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NON-GAUSSIANITY IN THE SKY

Rendicontazione

Informazioni relative al progetto

NGsky

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Progetto chiuso

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Final Report Summary - NGSKY (NON-GAUSSIANITY IN THE SKY)

The Cosmic Microwave Background (CMB) provides an essentially unique window on the universe at very great distances from our local neighborhood, or equivalently at very early times before the present epoch. The fact that the CMB exists at all, with a high degree of isotropy and a thermal spectrum, is evidence that the primordial universe was to high accuracy at some point in a nearly uniform state of thermal equilibrium, and therefore in causal contact at the time and place of the last scattering of the CMB photons. The small but measurable anisotropy in the CMB presents the most compelling clues to the possible quantum origin of the universe, as well as the source of the complex large scale structure of matter we observe today. The leading theory explaining the primordial origin of cosmological fluctuations is cosmic inflation, a period of accelerated expansion at very early times. During inflation, microscopic quantum fluctuations were stretched to macroscopic scales to provide the seed fluctuations for the formation of large-scale structures like our own Galaxy. Despite the simplicity of the inflationary paradigm, the mechanism by which cosmological perturbations are generated is not yet established. In the standard slow-roll inflationary scenario associated to one-single field, the inflaton, density perturbations are due to fluctuations of the inflaton itself when it slowly rolls down along its potential. In the curvaton mechanism the final curvature perturbation ζ is produced from an initial isocurvature mode associated with the quantum fluctuations of a light scalar (other than the inflaton), the curvaton, whose energy density is negligible during inflation. Other mechanisms for the generation of cosmological perturbations have also been proposed recently like the inhomogeneous reheating scenario, ghost-inflation, Higgs and New Higgs Inflation.

A precise measurement of the spectral index n of comoving curvature perturbations will provide a powerful constraint to slow-roll inflation models and the standard scenario for the generation of cosmological perturbations which predicts $n\zeta|$ close to unity. However, a third observable which will prove fundamental in providing information about the mechanism chosen by Nature to produce the structures we see today: non-Gaussianity. A detection of NG in the CMB anisotropies and/or in the large scale structure will provide a crucial step in understanding the way the seeds for all the structures we observe were generated in a very primordial epoch of the evolution of the universe. Non-Gaussianity in the cosmological perturbations represented a very hot topic in modern cosmology at the time the proposal was written. However, the data realised by the Planck collaboration on March 2013, few months before the project started was consistent with Gaussian power spectrum. This weakens our interest in investigating the non-Gaussianity but on the other hand, turned our attention to investigate inflationary models in accordance with the measured Planck inflationary parameters. One of the favorable models of Planck is the Starobinsky model, which is based on higher curvature gravity. We were interested in embedding this theory in some fundamental theory like supergravity, the low energy limit of superstring theory. We discussed various aspects of the supersymmetric Starobinsky model as well as its relation to another class of theories, the Higgs inflation. On the other hand, we were interested in finding consistency relations for the large scale structure of the Universe, generalizing corresponding consistency relations for inflation. These relations are nothing else than ward identities for underlying symmetries of the theory. We were among the first to write down such consistency relations for the large scale structure, a subject that became fashionable after our work. In addition, in the same context, we discussed various aspects of the dark matter and halo dynamics by investigating the Boltzmann and the Poisson-Vlasov system.

On the cosmological side, we have computed a three-point function in the squeezed limit, where the temperature fluctuations at large scales are correlated with two polarization modes at small scales. In the particular case of the B-mode polarization, a relation that connects the squeezed limit of TBB to the three-point function with the cosmological B-mode power spectrum was obtained, which can be used as a consistency relation.

We investigated also a recent claim, in agreement with peak theory, that any halo velocity bias present in the initial conditions, does not decay to unity. Starting from conservation laws in phase space, we discussed why the fluid momentum conservation equation for the biased tracers needs to be modified. Our work indicated that a correct description of the halo properties should properly take into account peak constraints when starting from the Vlasov-Boltzmann equation.

Another problem which was one of the objectives of the project was the question of the role of heavy fields during inflation, where the geometry of spacetime is described by a (quasi-)de Sitter phase. Inflationary observables are determined by the underlying (softly broken) de Sitter isometry group SO(1, 4) which acts like a conformal group on three-dimensional space: when the fluctuations are on super-Hubble scales, the correlators of the scalar fields are constrained by conformal invariance. Heavy fields with mass m larger than the Hubble rate H correspond to operators with imaginary dimensions in the dual Euclidean three-dimensional conformal field theory. By making use of the dS/CFT correspondence we showed that, besides the Boltzmann suppression expected from the thermal properties of de Sitter space, the generic effect of heavy fields in the inflationary correlators of the light fields is to introduce power-law suppressed corrections. This can be seen, for instance, at the level of the four-point correlator for which we provided the correction due to a massive scalar field exchange.

The topic of the project is of particular importance to European interests and achievements. The basic reasons for this are:
1. it is a subject of great intellectual and cultural interest, which may provide answers to basic questions in our understanding of the physical cosmos;
2. it is a highly competitive research area, characterized by its intellectual challenges, thereby attracting the interest of a large number of gifted scientists;
3. it has an intrinsic multidisciplinary character, encompassing many, areas of physics.

Indeed, we should note that the project had very strong interdisciplinary aspects. In the past decade much common ground has been found between the physics of the very small (elementary particles) and the physics of the very large (cosmology). The early universe offers to the particle theorist the ultimate laboratory for testing exotic theories of unification and high-energy phenomena. The concepts of particle theory offer the cosmologist physical explanations for the origins of otherwise mysterious phenomena such as the fine-tuning problem ($\Omega \approx 1$), the source of the fluctuations that gave rise to large-scale structure in the universe, and the nature of the dark matter. The field of research of the proposed project is highly interdisciplinary, involving as it does, both particle physics and astrophysics and cosmology, each of which is a complex and highly developed discipline. In particular, understanding the origin of the non-Gaussianity is a quantum field theory problem. In addition, the study of cosmological NG of the primordial spectrum involves besides cosmology, quantum physics, general relativity and probability theory.

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