DOTTORATO DI RICERCA IN FISICA, XXX CICLO

PROGETTO SCHEMATICO DI TESI

CMBR spectrum from spinfoam cosmology

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Nowadays, Gravity still fails to have a microscopic (i.e. quantum) description like we have instead for the other fundamental interactions. Many attempts have been done so far to address this issue, which is one of the most longstanding cunundrum in theoretical physics [1],yet we are still waiting for an empirical evidence indicating which one (if any) of these tracks is the good one. The Quantization of Gravity remains is still hidden beyond our event horizon because of the incredible smallness of the scale we expect quantum gravity effects to be relevant, namely the Plank scale

$$l_P = \sqrt{\frac{\hbar G}{c^3}} = 10^{-33} cm\,.$$

This suggests that answers can come mostly from observations of very peculiar astrophysical objects like black holes and from primordial cosmology In my Ph.D thesis I'll work within the framework of Loop quantum gravity (LQG) [2, 3], one of the most promising theory on quantum gravity we have today. LQG has two different formulations: the "canonical and the "covariant" one. In the present work my main focus will be on the latter, studying a model introduced by Bianchi, Rovelli and Vidotto (BRV) [4], which quite recently opened a new research field called Spinfoam cosmology. This recent approach to quantum cosmology is important for several reasons, both technical and physical. The study of Cosmology, also classically, means the study of some symmetry reduced version of the set of the gravitational field's degrees of freedom, e.g. the study of the homogeneous and isotropic spacetime described by FRWL metric. Going to the quantum, one can thus choose between two alternatives: symmetry reduce the system and then quantize or quantize before symmetry reducing. The former is the approach followed by Loop Quantum Cosmology (LQC) [5], i.e. the cosmological sector of the canonical formulation of the theory, the latter is the new path of Spinfoam Cosmology, which *de facto* studies cosmology starting from the full (covariant) theory, truncated down to a single graph.

Despite the great success of LQC in describing this symmetry reduced models (the most important being the discovery of the resolution of the classical cosmological singularity with the prediction of the Big Bounce) this kind of approach starts from the beginning washing away everything but the mean value of gravitational field's fluctuations. Therefore difficulties arise when one want to recover also the quantum fluctuations of geometry where these are expected to be dominant, such us in spacetime region near the Bounce. Conversely, Spinfoam cosmology faces the problem within the framework of the full (covariant) theory taking care from the beginning of such quantum fluctuations and hence poses itself as the natural candidate to the study of the primordial density perturbations.

In my work i will address the following issues within both the formulations of LQG:

Quantum cosmology from polymer thermostatistics

LQC shows itself as a polymeric quantization of the cosmological spacetime degrees of freedom, which appears as a deformation of the canonical commutation relations modified by a (minimal)length scale parameter (possibly related the planck scale). From a semiclassical point of view, Polymer quantization modifies the phase space symplectic structure, introducing a non trivial Liuville's measure leading to a different statistical mechanics for a gas, for instance. I propose to study the statistical mechanics of the early radiation dominated universe to investigate the role of that length scale in the cosmological dynamics and to relate its value to the Immirzi's parameter one, which is a free parameter[1] of LQG.

First order modification to the Friedman equation from Spinfoam cosmology

In my thesis project I focused on the computation of the probability amplitude of a process corresponding to the transition from *nothing* to an homogeneous and isotropic quantum cosmological state and the study of its semiclassical behaviour. There I showed that the radiative correction doesn't destroy the right expected classical limit, i.e. the Friedman equation, also taking into account the cosmological constant. Here the aim is to compute the first order correction to that equation looking for possible experimental effects.

Cmbr spectrum fluctuation from spinfoam cosmology

This is the core of my project. Quantum early Universe left its footprint in the the cosmic microwave radiation (cmbr), resulting in the observed pattern of temperature fluctuations. Nowadays the standard model of cosmological perturbations perfectly agrees with observations, once some initial condition are fixed. However those initial conditions should come from a fundamental theory of quantum gravity, rather than being hand-fixed. In order to move along that direction, I'm planning to start from the study of correlations between two fixed boundary states in the BRV model, possibly q-modifying the algebra of the observables (as preliminary steps towards this issue suggest). Another way introduced by Eugenio Bianchi et al.[6] take into account entanglement entropy as a measure of correlation thus, in an appropriate cosmological setting, it should be related also to those correlations we are interested in. In pursuing this track the main issues will be the computation of what one could call "spinfoam entanglement entropy."

[1] However, it has been fixed in order to agree with standard results of semiclassical Black hole physics.

References

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