Symmetry-Breaking Vacuum and State Vector Reduction

H. D. Zeh

Institut für Theoretische Physik
Universität Heidelberg
Heidelberg, West Germany

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It is argued by means of analogy with certain irreversible processes that a symmetry-violating vacuum need not necessarily be explained by a special cosmic initial condition.

States not invariant under symmetries of the Hamiltonian are of importance in many fields of physics. However, the quantum mechanical description of microscopic objects contains a consequence foreign to classical descriptions. Superpositions of the symmetry-violating states also form possible states. In this way symmetric states can be constructed again.\(^{(1)}\) For example, the ground state of an intrinsically deformed nucleus can be described as a symmetric superposition of all its orientations in space. In contrast, macroscopic objects are known to be observed only in states of certain orientation. Therefore, their rotational motion is conveniently described classically, that is, by using the concept of definite coordinates. The possibility of superpositions of macroscopic properties is sometimes "postulated away" by superselection rules.\(^{(2)}\)

Quantum field theories with a symmetry-violating vacuum\(^{(3)}\) are also interpreted "classically." Only definite values are considered for the generator parameters of symmetry transformations.

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The assumption excluding the existence of superpositions of macroscopic properties appears dynamically consistent. The dispersion of the localized wave packet in the course of time can be neglected for sufficiently large systems. The only important dynamical connection between different orientations is due to the corresponding collective motion (rotation), which in the limit of infinite systems has properties of a Goldstone excitation. The non-occurrence of superpositions therefore in this case may be explained by a cosmic initial condition stating that this universe was created with states of macroscopic properties only in very narrow wave packets. Similar arguments could be used to exclude superpositions of vacua with different symmetry orientations. Dynamical transitions are here usually neglected by restriction to the corresponding Fock space in connection with renormalization procedures.

The above argument about the dynamical consistency of classical descriptions of macroscopic properties cannot always be used. Different situations are known to occur with irreversible processes like boiling in overheated liquids. The occurrence of bubbles at certain places is generally attributed to impurities disturbing the translational symmetry. In completely pure liquids bubbles would originate from quantum fluctuations by a "reduction of the wave function," which is better known from the process of measurement, another irreversible process. Application of the linear equation of motion alone would lead to superpositions of different locations of bubbles in the first case, and to superpositions of different measurement results in the second. These linear transitions may form irreversible processes in themselves, which can be understood by statistical (dimensionality of subspace) considerations. For example, the number of linearly independent states with bubbles may by far outweigh the number of such states without bubbles. The statistical arguments, however, cannot explain the reduction of the wave function that is responsible for the symmetry violation. The way in which the wave function is decomposed for the purpose of the reduction is usually determined intuitively; general criteria so far have been proposed very vaguely. It is known empirically that the reduction tends to separate different values of such properties which we call macroscopic. The above-mentioned cosmological assumption is then unnecessary.

The analogy with quantum field theories is obvious. The observation of definite values of the parameters of symmetry groups does not require the assumption of an initially asymmetric universe. It does require an intrinsically broken symmetry (that is, the existence of certain intrinsic correla-

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1 Here we will not distinguish between the reduction assumption and the multiuniverses assumption, although these two versions may lead to different dynamical consequences.