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Editorial

Quantum Models for Cosmology

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This Special Issue presents a collection of review and original papers on various aspects and applications of quantum cosmological models. Despite that it only consists of seven contributions it covers a relatively broad range of topics and gives a useful picture of problems and challenges that researchers presently face in this domain.

Martin Bojowald [1], in his contribution, critically examines the celebrated result of the singularity resolution in Loop Quantum Cosmology (LQC). Bojowald, initiator of LQC who examines the whole domain through the fundamental principles, provides a unique and valuable perspective on some of the still unresolved issues in this field. His careful arguments help us to develop a more realistic viewpoint on the mentioned result. To be fair, some of his criticism also applies to approaches other than LQC. For instance, the so-called problem of time that has not been yet solved satisfactorily, despite many attempts, is present in any approach to quantum cosmology.

The contribution by Claus Kiefer and Patrick Peter [2] is a very useful review of the problem of time in quantum cosmology. The authors explain its origin and discuss some of the strategies researchers have been using to deal with the problem. They propose and briefly but clearly describe two possible solutions to the time problem. Their discussion is based on both older and more recent works.

A lot of evidence has pointed to the ultralocal and oscillatory dynamics of the universe on the approach towards a generic cosmological singularity. Such a behavior is exhibited by the so-called mixmaster universe. Hence, a quantum theory of this model that is free from singularity has always been thought to provide an important physical insight into the fate of singularities in general relativity. Hervé Bergeron, Ewa Czuchry, Jean-Pierre Gazeau and Przemysław Małkiewicz [3] propose a very general quantization of this model based on the integral covariant quantization method. The authors show that the initial singularity is replaced with a quantum bounce as well as other interesting features.

In their contribution, Hing-Tong Cho, Jen-Tsung Hsiang and Bei-Lok Hu [4] investigate the interplay between quantum fields, spacetimes and thermodynamics. The thermodynamic stability of quantum fields is the basic requirement for the co-existence of quantum fields and spacetimes. The authors develop their analysis based on the heat capacity and the quantum compressibility of some model geometries filled with a quantum field at high and low temperatures.

In his contribution, Igor I. Smolyaninov [5] considers corrections to the Friedmann equations due to fast fluctuations in the universe scale factor. Note that experimental evidence of relatively fast scale factor oscillations started to emerge very recently, possibly originating the modification of Newtonian dynamics in galaxy-scale and the cosmological evolution. The author precisely demonstrates that quantum fluctuations in the scale factor modify the Friedmann equations, giving rise to the late-time accelerated expansion of the universe, and they may also considerably modify the effective universe potential.

Vesselin G. Gueorguiev and Andre Maeder [6], in their contribution, examine the Cosmological Constant Problem (CCP) within the multiverse approach of Quantum Cosmology. Assuming that each member of the ensemble of universes owns a characteristic scale, they use the latter as integration variable in the corresponding "multiverse" partition function. An averaged characteristic scale of the ensemble is estimated by using

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only members that satisfy the Einstein field equations and is compatible with the Planck length when considering an ensemble built on Planck-scale seed universes with a vacuum energy density of order one. For a universe with a characteristic scale of the order of the observed Universe, the cosmological constant is close in magnitude to the observed value. Hence, Gueorguiev–Maeder's approach to the CCP is appealing in view of reconciling the Planck-scale huge vacuum energy, as is derived from Quantum Field Theory, with the currently observed small value of the cosmological constant.

Through a new quantization method combining fractional quantization and Bohmian interpretation, the contribution of Isaac Torres, Júlio César Fabris, Oliver Fabio Piattella and Antônio Brasil Batista [7] shows that a Wheeler–DeWitt equation of a second order can be constructed through a Bohm–de Broglie interpretation. Their approach is based on the so-called Fab Four John theory, that is, a quantization via a fractional derivative of a nonminimal derivative coupling cosmological theory, whose Hamiltonian version exhibits fractional powers in the momenta. Their construction is achieved through conformable fractional derivative formalism. They point out the existence of a bouncing solution analogous to the perfect fluid cosmology among a wide range of possible solutions for the scale factor.

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