Interactions, Symmetry, Lorentz Invariance: The Struggle of Physicists About These Concepts

Eliano PESSA
Department of Brain and Behavioral Sciences
University of Pavia, Italy
and
Italian Association for Systems Research

As well known, a still large number of physicists understands the whole corpus of theoretical physics as a complex system which, after all, is based on three primeval and fundamental pillars, constituted by the concepts of Interaction, Symmetry, and (excluding Cosmology) Lorentz Invariance. The latter have been introduced from long time and boast a tradition dating to Newton times. In the last century some new ideas, like the ones arising from quantum theory or disordered systems, seemed to introduce deep changes into this sound conceptual picture. In practice, however, the theoretical innovations so far did not change very much the old scheme: even the most inveterate quantum physicist continues to use the Hamiltonian dynamics just in the same ways as his nineteenth century predecessors.

In this contribution I will try to evidence that this state of affairs is actually changing, on the basis of new suggestions introduced by researchers such as Jean-Pierre Vigier, who put forward strong arguments supporting the need for a radical change of the conceptual structure of physics. These arguments came, on one side, from the attempts to build a sounder philosophical foundation of physics and, on the other side, from the applications of physics to highly complex systems (very different from the ones considered by traditional physics). This situation gave rise to a sort of struggle between the holders of different conceptions. Even if it impossible to foresee the final destiny of this struggle (if any) it is becoming clearer that the old concepts of interaction, symmetry, and Lorentz invariance will survive only when applied to enough simple systems.

Among the many evidences of the aforementioned change I will limit myself to discuss two cases: 1) the introduction, within classical field theories, of new theoretical proposals which generalize in a somewhat 'heretical' way the traditional constructs of interactions and symmetry used in mathematical physics; 2) the need for using, within mathematical models of complex system behaviours (like, for instance biological neural networks), methods for assessing the validity of the introduced models based not only on general mathematical arguments, but also on computer simulations of model dynamics.

As concerns the case 1), we quote an example given by the introduction of the so-called 'deformed relativity', which not only appears as a natural generalization of usual relativistic theories, but also shows that the usual hypotheses about the Lorentz invariance and the absolute existence of interactions, independently of the considered energy range, are often violated.

The case 2) raises a number of questions. Here I will discuss only two of them: a) most physical theories are expressed making use of a continuum-based mathematics; on the contrary the simulations (and the network science) involve discrete approaches; what is the relationship (if any) between continuous and discrete models?; b) most observable phenomena (not only in inanimate matter, but even in biological, cognitive and social systems) seem to evidence a quantum nature; now, while it is possible to simulate on a computer quantum behaviours (for instance through the so-called 'Quantum Probability' methods), how to detect from the results of these discrete simulations the presence of interactions and symmetries, which are concepts typically born for describing continuous and macroscopic phenomena? Of course, techniques of statistical network analysis can help very much to reach this detection, but what will happen if the future physics will be forced to treat interactions and symmetries only as statistically defined entities? What will be the destiny of concepts such as 'particle' or 'molecule'?