Detailed contents of the course ``Cosmology of the Early Universe" Academic Year 2018-2019

Lecturer: Nicola Bartolo

- **General Introduction.** The "issue" of initial conditions: primordial density perturbations at the origin of large-scale structure formation in the universe. Inflation, dark matter (and baryogenesis), cosmological perturbations: ingredients of the early universe that go beyond the standard Hot Big-Bang model.

- Short recalls of the standard Hot Big Bang cosmological model and of its main ``shortcomings":

The horizon problem and its different formulations; the flatness problem (evolution of the parameter density); mention to cosmic defects.

- Inflationary cosmology in the early universe:

solutions to the standard Hot Big-Bang model: kinematics of inflation; de Sitter universes - **Modelling:**

Inflationary models: vacuum enegy and the "inflaton" field; energy scale of inflation; dynamics of a scalar field in a Robertson-Walker metric;

background evolution and cosmological perturbations in the early universe;

slow-roll parameters and their importance to confront with observations.

- Generation of first density perturbations at the origin of cosmic structures:

From quantum perturbations in an expanding universe to first density primordial perturbations: computations for different cases (starting from the simplest case of a massless scalar field in a de Sitter universe) and different computational methods.

- Primordial gravitational waves (tensor perturbations) and their observability

- Possible realizations of the inflationary scenario:

Inflationary models within high-energy particle physics

- Observational predictions of inflationary models:

power spectra for scalar and tensor perturbations; tensor-to-scalar ratio;

(n_s-r) plane; main present constraints on inflationary models

- **Reheating phase:** simple toy model for the transition from the primordial inflationary universe to the standard Friedmann-Robertson-Walker universe.

- Baryogenesis: basic concepts and details on some concrete models.

- Mechanisms of dark matter particle production.

- Cosmological perturbations in General Relativity

classifying cosmological perturbations into scalar, vector and tensor perturbations; gauge transformations; issue of gauge-invariance;

Einstein equations linearly perturbed around Robertson-Walker metric

- Computational methods:

Delta-N and in-in formalisms to compute correlation functions; example: primordial non-Gaussianity

- Observational tests of the early universe

Textbooks:

- Andrew R Liddle and David H Lyth, The Primordial Density Perturbation, Cambridge University Press, 2009
- Andrew R Liddle and David H Lyth, Cosmological Inflation and Large-Scale Structure, Cambridge University Press, 2000.
- Kolb, E.W. and Turner, M.S., The Early Universe. Redwood City: Addison-Wesley, 1990.