The time and canonical transformations in quantum physics

E.A. Solov'ev

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia

e-mail: esolovev@theor.jinr.ru

The general aspects of the interpretation of quantum theory is discussed. Namely, the role of the time and canonical transformations.

In 1926 Schrödinger proposed his wave equation as an eigenvalue equation for the Hamiltonian operator. The validity of such approach has been confirmed by comparison of obtained energy spectrum for the hydrogen atom with the experimental data. Later Schrödinger introduced time-dependent equation and this version has found much wider application than the eigenvalue problem. But, the Hamiltonian operator does not contain the time and the time-dependent Schrödinger equation looks like artifact which has no support from experiment. To clarify the situation the collision problem is analyzed. The inelastic transitions of electron in the atomic collisions are described by the three body (electron and two nuclei) stationary Schrödinger equation. In the semiclassical limit with respect internuclear motion the Schrödinger equation transforms into well-known, time-dependent form where first order 'time' derivative appears from the second order derivative with respect internuclear separation. Now, if we apply the same approximation to the time-dependent three-body Schrödinger equation we obtain the equation which has two (!) independent time-like variables. Just the extraction of the classical subsystem (nuclei) from the total system leads to the appearance of the time.

The quantum theory is much less symmetric than the classical mechanics. In contrast to classical mechanics, the quantum theory is not covariant with respect to canonical transformations. Moreover, an analogue of canonical transformation cannot be introduced in quantum mechanics. It is a law of nature, and it can not be derived. In all other coordinates (or representations) the Schrödinger equation is obtained by a mathematical transformation of the Schrödinger equation from the Cartesian coordinates to desirable coordinates (or representation) which does not change the physical results. The alternative way based on the 'canonical' transformations has a serious problems. For instance, if we substitute the spherical 'canonically conjugated', Hermitian momentum operators into the operator of kinetic energy an incorrect result is obtained, since a term additional to the Laplasian appears. Thus, in the simplest case of transformation from Cartesian to spherical coordinates the Hamiltonian formalism (which is mostly coordinate-momentum variables plus covariance of the theory with respect to the canonical transformation) does not work.