ELEMENTARY PARTICLES .....

... AND THE THIRD LIMITATION ON PHYSLCAL EXPERIMENTS

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The increase of entropy in a measurement is very small out cannot be zero, because the smallest possible amount is of the order of k, the constant of Boltzmann. In this paper it is argued that the negentropy perturbation, usually negligible, is crucial in the domain of elementary particle physics. For in that domain observed systems must be assigned an entropy which has the same order of magnitude as the inevitable increase of entropy due to measurement. This leads to the conclusion that notions of no equilibrium thermo-dynamics, especially entropy production, are indispensable for an understanding of the characterizing properties of elementary particles. Finally it is discussed that an important class of particles, the hadrons, appears to have essential characteristics of dissipative structures.

1. Increase of entropy due to measurement
   In the early fifties Brillouin formulated the negentropy principle of information, according to which information must always be paid for in negentropy.1 Any experiment by which information. Al is obtained about a physical system produces an increase of entropy AS 2 AI in the system itself or in the equipment used for the experiment. This principle is independent of Quantum Theory (QT) and its uncertainty relations. It is a new and independent category of perturbation, due to the essential irreversibility of all observations. ln other words, it imposes a new limitation on physical experiments (p. 233). The negentropy perturbations, like the qauntum perturbations, are subject to a lower limit: no information can be obtained for a cost of less than kln2 ($:1ä”') units of negentropy (p. 184). This amount is very small and in general practice negligible. However, in this century it has become clear that minute quantities can become very important. Therefore Brillouin hoped that despite the tiny value it will "sooner or later, come into the foreground, and that we will discover where to use it to its full value" (p. 294). When will this new limitation be crucial? ln my opinion, when the entropy of the observed system is of the same order of magnitude as the inevitable increase of entropy due to measurement. This is analogous to the two limitations on physical experiments which physics encountered in this century.
   The quantities-ä and h, not being zero but finite, became pivotal in Relativity Theory and QT respectively, when the velocities and actions of the observed systems are of the some order of magnitude as the velocities and actions of the means of observation.

2. The measurement of elementary particles
Any measurement necessarily requires a certain temporary coupling and exchange between the system and the measuring instrument. Therefore, any observed system is an open system, which implies entropy production and irreversibility. This aspect of measurement is not crucial in QT, because this theory is not affected in its structure by it. Quantal laws, just as the classical ones, are reversible with respect to time. Neither is the irreversibility a result of the quantum mechanical aspect of measurements. In QT the negentropy perturbation and the openness of the observed system can be neglected because QT concerns many possible states of atomic systems; this implies a large number of complexions and thus a high entropy value. A different situation we encounter in the domain of special properties of elementary particles. Fundamental properties of

the so called elementary particles are those which characterize the identity of the particles. Definite values of rest mass energy, charge, lepton number (e.g.) characterize, not the state of a particle, but the particle itself. These properties are only partially Understood. There are important differences between the properties which are subjected to the (quantum mechanical) superposition principle (e.g. energy, position, linear momentum), and the typical non-superposaÉ5properties (e.g. charge, lepton
number), which characterize the particle (e.g. an electron) as a structure of individuality. Remarkably, these fundamental properties have only two possible values, characterizing the particular particle and its antiparticle. The importance of this fact can be seen when we realize that information concerning these properties is gained in modern elementary particle physics, especially by means of tracks of individual particles (e.g. in a bubble chamber). Elsewhere3›4 I discussed the special character of these records (in contrast to the spectral lines which played a central role in the development of QT). The track and thus the whole recording process and irreversibility due to it, is directly connected with the particle itself. Concerning the so recorded information the system is therefore essentially, and not negligibly, an open system. An adequate theoretical treatment of such a system requires the use of thermodynamical notions. In other words, an - abstract - no equilibrium thermodynamics must be introduced into this domain of elementary particle physics. (Note: such a development will be analogous to the introduction of an - abstract - wave theory into the quantum domain in the twenties.) Then the observed open system - the elementary particle concerning the characterizing properties - must be assigned an entropy. As mentioned above, these properties have only two possible values. With the universal constant k this yields an entropy of the order kln2. I conclude: here we have indeed a domain in which the observed systems have an entropy of the same order of magnitude as the minimal increase of entropy due to measurement.

3. Elementary particles as steady states and dissipative structures

Since now negentropy perturbation is crucial, the entropy production, which occurs due to the coupling between system (elementary particle) and instrument (which consists of similar systems), implies substantial disturbance of order end increase of lack of information. Yet, this does not mean that at the discussed level of elementary particles order is completely absent and that information acquisition is totally impossible. On the contrary. _ ,

We know from the thermodynamics of irreversible processes, that open systems - despite considerable entropy production - can display ordered behaviour. There are two main classes of such systems, dependent on the strength of the forces between the system and the surroundings. In the range of linear thermodynamics of irreversible processes, when the permanent external constraints are weak, steady states are characterized by (continuously compensated) minimum entropy production. In the non-linear range, with strong external constraints, entropy production is large. The irreversible processes and exchange of energy can result in the creation of new highly organized structures, called dissipative structures. Large entropy production is thus connected with dynamical structures which display highly ordered behaviour. It is remarkable that, despite the entropy production, the number of complexions is extremely small, so there is a low entropy value. As discussed, an understanding of the elementary particles - concerning the fundamental characterizing properties - requires a no equilibrium thermodynamics adapted to the micro level.(note that the concepts temperature etc. should be used in an abstract sense, see ref. 4). Because the entropy production is pivotal, this evokes the conjecture that the two main classes of elementary particles, the leptons and the hadrons, can be understood in strong analogy to the aforementioned two main classes of systems from the macro theory. (This analogy resembles the similarity between the stationary states of QT and those of classical wave theory.) The hadrons participate in the strong nuclear force and have an internal structure. When entropy production is indeed crucial, then hadrons have similar characteristics as dissipative structures. Accordingly, quarks will probably appear to be not particles but abstract sub-structures, 'confined' inside the structured organization of the whole dissipative structure. By this approach it may also become clear why similar phenomena are important in macro no equilibrium thermodynamics as well as in the domain of elementary particles: symmetry _ breaking, instability of systems, systems having a 'historical dimension, etc. Exactly the insight that the third limitation on physical experiment is crucial, provides the possibility for a further understanding of elementary particle properties. Obviously, this conclusion has considerable philosophical consequences [7].

References

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