

A Quantum Number Whose Time Has Come

Modern physics began with quantum numbers, characteristics of physical systems that change only by discrete integral amounts rather than in the smooth continuous way of classical physics. The first quantum numbers that appeared in atomic physics concerned qualities familiar from macroscopic physics such as electric charge or angular momentum (spin). Today there are many others, and the existence of the latest to be hypothesized, charm, seems now overtly proven.

With quantum numbers went conservation laws. Conservation laws specify that in any activity of the physical system (such as radioactive decay or various collisions and what comes out of them) the total amount of the given quantum number must be conserved (or may change only in certain circumstances under strict rules). Conservation laws are an inheritance from classical physics. In that realm both charge and angular momentum are absolutely conserved.

It was difficult enough to understand why old familiar things like electric charge or angular momentum, which could change continuously in the macroscopic world, suddenly turned into quantal jumpers when the boundary of the atom was pierced. But then the real fun began. As physicists discovered more and more "elementary" particles that behaved in many complicated ways, they had to invent ever newer and more exotic quantum numbers and conservation laws to sort out permissible from impermissible behavior. Some of these were named for a physical connection (for example, isotopic spin, which refers to differences among isotopes of the same system); some are arbitrary or even whimsical, like charm, whose hour now seems to have struck in two different laboratories.

Charm came into theory in the usual way to explain why certain decays, permitted under all the previous rules, were not seen. Like most changes in theory, charm brought new predictions in its train, and experimenters began to look for these. For more than a year, since the discovery of the psi particles in November 1974, physicists have suspected that charm was responsible for anomalies in the behavior of these new and exotic objects. But the psi's were viewed as combinations in which charm and anticharm balanced each other and were therefore not overtly detectable. To clinch the case, particles were needed that displayed unbalanced, overt charm. These now seem to have been found in three events recorded at the CERN laboratory in Geneva and four more at the Fermi National Accelerator Laboratory near Batavia, Ill.

The work concerns the interactions of neutrinos in bubble chambers. All of FermiLab's four events yield a negatively charged muon, a positron and a neutral K meson. The crucial point is that the muon and the positron belong to the class of particles called leptons and the K meson possesses the quantum number called strangeness. Charm was invented to explain certain anomalies in the behavior of particles with strangeness, and this kind of a decay, yielding two leptons and a strange particle at the same time, is the sort theory would expect from a particle with unneutralized charm. The three CERN events are exactly the same as FermiLab's four, and the conclusion there is the same. CERN's statement even refers to this "as a new process of nature."

Apparently the neutrino, striking a neutron or proton in the bubble-chamber liquid, produces the new charmed particle, and that then decays into the products recorded. From the energies of the positron and K meson, the FermiLab people estimate the mass of the new particle at twice that of the proton (approximately two billion electron-volts), and from the virtual lack of any flight space for it in the pictures, they believe its lifetime should be less than 10^{-13} seconds.

The introduction of charm into theory required an important amendment to the decade-old quark theory of the structure of particles. The theory had held that the properties of the particles could be understood if they were regarded as various permutations of combinations of three basic subparticles called quarks and three basic antiparticles called antiquarks. Charm requires the existence of a fourth, charmed, quark and a fourth, anti-charmed, antiquark. The psi particles are regarded as containing within themselves pairs of the charmed and anti-charmed quarks. Thus, although they do not exhibit

charm overtly, it does influence their behavior. The new particles now reported by CERN and FermiLab seem to contain an unbalanced charmed quark and may be the first of a whole new series.

The rarity of the events should be stressed. The CERN statement refers to one of CERN's events as literally one in a million pictures. Particle physicists are used to having thousands or millions of events on which to base arguments. Three or four make them very cautious.

So news of this kind transpires slowly and painfully. (If there were ever an accurate use of "transpire," this is it.) At first a few close colleagues are informed confidentially. Then the circle of those in the know is widened. Eventually, a statement may be made by the way at a meeting, or a carefully worded paper in which the real discovery is treated in a throw-away line is published as a trial balloon. If by now the proponents have not been flattened by the critics' artillery, they may venture a formal claim to discovery. The only literature reference for this affair so far is a paper referring to one of the events published in *PHYSICS LETTERS* (58B:361) by 54 physicists from all over Europe working at CERN.

These days physics seems to have completed a kind of circle. In Newton's day there was a certain specificity about it. There is, after all, only one moon, and from its behavior Newton was rash enough to generalize the whole universe. As physicists began to study large aggregates of similar bodies, gas molecules, for example, statistics and statistical laws came to the fore. In atomic and particle physics statistics became intrinsically necessary because of a built-in uncertainty about what any individual particle would do. Now it seems we are back to the point of supporting universal theories with very few instances. □

Ethiopian fossils: The way we were

When and where are pretty well settled. Now it is time to concentrate on what. That question has to do with the earliest true humans, the genus *Homo*. Recent finds reported by Richard E. Leakey, Donald Carl Johanson and Mary Leakey (SN: 11/8/75, p. 292) have all placed *Homo* in East Africa at least three million and possibly four million years ago. This week another fossil find was reported. It confirms the place and time and adds to the growing body of knowledge of what our ancestors were like.

The find—bones of two infants and three to five adults—was made by Johan-

son of the Cleveland Museum of Natural History and Maurice Taieb of France's National Center for Scientific Research. Their work, sponsored by the National Geographic Society, was done in the Hadar region of Ethiopia.

The site of the find is a sharp, narrow slope that may once have been on the shore of a lake. The volcanic soil in which the fossils were found was tested by Taieb, a geologist, and confirmed to be more than three million years old. A previous find by the researchers in the same area could not be as well dated and was only estimated at three million to four



National Geographic Society

Johanson examines a day's fossil finds.
million years by associated fossils.

"Finding a group of individuals of this antiquity in one small site is exceptional," says Johanson. He suggests that they may have been caught by a sudden disaster, possibly a flash flood that trapped them in the small defile or gorge. The site, about 40 feet wide and 60 feet from top to bottom, was apparently filled in a single day.

Previous human fossil finds in this age range have consisted mainly of skulls, jawbones and teeth. The Hadar fossils are somewhat more complete. Johanson not only concludes that the bones are those of *Homo* but also has enough evidence to begin a physical description of what these humans may have been like.

"One nearly complete hand is almost modern in size and obviously was capable of a long grasp and probably of fine, precise movements," says Johanson. Measurements of leg bones from the site have helped him determine that at least one of the individuals was a large person, approaching the height of modern humans, more than five feet tall.

Mary Leakey's recent finds at Laetoli, Richard Leakey's almost 150 hominid bones from digs on the eastern side of Lake Turkana (formerly Lake Rudolf) and the latest Hadar finds are all adding up to what will eventually be a complete morphological description of our early ancestors. And with the growing number of human fossils it is now possible to begin asking other questions. Richard Leakey (in a recent interview with Unesco Features) discussed the apparent fossil richness of East Africa and some of the questions that can now be asked about *Homo*: "Previously a book would be written about a single skull or jaw; nowadays, studies are based on whole collections of data. We have enough material in some instances to begin to talk about population dynamics and population variation in the Pleistocene era." □

Crab nebula pulsar: Superslippy

Now that neutron stars are actual objects of observation rather than theoretical speculation—most astrophysicists would now agree that pulsars are neutron stars—much observational and theoretical effort is going into attempts to determine the details of conditions and activities in them.

A group from Columbia University (Robert Novick, professor of physics, Richard S. Wolff, assistant professor of physics, Howard I. Kestenbaum, research associate in the Columbia Astrophysics Laboratory and graduate student William Ku) now report the first measurement of the surface temperature of a pulsar, a datum that has an important bearing on the state of the matter in the neutron star. In fact they conclude that this neutron star, NP 0532 in the Crab nebula, at least, is a ball of superfluid.

To get the surface temperature, it was necessary to distinguish between the pulsed X-ray emission that makes the object a pulsar and is believed to come from the neutron star's magnetosphere, and continuous X-ray emission which would be the result of thermal activities at the surface of the neutron star, and from which its surface temperature could be determined.

The way to make this distinction was to use a lunar occultation of NP 0532. Every 11 years the moon makes a series of passes in front of the Crab nebula. The occultations of 1974 were the first to occur since the discovery of pulsars and are thus the first opportunity for this kind of measurement. As the moon's edge passes across the nebula it cuts off radiation from one location after another.

The observations were made with a rocket that went a hundred miles up. As the moon eclipsed the pulsar, the observers could record the X-ray emission of the surrounding nebula. Then, as the pulsar came out from eclipse, its own contribution could be distinguished from the nebular background. The observers then searched between the 30-hertz pulses of NP 0532's contribution for a steady flux that would be expected from the surface. They found none.

They conclude, therefore, that the pulsar's surface temperature is no more than 4.7 million degrees K. Since neutron-star models that exclude superfluidity require much higher temperatures (9 million degrees K. or more), the Columbia group conclude that superfluidity must be part of the picture. Their findings are being published in the *ASTROPHYSICAL JOURNAL* (the first appears on p. L77 of vol. 202).

Superfluidity is a state in which a fluid loses all viscosity and flows without friction. The fluid can perform many amazing tricks such as climbing the walls of its container or passing through orifices normally too small for it. On earth superfluidity appears only in liquid helium at tem-

peratures near absolute zero, but the pressures and forces between the neutrons (and some protons and electrons) that make up a neutron star are so different from those between liquid molecules on earth that a much higher temperature limit is possible. □

Breeder reactor: Full speed ahead

When the Energy Research and Development Administration earlier this year announced a sweeping "National Plan" for energy development, a key feature was to be reassessment of the breeder reactor program and a shift of emphasis in favor of non-nuclear alternatives (SN: 7/5/75, p. 4). Specifically, ERDA Administrator Robert C. Seamans Jr. ruled that the previous environmental impact statement for the breeder was inadequate, and called for a complete review of the seven-volume document.

The reassessment has now apparently been completed and the breeder reactor program is being pursued with renewed vigor. Seamans's review added three more volumes to the environmental impact statement but created little change in the program direction. Simultaneously, ERDA has created a new Division of Reactor Development and Demonstration devoted exclusively to the breeder. Elevation of the program to full division status reflects both "the importance assigned to the program by ERDA, and the Government's determination to carry the program forward with proper safeguards and sound environmental considerations," according to the official announcement.

Seamans admits "major areas of uncertainty" remain, including plant operation, fuel cycle performance, reactor safety, safeguards, health effects, waste management and uranium resource availability, but says these should be cleared up by 1986. At that time a decision would presumably be made as to whether the breeder reactor could be safely licensed for commercial application and whether the economics of doing so are attractive.

A three-stage program for the breeder is now contemplated: a demonstration reactor at Clinch River, Tenn. (CRBR); a Prototype Large Breeder Reactor (PLBR); and the first Commercial Breeder Reactor (CBR-1). By the 1986 deadline for a decision on whether the breeder is feasible for commercial use, CRBR should have been in operation three years, construction of the PLBR should have been largely completed, and the CBR would be in the design stage. The goal, in the words of Assistant Administrator Richard W. Roberts, is to have the breeder as an "alternative for the 1990's." □