Chapter XI

POSSIBLE INTERNAL SUBQUANTUM MOTIONS OF ELEMENTARY PARTICLES

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Most of the past discussions of quantum mechanics have concentrated on the behavior of matter under the influence of the so-called long-range fields (with singularities of the Coulomb type), namely the gravitational and electromagnetic fields. Indeed, Einstein’s last attempts were devoted to the construction of a unified geometrical description of their effects at the classical level.

In this paper, I will make an effort to present the essential results of the most modern type of high-energy physics: the theory of elementary particles. Such a step is indeed indispensable for two fundamental reasons. First, it is clear that only within this field can we look for experimental confirmations (or infirmations) of any assumption we can make on the deep nature of matter itself (see, for example, de Broglie [1]). Second, because all discussions of the epistemological problems raised by the development of physical theories within the last fifty years (they have been more important and deeper than ever before in the history of human knowledge) must, in my opinion, keep abreast in principle with the progress of the most advanced type of physical theories. If that were not the case, our discussions would soon resemble the bar talk of retired war veterans. They would turn into a Byzantine exchange of arguments on dead problems foreign to the preoccupations of the ‘plumbers’ — the men who really raise (and solve) the most advanced types of philosophical problems of our world: the scientists themselves.

In my opinion, the most striking fact in the recent period has been the appearance of new quantum numbers associated with the new short-range types of fields (strong and weak interactions), introduced to describe the behavior of matter in the high energy domain. Indeed, along with the “old” quantum numbers such as electromagnetic charge $e$, mass (defined

*Yourgrau, who coined this label, seems to enjoy not only rational controversy, but even polemical, plainly crude, terminology. Well, this is perfectly alright with me!
by $P_\mu P^\mu = -\mu_0^2, P_\mu$ being the 4-momentum), and spin $J$, we have been obliged to introduce "new" quantum numbers such as $T$ (isobaric spin), $Y$ (hypercharge), and $B$ (baryon number), all related to new conservation laws which have been discovered in the fields of strong interactions.

This immediately raises new fundamental problems:

A. What is the physical nature of the new fields? Is it possible to "geometrize" them as Einstein had done for the old long-range fields?

B. What is the meaning of the new quantum numbers? Can they be associated with the quantization of some dynamical behavior? Or should we interpret them in a completely new way?

Note here that (still in my opinion) one of the most mysterious aspects of modern physics is encountered in the existence of empirical relations which connect the old with the new quantum numbers. Indeed, we have

$$Q = T_3 + \frac{Y}{2},$$

the Nishijima-Gell-Mann relations, and

$$m = a + bY + c \left[ T(T+1) - \frac{Y^2}{4} \right],$$

the Gell-Mann-Okubo formula; though the second (as is well-known to physicists) is not as satisfactory as the first.

This suggests that there must be something in common between them, and one of the essential theoretical problems of our time is precisely to justify and understand this connection.

C. If one accepts the idea that quantum numbers are associated with dynamical behavior (so that the new quantum numbers are somehow connected with a dynamical behavior at a deeper level, that is, with strong interaction regions with radii $r \approx 10^{-13}$ cm), then we must raise the problem of the connection of the old external invariance groups (associated with the long-range forces), such as P (Poincaré) or de Sitter SO(4,1) or U(1) (electromagnetic gauge invariance), with the new strong invariance groups such as SU(3).

This raises two subquestions:

C1. Until now, one always assumed that the global symmetry group could be written in the typical form $P \times SU(3)$ ($\times$ denoting the direct product) which implies that the operator $P_\mu P^\mu$ commutes with the SU(3) multiplets which are thus degenerate in mass. This entails that, if one wants to remove this degeneracy, one should break this symmetry—a very disturbing fact since conservation laws result generally from the existence of exact symmetries.