

# RELATIVITY AND COSMOLOGY 2

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## Top-hat perturbations

The spherical top-hat perturbation. Conditions for generating a bound structure. Equation of motion: the cycloid. Turn around and virialization epochs. Linear theory. Definition and time dependence of the fractional density fluctuations, the peculiar velocity and the potential fluctuations. Qualitative connections between these linear theory quantities and the anisotropy of the CMB.

## Fluctuations in a continuum

Gravitational of instability equation. The case dominated by gravity in: a static universe; the Einstein-de Sitter universe; the Milne universe. Density fluctuations growth rate in different cosmological models, with and without a cosmological constant. Peculiar velocities. The case dominated by pressure: acoustic oscillation and characteristic scales.

## The statistics of the density fluctuation field

Probability distribution function. Two-points correlation functions. Matter density power spectra and a spectral index. The observed galaxy-galaxy correlation function. Correlation functions and variances in a smoothed random field: the top-hat and the Gaussian window functions. Peculiar velocities as a random field. Bulk motions. Dipole anisotropy of the CMB and large scale structure of the universe. Cosmic variance at the entrance in the horizon. The Zeldovich power spectrum.

## A two component universe

Baryons and photons. Adiabatic vs. Isocurvature initial conditions. Time evolution of the matter power spectrum: the gravity and the pressure dominated regimes; photon diffusion and damping scales; radiation drag. Transmission factors. Top-down and bottom-up scenario for the structure formation in the universe.

## A three component universe: HDM

Introduction to neutrino cosmology. Neutrino masses and density parameters. The epoch of transition from the relativistic to the non relativistic regime: a comparison with the equivalence epoch. Growth of fluctuation in the neutrino and in the baryonic components after recombination. Estimates of the expected CMB anisotropy level.

## A three component universe: CDM

Cold dark matter scenario. Gravitation instability in CDM and baryon-photon fluid. Discussion of the time evolution in the CDM component before and after the equivalence epoch. Stagnation effect and the CDM transmission factor. Normalization of the matter power spectrum to the galaxy-galaxy correlation function. Biased galaxy formation and biasing factor.

## A relativistic approach

Perturbation of the Friedmann metric. Ricci tensor components. Conservation equations. Density fluctuations outside the horizon. Gauge modes: decaying solution and coordinate transformation. Kinetic approach for collisionless particles: the Liouville equation. The Boltzmann equation for the perturbation with the radiative component. Free streaming solution: discussion of the different sources of anisotropy in the CMB; simple connection with the Newtonian spherical approximation. The Sachs-Wolfe effect and the CMB temperature expansion in multiples. Theoretical predictions for the CMB angular power spectra. Acoustic peaks: discussion on their origin and their connection with the acoustic oscillation. Constraints on the cosmological parameters from the WMAP and Planck satellites.