

Quantum mechanics and quantum cosmology in an extended phase space approach

People have always been interested in the past. Except the possibility to find one's roots, history gives us a tool to formulate conclusions from the past to foresee possible futures. All of science depends on the assumption that the observations performed some time ago can be translated to scientific hypotheses and theorems. The branch of science which is interested in research on the greatest time scales is cosmology. During the last century cosmology developed very fast, and the currently available observational methods can provide us with clues about the beginning of the universe. Even the statement that the universe has a beginning is non-trivial; up to the XX century mainstream science stated that the universe is eternal and static. The observational data obtained in the XX century from nearby galaxies by Vesto Slipher and Milton Humason, and the brilliant idea by Edwin Hubble to relate proportionally the distance from the galaxies and their, so called, redshift, led to the conclusion that the universe is in fact not static, it expands. If we consider the distant past of the universe we will notice that it becomes smaller and smaller up to the moment when its size is reduced to a point called a singularity. We call this scenario the big bang hypothesis. Physicists agree that the appearance of a singularity in the considered model usually means that the description is incomplete. In this case it is expected that the study of the early universe era with general relativity is insufficient, because at that time, quantum effects were important. A popular scenario which removes the initial singularity is the big bounce. It assumes that the universe approaching a singularity "bounces off", it changes the contraction phase into an expansion phase. One of the theories which predict such behavior is the formulation of quantum gravitational systems with coherent states. Application of coherent states in the description results in appearance of a strong repulsive potential which prevents the universe from collapsing. In the proposed project the mentioned formalism will be extended in such a way that it becomes more accurate, and it will be possible to study quantum effects imperceptible in the current methods of analysis. The number of parameters with respect to which we describe the universe will be extended. Except for the well known classical degrees of freedom, like scale factor and expansion rate of the universe, we will introduce parameters connected to quantum properties of the universe, like dispersion of the scale factor and expansion rate. Evolution of the state of the universe will be represented as a trajectory in higher-dimensional phase space. It will allow us to answer questions which were not studied up to this moment: could the big bounce be non-symmetric in time? What was the uncertainty of the scale factor and expansion rate of the universe during bounce? How did the universe look like before the big bounce? The developed formalism predicts that during the big bounce primordial gravitational waves were produced. During our project we will derive properties of those waves and we will translate them to observational effects. If the primordial gravitational waves are observed in the future we will be able to conclude whether the observations support the big bounce scenario.