whether parity was conserved or not. The experiment was performed by Wu in 1956. She found that more beta rays were emitted against the spin direction than along it. This showed a definite asymmetry between the process and its mirror image--parity is violated in the process. This created a sensation, and Lee and Yang were awarded the Nobel Prize. As Wolfgang Pauli put it, if the Almighty is a weak left-hander, why does He express Himself symmetrically when He expresses Himself strongly? The question has not been answered as yet.

Although both the symmetries C and P are violated in nature,the combined symmetry CP (i.e. two successive reflections in the C and P mirrors) was still expected to hold in every case. Even this symmetry was found to be very weakly violated in a specific process involving neutral kaons. In 1964 Christensen, Cronin, Fitch and Tourlay were measuring the pionic decays of the long-lived neutral kaon K_l^0 which, if CP was a good symmetry, was expected to decay only into three pions. They actually observed a minuscule fraction of two pion decays as well, signifying a violation of CP symmetry. The group was awarded the Nobel Prize for this important discovery.

Shortly afterwards, Andrei Sakharov pointed out that this minuscule violation of CP symmetry might actually account for our very existence, i.e. the predominance of matter over antimatter in this universe if certain likely conditions like thermodynamic nonequilibrium held in the early universe.

A recent meeting* in Calcutta took stock of this important issue after 25 years during which much further experimentation and theoretical work has been done. 'Yet, we are no wiser today than we were 25 years ago', said Prof. P. K. Kabir of Virginia who inaugurated the meeting. CP violation has not been seen in any other process. There is much speculation about whether it will be seen in analogous processes involving the so-called neutral B mesons (carrying the 'bottom' quarks). There is a proposal to build a B factory which will produce a sufficient number of B mesons to verify the effect.

A small electric dipole moment of the neutron, if discovered, would also be a signature for CP violation. The standard model of electro-weak interactions proposed by Salam, Weinberg and Glashow predicts a small value for it. Measurements so far seem to indicate a somewhat larger value. More accurate measurements are therefore necessary to establish (a) whether the neutron really has a small electric dipole moment, and (b) whether its magnitude is consistent with the prediction of the standard model.

*The Topical Meeting on CP violation was held at the Variable Energy Cyclotron Centre in Calcutta from 3 to 5 January 1990. The meeting was sponsored and organized by the S. N. Bose National Centre for Basic Sciences, Calcutta. About 60 scientists from India and abroad participated.

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