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Quantum origin of cosmological expansion and primordial structures in the Universe

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The standard cosmological model is based on the idea of cosmic expansion and explains the observed galaxy redshifts, the origin of the cosmic microwave background radiation and the abundances of primordial elements in the Universe. However, according to Einstein's theory of gravity the expansion must have had its beginning some 13.7 billion years ago at a singular point where the equations of the theory break down. The existence of the singular point is considered an artefact of the incomplete cosmological model. Moreover, observations of space regions in the thermodynamic equilibrium that are farther apart than any physical signal could have travelled since the singular point, indicate the existence of an unexplained physical process that must have occurred at the singular point, or have replaced it completely.

We propose an extension to the standard cosmological model that includes contraction as a preceding phase to the present expansion of the universe. The universe becomes small and dense before it bounces to expansion due to the so-called quantum effects of the gravitational field. The quantum effects improve the incomplete Einstein theory of gravity and cause nonsingular dynamics of the universe. The cosmological evolution at the bounce is very complex due to interplay between many gravitational degrees of freedom. If one could view the bouncing universe from outside, one would see a rapidly contracting and expanding three-dimensional ball that is all the time being stretched and squeezed in all directions. In such a universe matter waves and gravitational waves propagate across space. The bounce of the universe amplifies the matter waves to large amplitudes so that later they form the large-scale structure observed in the present-day Universe. The gravitational waves are distortions of space that travel at the speed of light. We will use the extended model to make precise predictions of the cosmological gravitational waves that are looked for by many ongoing and projected experiments.

The model will provide a cosmological scenario that extends the standard cosmology by contraction and a bounce that is due to quantum effects of the gravitational field near the singular point. It will explain the origin of structure in the universe that is currently being measured with high precision as a result of the complex dynamics of the bouncing universe rather than exceptional initial conditions. The model will be an alternative to the theory of cosmic inflation but free from the problems of the latter. Based on the proposed model we will work out the predictions for the amplitude of primordial gravitational waves, which are expected to be different from the inflationary predictions. Coming experiments should be able to confirm or disprove these predictions. Thanks to the proposed model, coming data can be used to improve our understanding of quantum effects of the gravitational field.