Quarks Down Under? Physicists Have Reservations

The report by Australian physicist Charles McCusker that lightly ionizing particles photographed in his cloud chambers might be the eagerly sought quarks is already a candidate for the most exciting physics story of the year. If verified, the work reported on 2 September will be a major landmark in 20th-century physics because it will provide physicists with a relatively simple method of studying the most fundamental processes known.

A team of physicists from the Cornell–Sydney University Astronomy Center and the University of Sydney discovered the tracks with four 30-centimeter Wilson cloud chambers, Geiger counters, and a plastic scintillator array—almost "off the shelf" apparatus by modern high energy standards. The experiment has provided five quark candidates among the more than 66,000 tracks photographed since the equipment went into operation in June 1968.

Quarks have roots in two venerable traditions of natural science—explanation through the use of physical models and belief in the mathematical nature of matter. In the 19th century, chemical behavior was described in terms of the atomic model. This model, in turn, was described during the first third of this century by a model consisting of electrons, protons, and neutrons. As more particles were discovered, however, the physical models were pushed into the background and replaced by mathematical systems incorporating quantum physics, special relativity, and a concept of symmetries.

One of the more powerful of these systems is the SU(3) symmetry that was developed to treat the strongly interacting particles. Many properties of these particles could be explained if they were placed in families of eight or ten, and the theory successfully predicted the existence of the omega-minus particle, which was discovered in 1964.

This was not a particle of a new fundamental substratum but a missing member of one of the families. The only candidates within the theory for elementary particles are triplets used to generate members of the particle families. In 1964 Murray Gell-Mann and Georg Zweig independently modified the theory in a way that made it possible to assign fractional charges to the triplets. In tune with a certain levity evident in high energy nomenclature, Gell-Mann dubbed the triplets "quarks," from the line "three quarks for Muster Mark" in James Joyce's *Finnigans Wake*. In the minds of some, mainly theorists, naming the triplets did nothing to make them any more than a mathematical device, but others took the possibility of physical quarks seriously, and schemes for detecting them have been operating since the theory was modified.

McCusker's team gambled on the possibility that quarks are sometimes produced in the showers that form when extremely high energy cosmic rays strike the earth's atmosphere. Their apparatus was designed to detect showers generated by particles with a mean energy of 4×10^{15} electron volts, or about 60,000 times the energy of the world's most powerful accelerator at Serpukhov in the Soviet Union. At these high energies, the ionizing ability of a particle is almost entirely dependent on the square of its charge. Quarks can have charges of one-third or two-thirds, so their ionizing ability is only 0.11 or 0.44 (their charges squared) as strong as that of normal particles.

Ionization is measured in cloud chambers simply by counting bubbles that form on the ionized particles, so quarks should show up as tracks with fewer bubbles. The Australian apparatus is not sensitive enough to distinguish the particles with one-third charge from the background, but it provides impressive evidence for the particle with the two-thirds charge.

For example, in the best photograph—event 66240—there are five tracks with an average of 230 bubbles each. A sixth track has 110 bubbles; thus its ionizing power is 0.48 that of the other five. The statistical method for counting bubbles introduces an error of ± 0.05, so the result is within the prediction of 0.44.

Several hurdles must be cleared before the existence of quarks is widely accepted. At the 1969 International Conference on Cosmic Rays (Budapest, 25 August to 4 September), where the work was presented, the strongest attacks from the devil's advocates were on the statistical methods used to treat the data. For example, one participant showed that the probability of occurrence of lower energy particles (these ionize less and hence simulate the behavior of a two-thirds charge) could be treated statistically in a way that would account for the rate of four lightly ionized tracks per year. Arguments like this will keep most physicists skeptical until McCusker can present more experimental details than he did at the Budapest conference or in a report in *Physical Review Letters* of 22 September.

Another hurdle is the incompatibility of the Australian results with an experiment done at Argonne National Laboratory 3 years ago. Theory indicates that quarks could form stable composite particles with nucleons (normal protons and neutrons), and that the odd charge of these composites should make their detection possible. The Australian work implies that quarks should be present in concentrations of one quark in 10^{24} nucleons, but the Argonne team failed to turn up quarks with equipment sensitive enough to detect one in 10^{27} nucleons. This discrepancy may be cleared up either by showing that one of the experiments is wrong or by showing that quarks do not remain in the vicinity of the earth after they are formed in cosmic ray showers.

Other laboratories should be able to confirm or negate the Australian work within a year or so, because, unlike most recent high energy experiments, the equipment required for this one is readily available. Use of cloud chambers declined in the late 1950's as bubble chambers and scintillation counters were developed for use with accelerators; thus at present there are a number of idle cloud chambers, many of them as good as those used by the Australians. The importance of the Australian findings will undoubtedly stimulate a number of researchers to dust off their old cloud chambers for a quark hunt of their own.

—ROBERT W. HOLCOMB

Robert W. Holcomb recently joined the staff of Science *to write "Research Topics."*