Cosmology: Early universe

Lesson 2

R.L. Lechuga

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Outline

The problems on cosmology in 1981

Initial conditions of the hot Big Bang

Inflation

The problems on cosmology in 1981

The standard cosmological model was incomplete, it needed to explain the initial conditions of the hot Big Bang, an epoch in the universe in which it was dense and hot.

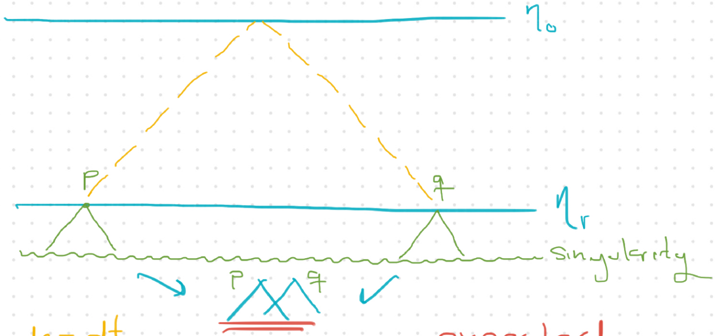
Initial conditions of the hot Big Bang

In words of [D.Baumann]): To specify the initial conditions of the hot Big Bang, it is necessary to determine the positions and velocities of all particles on an initial time slice. Alternatively, in the fluid approximation, the density and pressure as functions of position must be known.

Initial conditions of the hot Big Bang

In the cosmological model before 1981 people assumed the distribution of matter to be homogeneous and isotropic. But, how do we explain the extraordinary smoothness of the early universe? This is a significant question because, during the Big Bang, the universe seems to have not been in causal contact. There is no dynamical reason why these causally disconnected regions should have similar physical properties, such as temperature.

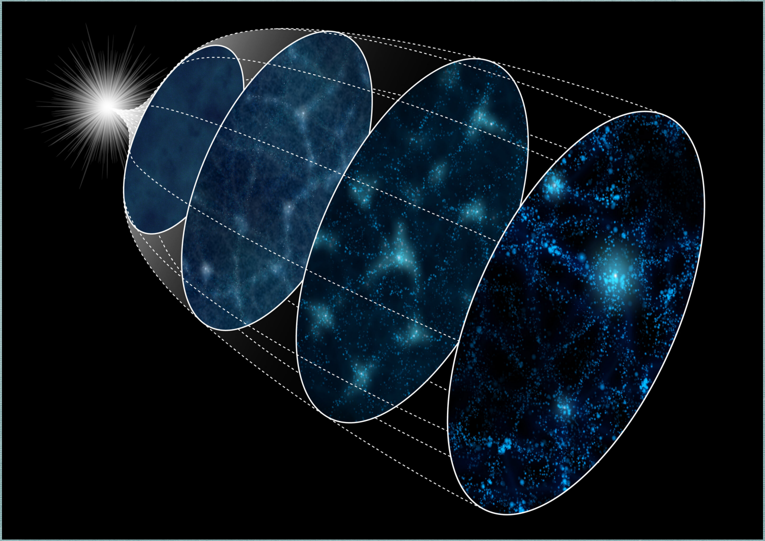
Horizon problem !



where $d\eta = \frac{dt}{a(t)}$

expected situation

Inflation



Inflation

The inflation period was incorporated into the cosmological model in 1981 by Alan Guth [A. Guth, 1981] to solve several important problems in cosmology, among them the horizon problem.

Successes of the inflationary paradigm

The incorporation of this period into the cosmological model addresses the naturalness problems and explains the primordial cosmic structure. Accelerated expansion resolves these problems, while symmetry breaking accounts for the formation of cosmic structures.

Inflation

The model is described by the action,

$$S = \int dx^4 \sqrt{-g} \left\{ \frac{R}{16\pi G} - \frac{1}{2} \nabla^\mu \phi \nabla_\mu \phi - V(\phi) \right\}, \tag{1}$$

with the matter sector characterized by a scalar field ϕ, named the inflaton.

Inflation

The space-time is described by

$$g = g_0 + \delta g, \tag{2}$$

where

$$g_0 = a^2(\eta)[-d\eta^2 + \delta_{ij} dx^i dx^j] \tag{3}$$

and the inflaton field is expressed by

$$\phi = \phi_0(\eta) + \delta\phi(\vec{x}, \eta), \tag{4}$$

where, η is the conformal time.

Assumptions

- The inflation is characterized by the highly excited zero mode of the inflaton field, ϕ_0, and the other modes are in the so called Bunch Davies vacuum.
- We focused on the chaotic potential $V = \frac{1}{2}m^2\phi^2$.

The relevant equations

The relevant Einstein equations and the Klein-Gordon equation are:

$$3\mathcal{H}(\eta)^2 = 4\pi G\left[\left(\frac{d\phi_0}{d\eta}\right)^2 + 2a^2V(\phi_0)\right], \tag{5}$$

$$\frac{d^2\phi_0}{d\eta^2} + 2\mathcal{H}(\eta)\frac{d\phi_0}{d\eta} + a(\eta)^2\frac{\partial V}{\partial\phi_0} = 0, \tag{6}$$

where $\mathcal{H}(\eta) = \frac{a'(\eta)}{a(\eta)}$, $' = d/d\eta$.

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