Jinn-Ouk Gong

It has been only one century since cosmology, the study of the origin and evolution of our own universe, has become a subject of physical sciences rather than that of philosophy and theology. After the advent of general relativity, people could deduce the physical laws that govern the evolution of the universe. The standard cosmological model, the hot big bang picture, was established following the discovery of the cosmic microwave background (CMB), which is the afterglow of the hot plasma in the very early universe, and has been tested in the last decades.

The most recent cosmological observations on CMB and the large scale distribution of the galaxies (large scale structure; LSS) tell us that the current observable universe is very well described by the hot big bang cosmology with a certain combination of matter contents, and that it is consistent with a special period in the very early moment, primordial inflation; to explain the universe as we observe it now according to the hot big bang picture, we need extremely fine-tuned initial conditions, as much as 1 part of 10^{60}. Primordial inflation, a period of accelerated expansion caused by one or more scalar fields, the inflations , is an add-on to provide the necessary initial conditions. Furthermore, during inflation the expansion is so fast that the quantum fluctuations on subatomic scales become classical perturbations on cosmological distances. Thus, observing CMB and LSS, we can infer the physics relevant for the very early universe.

The primordial perturbations later have become, after inflation, the seeds for the all observable structure, like the temperature fluctuations in the CMB and galaxies. Hence, to make full use of cosmological observations for the very early universe, we have to understand how this primordial perturbation is generated and their properties. The Junior Research Group "Generation and Evolution of Cosmic Structure" aims to develop cosmological perturbation theory to understand the nature of these perturbations and their novel observational signatures. This is in particular timely since a number of sensitive observational programs are being made and under progress in the following decade.

We will be studying the following topics in the next few years:

1. Non-linear nature of cosmological perturbation: In the simplest scenario of inflation, the primordial perturbation is essentially a free field so that it is linear and Gaussian. But the non-linear nature of gravity tells us that it possesses intrinsic non-linearity, despite the fact that it may be too small to be observed. Indeed, the most recent observation of the CMB gives the bound of the non-linear parameter, a convenient parametrization of non-linearity, |f_{NL}|<100, which means the universe is Gaussian up to 99.9%. However, the future observations are sensitive enough to discriminate f_{NL} as small as 5. This appears as a non-vanishing 3-point correlation function, or the bispectrum, which may have a very complex shape and size. We will employ different approaches which complement each other to study the non-linear nature of cosmological perturbation.

2. Effective theory of inflation: A homogeneous and isotropic background postulates that the primordial perturbation is associated with time translational symmetry. This strongly restricts the form of the Lagrangian of the perturbation in such a way that a constant solution is always allowed, and we can write the effective operators of the primordial perturbation consistent with the requirement of its constancy. Further, this observation is based on the symmetry principle and thus should be valid non-perturbatively. Thus, the amplitude of the n-th order correlation function is given by the coefficients of the n-th order action. All this is independent of the specific model detail and is completely general. We are interested in extending this effective theory approach to broader contexts, like multi-field inflation, loops effects and so on.

3. Signatures of early universe in LSS: Essentially, the relation between LSS and the primordial perturbation is the same as that between that of CMB: the primordial perturbation is related to matter density perturbation produced by the annihilation and/or decay of the inflation through the gravitational potential. Matter perturbation evolves by the gravitational interaction, and baryon is further concentrated to eventually form galaxies and galaxy clusters which we can observe. Thus, to study the early universe with LSS we should identify the relations between the primordial, gravitational, matter perturbations and the distribution of galaxies. The discrepancy between the distributions of dark matter and galaxies is parametrized by the so-called bias. We will study the contributions of non-linearity to the bias, which induces a novel scale dependence. The full general relativistic description of the bias is also of great interest.

Jinn-Ouk Gong received his Ph.D. in physics from KAIST in 2005. After postdoctoral research experiences most recently at CERN, Switzerland, he joined APCTP in November 2012 as a Junior Research Group Leader. His main research field is theoretical cosmology.