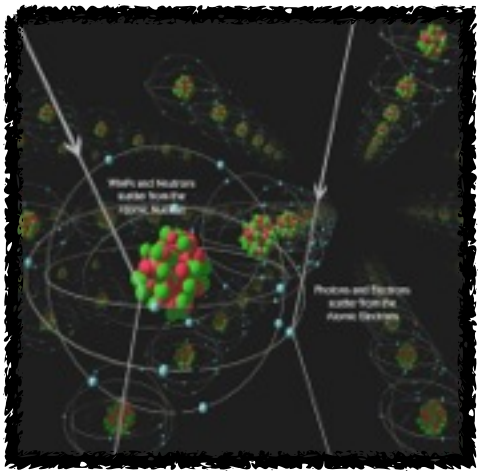
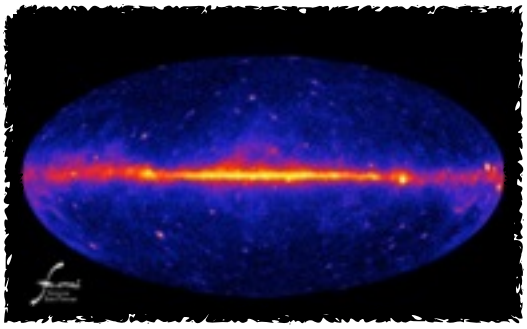
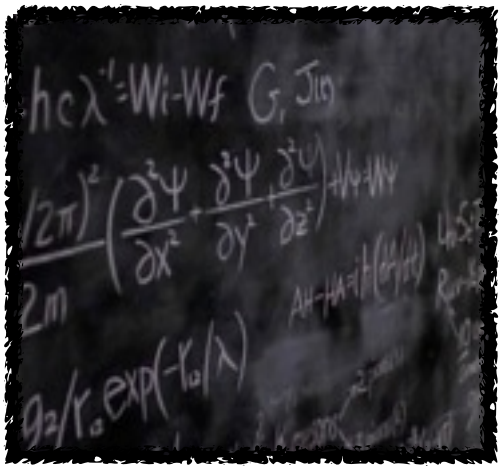
Master Joint-Lectures at the Skobeltsyn Institute of Nuclear Physics (SINP), Lomonosov University, Moscow

« Histories of particles in the Dark Universe »

Looking for the microscopical cosmos

by Yann Mambrini from the University Paris-Saclay

http://www.ymambrini.com/My_World/Physics.html

LPT Orsay

SINP MSU

PARIS-SACLAY

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Lecture 1

The primordial dark Universe

Abstract :

In this lecture, we propose to have a look at the first instants after the inflation. From the reheating time, when the Universe begins to be dominated by the radiation till the formation of the first nuclei. We will study in details the thermodynamics of the primordial plasma and how each particle decouple one by one from it. We will concentrate more specifically on the dark matter candidate(s) and look at their evolution in the thermal bath depending on their nature (hot, warm or cold dark matter). We will then see how to compute the relic abundance observed nowadays by the WMAP and the european PLANCK satellites.

keywords : reheating, thermodynamics, equilibrium, Boltzmann equation.

Lecture 2

A story of cosmic neutrino

Abstract :

After the decoupling of dark matter, the neutrino begins to decouple from the thermal bath about 1 seconds after the Big Bang. The weakness of its interaction with the Standard Model particles, makes him a particular specie. We will see how the neutrino decouples while still being relativistic, the constraints on its mass from the relic abundance calculation, and the measurement/observation of the relativistic degrees of freedom. We will also see how it could be possible to detect these « ghost » relic neutrino nowadays, and also to distinguish them from all the astrophysical sources of high energy neutrino in our galaxy or beyond.

keywords : neutrino, cosmic rays, IceCube, oscillation.

Lecture 3

3 minutes after the Big Bang

Abstract :

In this third lecture, we will study the second phase of the thermal bath, from the formation of the nuclei till the last scattering surface (horizon) when the photon decouple. We will see the mechanism of the Big Bang Nucleosynthesis (BBN) and compute in detail the time of the decoupling of the photon (recombination time, 380 000 years). We will also see how some B-mode generated by a fast phase of inflation can give perturbation in the CMB map and be observed nowadays, and how the stellar nucleosynthesis complete the atomic formation process.

keywords : BBN, CMB, inflation, recombination

Lecture 4

Modeling the Dark Matter

Abstract :

In this 4th lecture, we will understand how to build and extension of the Standard Model including a dark matter candidate, and still respecting the fundamental principles of symmetries. We will study the simplest extensions Beyond the Standard Model (BSM) like Higgs-portal or extra gauge group. We will also give some notions of supersymmetry and supergravity/string inspired models.

keywords : quantum field theory, unification, symmetry, Higgs boson.

Lecture 5

Detecting the invisible

Abstract :

In this last lecture, we will concentrate on the experiences and detectors present all around the world, trying to track the dark matter in the Universe. From the direct detection experiments [XENON (Europe), LUX (USA), PANDAX (China)] to the indirect ones [PAMELA (Russia-Italy), AMS (USA), FERMI (Europe-USA)] passing through the LHC (CERN) we will detail the techniques, limits, and prospects for the next few years.

keywords : direct detection, energy loss, interstellar medium, N-body simulation, Galactic Center signals.