SCIENCE NEWS OF THE WEEK

Time Symmetry: Back and Forth and a Break

Much of modern theoretical physics is derived from various principles of symmetry. Of these perhaps the one most likely to provoke exotic fantasies is the principle of time-reversal symmetry. Time-reversal symmetry means that a piece of matter moving forward in time looks the same as the corresponding antimatter going backward in time and vice versa. Experimentation should not be able to see a difference between the two actions.

Going backward in time is a proposition that has no meaning for macroscopic bodies such as cue balls, humans or planets — at least so far as has ever been found out. Large objects can only go forward in time. On the level of subatomic physics, however, the principle of time-reversal symmetry has practical consequences. It can be used to predict certain reciprocities between physical processes going one way and the corresponding inverse processes. A group of physicists working at the Université Laval in Quebec City, Canada, and the Lawrence Berkeley Laboratory in Berkeley, Calif., used one such reciprocal process to investigate time-reversal symmetry. They report in the Dec. 21 PHYSICAL REVIEW LETTERS that at least for this process the principle breaks down. Such a break, if confirmed, could have serious consequences for theoretical physics.

Time-reversal (T) is one of three symmetry principles that taken together make up a grand principle of symmetry and reciprocity between matter and antimatter that is one of the most fundamental statements in theoretical physics. The other two symmetries are charge conjugation (C), or reciprocity between positive and negative electric charges, and parity (P), which decrees spatial symmetry between lefthandedness and righthandedness. The combination of the three is called CPT, and it guarantees such things as that the universe is electrically neutral overall, that there are equal amounts of matter and antimatter in it and that the properties and behavior of antimatter are precise mirror images of those of matter.

The researchers, R.J. Slobodrian, C. Rioux and R. Roy of Laval and H.E. Conzett, P. von Rossen and F. Hinterberger of LBL, first bombarded lithium-7 and beryllium-9 nuclei with helium-3 nuclei. In both cases the target nucleus takes a neutron and a proton from the helium to become, respectively, beryllium-9 and boron-11. In each case a free proton is left over. The free protons come out with a certain polarization, a certain relation between the directions of their motions and the directions of their spins. The experiment measured this polarization.

The inverse process is the bombardment of boron-11 and beryllium-9 with polarized protons to get back either beryllium-9 or lithium-7 and helium-3. In this case the so-called analyzing power is measured, that is, the response of the target to the polarization of the incoming protons. If the principle of time-reversal symmetry holds, the polarization going one way should equal the analyzing power coming back. It doesn't, the researchers found. Incidentally, the experiments themselves were nearly reciprocal with respect to the two sides of the border and of the continent: most of the helium bombardments were performed at Laval's Van de Graaff Laboratory; the polarized proton bombardments were done at the polarized-beam facility of Berkeley's 88-inch cyclotron.

This is by no means the last word. Slobodrian and co-workers mention that since their measurements of polarization were done, a group at the Los Alamos National Laboratory in Los Alamos, N.M. (P.W. Keaton, R.A. Hardekopf, P.W. Lisowski and L.R. Veeser), have done a measurement of the polarization of protons coming out of the beryllium-to-boron reaction and have gotten a value that equals the analyzing power measured by Slobodrian et al. in the inverse process. "Thus, there is now a clear experimental disagreement to be resolved," Slobodrian and co-workers state. More experiments seem certain to be done.

The principle of CPT has been under attack for a quarter-century. In 1956 a violation of parity was discovered in certain interactions involving neutrinos. Some years later a violation of C and P together was discovered in the behavior of K mesons. These violations, although confined to a very small part of the total physics, have caused a great deal of puzzlement over how to explain them in particular and over how to preserve the overall CPT principle.

There is at present no experimental evidence for a violation of the complete CPT symmetry. To preserve CPT in the face of the partial violations of C and CP requires a compensating partial violation of T. Whether the violation of T reported here will prove to be anything like that remains to be seen. If there should be in the end a violation of the total CPT symmetry, then a lot of rethinking will have to be done. All of theoretical particle physics is based implicitly or explicitly on CPT symmetry. A break might mean very little in a practical sense — the known violations in C and CP are very little, in fact — but demand a good deal of new theorizing. — *D.E. Thomsen*

Hubble trouble from quasar bubble

The Hubble constant is the number that measures the expansion of the universe. It is perhaps symbolic of the current state of astrophysics (and maybe of the universe itself) that astronomers have never been able to agree on the value of the Hubble constant. The values used have ranged from about 500 (Hubble himself) down to 50 or less. Gradually, however, it had seemed that more precise observation and sharper reasoning were leading to a consensus for something about 50. Now, some unusual behavior observed in a quasar leads T. Matilsky and C. Shrader of Rutgers University and Harvey Tananbaum of the Harvard/Smithsonian Center for Astrophysics to suggest doubling the ante to 100 or more.

The Hubble constant relates the recession velocity of a distant object such as a galaxy or quasar to the distance of that galaxy. It is measured in units of velocity divided by distance, kilometers per second per megaparsec. The velocity of a distant galaxy can be calculated from the redshift in its light, but the Hubble constant remains unknown unless there is an independent way of measuring the galaxy's distance. For very distant galaxies with easily measured redshifts, there is no independent way. For nearby galaxies there is an independent way of measuring distance, but their redshifts are so small as to be uncertain or statistically insignificant. For decades estimates of the Hubble constant varied all over the lot.

In recent years observations and arguments based on the appearance of things seemed to be narrowing it down to a figure around 50. Now come Matilsky, Shrader and Tananbaum, who want to put it back up to 100 and halve the size and age of the universe.

Their reasoning, laid out in a paper they have submitted to ASTROPHYSICAL JOURNAL LETTERS, is based on the appearance of a certain quasar, 1525+227, or at least its appearance while it was doing some unusual long-term fluctuations in its X-ray output early in 1980. These fluctuations have periods in the hundreds of seconds and include sizable changes in luminosity. Relating these changes to a reasonable efficiency for the conversion of matter to energy in the usual theoretical model of a quasar (which sees a massive black hole at the bottom of things), they find the appearance of the fluctuations best explained if the Hubble constant is 100 or more rather than 50. — *D.E. Thomsen*