Joint Syllabis

“Problems of particle physics and cosmology”

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Degree program: 010975 “Physics of fundamental interactions”
Specialization: 010975 “Physics of fundamental interactions”
Chair “Fundamental interactions and Cosmology”
1th academic year of the Master of Science' degree, 2nd semester

Head of Chair, academician RAS
Victor A. Matveev

Lecture 1. Problems of the Hot Big Bang Theory (2 hours)
Horizon problem, entropy problem, flatness problem, origin of the primordial inhomogeneities.

Lecture 2. Inflation in slow roll regime (4 hours)
Inflation as a solution to the Hot Big Bang problems; the slow roll conditions; chaotic, new, hybrid inflationary scenarios.

Lecture 3. Gaussian random variables and Gaussian random fields (2 hours)
Propeties of Gaussian random variables, Gaussian random fields.

Lecture 4. Generation of cosmological perturbations at inflation (4 hours)
Inflaton field fluctuations; generation of primordial scalar perturbations, generation of primordial tensor perturbations (gravitational waves); amplitudes and tilts of the perturbation power spectra.

Lecture 5. Particle production in background fields (2 hours)
Method of the Bogoliubov transformation: bosons, fermions.

Lecture 6. Postinflationary reheating (4 hours)
Perturbative mechanism: decay of the inflaton field oscillations; thermalisation of particles in the expanding Universe; parametric resonance in the inflaton decay: decay of large amplitude oscillations, production of heavy fermions.

Lecture 7. Jeans instability (2 hours)
Jeans instability in static background, development of the instability in the expanding Universe, large scale structures in the Universe.

Lecture 8. Cosmological perturbations in linear approximation (4 hours)

Linearized energy-momentum tensor of ideal fluid; linearized Einstein equations; helicity decomposition: scalar, vector, tensor modes.

Lecture 9. Evolutions of vector and tensor modes (2 hours)

Superhorizon and subhorizon modes; matching at horizon.

Lecture 10. Scalar perturbation modes of single-component fluids (2 hours)

Radiation domination; matter domination; matter perturbation at dark energy dominated stage.

Lecture 11. Large scale structure formation in the Universe (2 hours)

Linear stage of scalar perturbation evolution after recombination; power spectrum; entrance to nonlinear regime; mass spectrum of the large scale structures.

Lecture 12. Cosmic microwave background anisotropy (2 hours)

Anisotropy of CMB within the photon instant decoupling approximation.

References

Basic references

1. Introduction to the theory of the early Universe: Cosmological perturbations and inflationary theory. Dmitry S. Gorbunov, Valery A. Rubakov, World Scientific (2011) 489 p
2. Introduction to the theory of the early Universe: Hot big bang theory. Dmitry S. Gorbunov, Valery A. Rubakov, World Scientific (2011) 473 p
3. Modern Cosmology, Scott Dodelson, Amsterdam: Academic Press (2003) 440 p
4. Physical Foundations of Cosmology», Viatcheslav Mukhanov, Cambridge University Press (2005) 421 p

Additional references

1. Cosmology, Steven Weinberg, Oxford University Press (2008) 593 p
2. Particle Physics and Inflationary Cosmology, Contemp.Concepts Phys. 5 (1990) 1-362
3. The Early Universe, Edward W. Kolb, Michael S. Turner, Redwood City: Addison-Wesley (1990) 547 p