Cosmology of the Early Universe

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Cosmology of the Early Universe

✔ Goals:

Early Universe physics nowadays is a building block of modern cosmology.

The course aims at

- offering an up-to-date overview of the main aspects of the physics of the Early Universe
- providing the necessary tools to *understand and analyze* such aspects, both from a modelling and an observational point of view
  (e.g., some basic principles and tools that can be appllied to different issues)
- being able to solve different types of problems

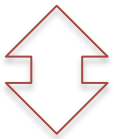
✔ Course contents:

The course contains three main parts:

I) the issue of the initial conditions (inflationary models)

II) cosmological perturbations

III) baryogenesis; production of dark matter particles



Observational tests

Cosmology of the Early Universe

✔ **Relevance for the degree in Physics:**

Interconnections with
- Cosmology
- Astroparticle physics
- Relativisitic Astropysics
- General Relativity
- Theoretical physics
- Field theory
- Multimessenger Astrophysics
- Gravitational physics

The course is higly interdisciplinary, but self-contained!

Course contents in details

- **General Introduction. The "issue" of initial conditions:** primordial density perturbations at the origin of large-scale structure formation.
  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; 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**
  scalar, vector and tensor perturbations; gauge transformation; 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**

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✔ **Teaching methods:**

48 hours: lectures with a proposal of exercises/examples/applications

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.

The relevant parts of the course will be clearly identified in the various textbooks and notes of the teacher will be available

and……your notes during lectures

Useful information

✔ Prerequisites: “Fundamentals of Astrophysics and Cosmology”
(equivalently "The Physical Universe”)
But in any case the course is self-contained

✔ Examination methods:

oral exam

✔ Exam dates: 2 for each sessions (1/02; 21/02; 2/07; 30/08; 12/09),

✔ Assessment criteria

Acquisition of the basic concepts of the course, ability of the student to elaborate in an original and *independent* way the concepts acquired, capacity of reasoning and of *applying the tools provided by the course*

Office hours

Office hours: in every moment, in person by phone or by e-mail.

To avoid coming to my office when I am not there, you are kindly requested to contact me before.

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For a description of the course see also

https://en.didattica.unipd.it/off/2017/LM/SC/SC2382/001PD/SCP7081761/N0