LUND UNIVERSITY

Faculty of Science

FYTN11, Theoretical Physics: Cosmology and Astroparticle Physics, 7.5 credits

Teoretisk fysik: Kosmologi och astropartikelfysik, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2012-05-24 to be valid from 2012-07-01, autumn semester 2012.

General Information

The course is an elective course for second-cycle studies for a Degree of Master of Science (120 credits) with a specialisation in physics.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
Physics	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The course aims to give the student basic knowledge in theoretical concepts in particle astrophysics and the evolution of the universe with a focus on the interconnection between cosmology and particle physics. The course intends to cover the major aspects of the hot big bang theory and the standard cosmological model at the forefront of theoretical and experimental high energy astroparticle physics.

Knowledge and understanding

After completing the course, the student should be able to

- explain the dynamics of cosmological expansion in the framework of standard cosmological model, identify basic stages of the Universe evolution, and their characteristics

- describe the properties and composition of the modern Universe, the basic features and dynamics of baryon matter, dark matter and dark energy
- describe the connection between cosmology and high energy particle physics, and relate their properties to each other

Skills and ability

After completing the course, the student should be able to

- derive evolution equations of the universe and cosmological solutions
- calculate properties of the universe, such as age, horizon size, temperature and entropy density, at specified times during its evolution, assuming realistic conditions
- derive particle abundances and mass bounds based on properties of particle interactions in the hot cosmological plasma in a particular cosmological evolution scenario and current astrophysical data.

Examples of problems that the student should be able to solve upon completion of the course:

- Find the bounds on maximum size and lifetime of the closed universe assuming that dark energy instantaneously switches off right after the present epoch.

- Estimate the temperature and age of the universe at the time when neutron burning terminates. What would be the residual neutron abundance if other reactions were negligible?

Course content

- Homogeneous, isotropic universe: Hubble's law, the Friedmann?Lemaitre?Robertson?Walker Metric, and the behavior of gases of stable non-interacting particles in the realistic case of expanding homogeneous isotropic Universe.

- Dynamics of cosmological expansion: the Friedmann equation, with solutions in a few distinct cases, e.g., non-relativistic matter, relativistic matter, vacuum, and general barotropic equation of state and solutions with recollapse.

- The standard cosmological model: the composition of the present universe. Dark matter and dark energy, and how these affect the cosmological evolution of the universe. The current age of the universe and horizon size. Brightness-redshift relation for distant standard candles.

- Recombination epoch and its influence on cosmic microwave background.

- Relic neutrinos: neutrino evolution and freeze-out in the hot cosmological plasma. Cosmological bounds on the masses of the neutrinos.

- Big Bang nucleosynthesis: kinetic theory of nucleosynthesis, the neutron-to-proton ratio and the primordial abundance of light elements.

- Dark matter: the properties of models with cold, hot and warm dark matter. The formation of dark matter during freeze-out of weakly interacting massive particles (WIMPs). Properties of dark matter candidates from particle physics. Direct and indirect methods of detection.

- Origin of baryon and lepton asymmetries: the necessary conditions for baryogenesis. Violation of lepton and baryon number in particle interactions
- Inflation: basics of chaotic inflation theory. The formation of large-scale structures in the latest stages of expansion. Origin of temperature and density fluctuations in the cosmic microwave background.

- The particle physics of cosmic rays and its sources: spectrum and composition of the cosmic rays. Implications for different observation techniques. Astro-physical sources of ultra-high energy cosmic rays and properties of galactic and extra-galactic gamma-ray bursts.

Course design

The teaching consists of lectures and exercises.

Assessment

The examination consists of written assignments and an oral test. Students who do not pass the regular exam can be offered a new possibility shortly after the regular exam.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
The grades awarded are Pass with Distinction, Pass and Fail. To pass the entire course, it is required to pass both the oral theory exam as well as the written hand-in assignments. The final grade is determined by combining the results of the different parts of the examination.

Entry requirements

For admission to the course, knowledge equivalent to FYTN04 (Theoretical particle physics) and English B is required. In addition, knowledge equivalent to FYTN08 (General relativity) is recommended.

Subcourses in FYTN11, Theoretical Physics: Cosmology and Astroparticle Physics

Applies from H12

1201 Cosmology and Astroparticle Physics, 7,5 hp
Grading scale: Fail, Pass, Pass with distinction