This Week’s Citation Classic

Ne'eman Y. Derivation of strong interactions from a gauge invariance. Nuclear Phys. 26:222-9, 1961. [Department of Physics, Imperial College, London, England]

The known hadrons are classified as octets of SU(3). Strong interactions should be approximately invariant under this symmetry. A spinless meson and an octet of spin-one mesons are predicted. This paper introduced SU(3) with correct particle assignments. It led to quarks, charm, color, etc. [The SCI® indicates that this paper has been cited over 510 times since 1961.]

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“...The search for a classification had been on since 1950, based on selecting some ‘more fundamental’ particles out of the known ones. The rest would then be composites. Fermi and Yang had suggested the proton p and neutron n and their antiparticles p, n as basic, and Sakata had added a A hyperon with a unit of strangeness. The “* or a”, hyperons, for example, were assumed to consist of (A p) and (AAP) respectively, the, latter with spin 3/2. This had led the Sakata group in 1959-60 to use SU(3) as a symmetry of p, n, A. “I was not aware of that fact at the time.

“I was an Israeli Army Colonel serving as defense attaché’ to the London Embassy. I now had a year’s leave, working at Imperial College under A. Salam for my PhD. He had suggested a good calculation but I was captivated by the classification problem. Salam warned me this was highly speculative. I used an abstract approach: could all known particles be plausibly fitted in representations of a Lie group of order two? I had abstracted this condition, observing that all reactions conserving strangeness and isospin appeared allowed in strong interactions. I checked systematically through Cartan’s list, which yielded SU(3) and the octet assignment for baryons (p, n, A, Ó+, Ó°, Ó-, E°, E*).}

I. Here I had spin 1/2 like p, n, versus the Sakata prediction 3/2. Later experiments confirmed 1/2. The seven spinless mesons fitted another octet, with one meson missing. Theory also required an octet of spin-one mesons. All this was experimentally validated within a year, mostly by the Alvarez group.3

“With baryons in an octet, could they themselves be composite? With H. Goldberg back in Israel we suggested the fundamental objects were ‘thirds of baryons,’ i.e., a proton would be made of three of them. This would ‘explain’ SU(3). That paper is seldom quoted. It appeared before the physics community had really adopted SU(3) and the octet, as a result of the Omega-Minus experiment in 1964.4 Cell-Mann and Zweig perfected the idea of a fundamental triplet (quarks) and happened to publish their papers in the wake of the Ù excitement.5

“Quarks have not been found in a free state to date but have been observed inside p, n. They are probably confined. SU(3) proved very useful beyond strong interactions, providing also a precise description of weak and electromagnetic interactions.

“Originally, the paper had a detailed mathematical introduction. However when I heard from Salam that SU(3) had already been used by the Sakata team, I naively shortened my introduction. Luckily, I kept the explicit matrices for the particle families.

“After I had sent the paper to Nuclear Physics, we received Cell-Mann’s (unpublished) draft with similar ideas. When my paper was returned with an angry letter from the editor complaining about single-spaced typing, I added a note about Cell-Mann’s draft and an independent suggestion by Salam and Ward of the spin-one octet, based on the Sakata model.

“The Ù experiment so unambiguously confirmed this paper’s theory that it became a paradigm upon which all further progress would be based (quarks, currents, color, charm, etc.), thus accounting for its frequent citation.”