I never understood why the theory of relativity with its concepts and problems so far removed from practical life should for so long have met with a lively, or indeed passionate, resonance among broad circles of the public … I have never yet heard a truly convincing answer to this question

Philosopher Richard Dawid, one of the organizers of the Munich meeting, has observed the same development and, in his book “String theory and the scientific method” argued that

string theorists in particular use a method of “non-empirical theory confirmation.” This method is used during the development of a theory and is based on collecting indications which increase the physicists’ confidence that a theory describes nature. These indications are, for example, the amount (or absence of) alternative solutions to a problem, the degree by which a theory is connected to already confirmed theories, and the amount of unexpected insights that the theories give rise to

The physics, both of the Academy and the Lycaeum, as they are built, not on observation, but on argument, have retarded the progress of real knowledge.

Edward Gibbon

The History of The Decline and Fall of the Roman Empire, Vol. 5

"*In questions of science the authority of a thousand is not worth the humble reasoning of a single individual ..the modern observations deprive all former writers of any authority...*"

Galileo (December 1612)

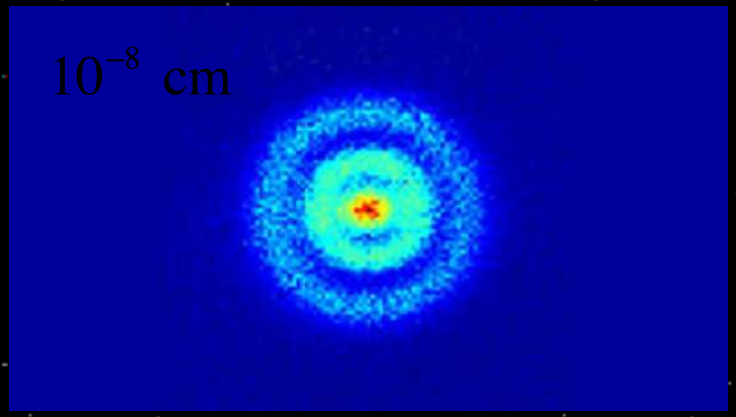
The Quantum Universe

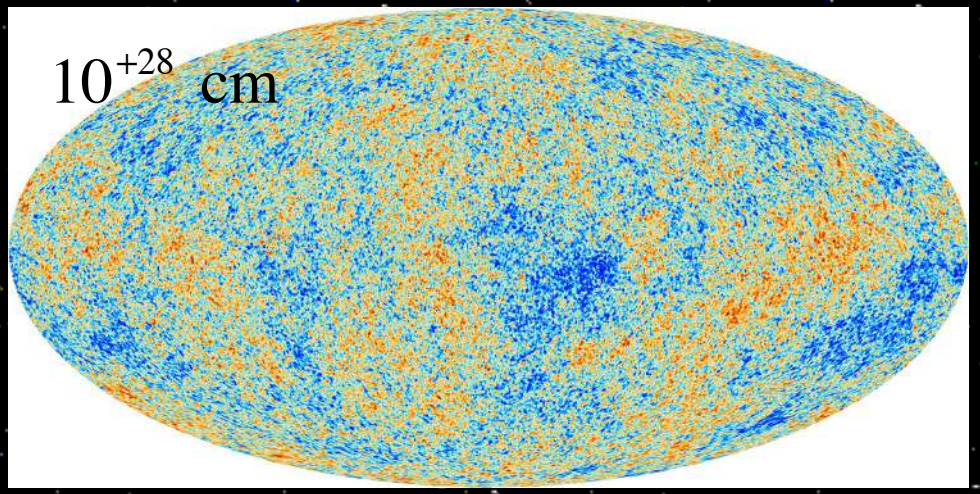
V. Mukhanov

LMU, München

The efforts to understand the universe is one of the very few things that lifts human life a little above the level of farce...

S. Weinberg, 1977





$$\Delta q \times \Delta p \geq \frac{1}{2}\ \hbar$$

Before 1990

Notre concitoyen, disaient-ils en pleurant,
Perd l'esprit : la lecture a gâté Démocrite.
Nous l'estimerions plus s'il était ignorant.
Aucun nombre, dit-il, les mondes ne limite :
Peut-être même ils sont remplis
De Démocrites infinis.

La Fontaine

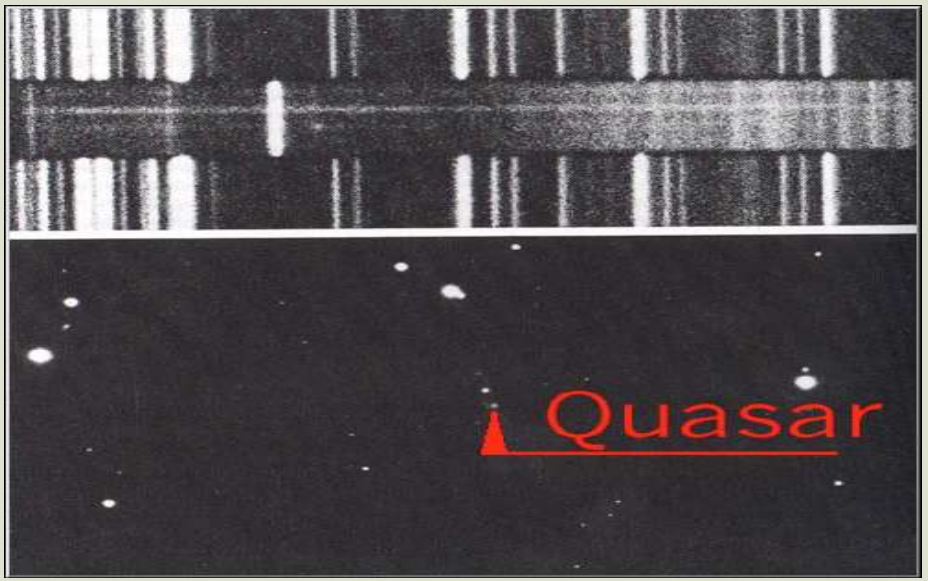
"Our fellow citizen," they said, "has lost his mind"
Reading has ruined Democritus.
If he knew less he'd have more sympathy from us.
There are more worlds, he claims, in number infinite,
And each of them may have in it
Another Democritus.

La Fontaine

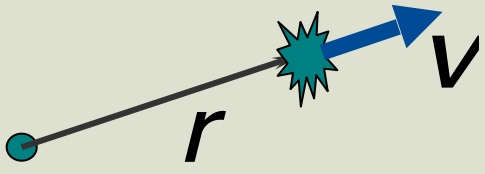
"Only by their breaking could the divine configurations be perfected"

Kabbalistic text; Ta'alumoth Chokhmah (The Channels of Wisdom)
1629, Joseph Samomon del Medigo of Crete

The Universe expands



Hubble law



$$v = Hr$$

$$t \sim \frac{r}{v} = \frac{1}{H} \sim 13{,}7\ bil.\ years$$

There is baryonic matter:

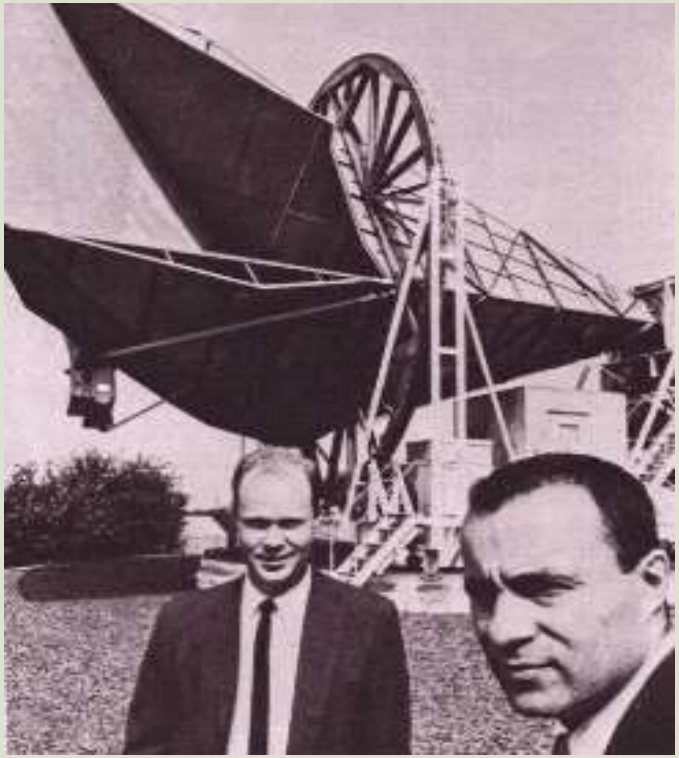
about 25% of ^{4}He, D....heavy elements

Dark Matter???? baryonic origin???

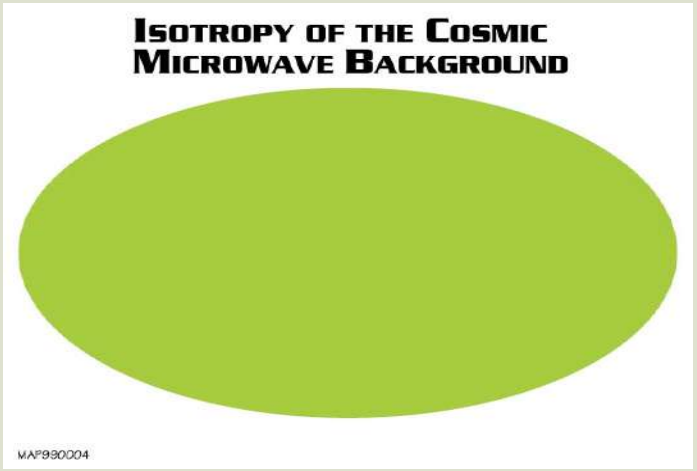
Large Scale Structure: clusters of galaxies!

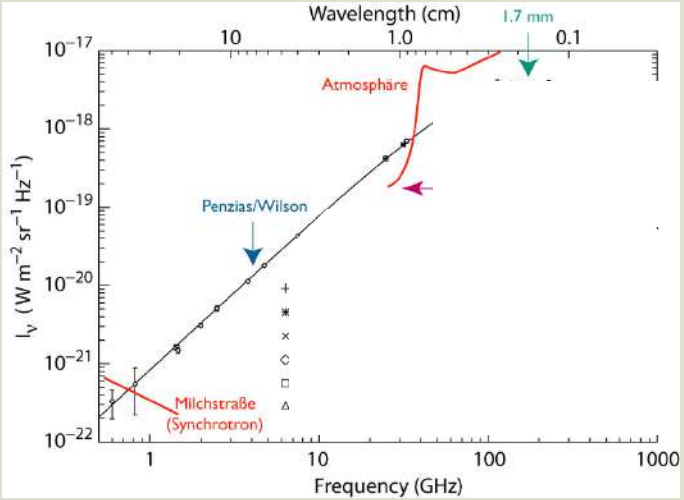
Filaments, Voids??????????????????????

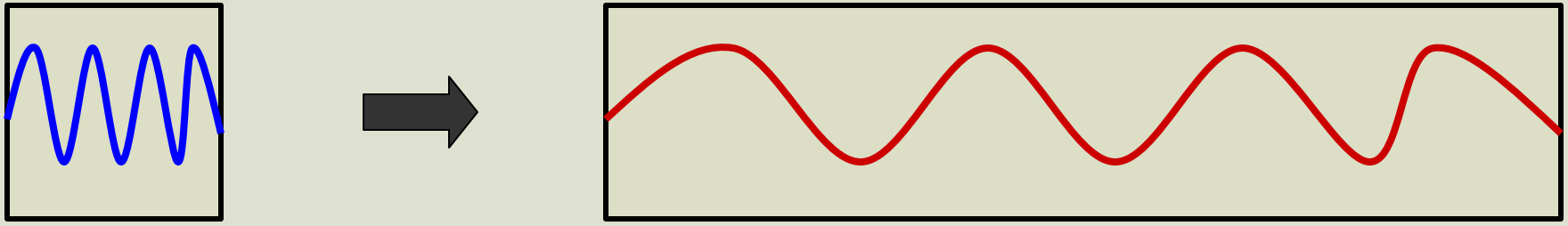
- There exists background radiation with the temperature $T \approx 3K$



Penzias, Wilson 1965



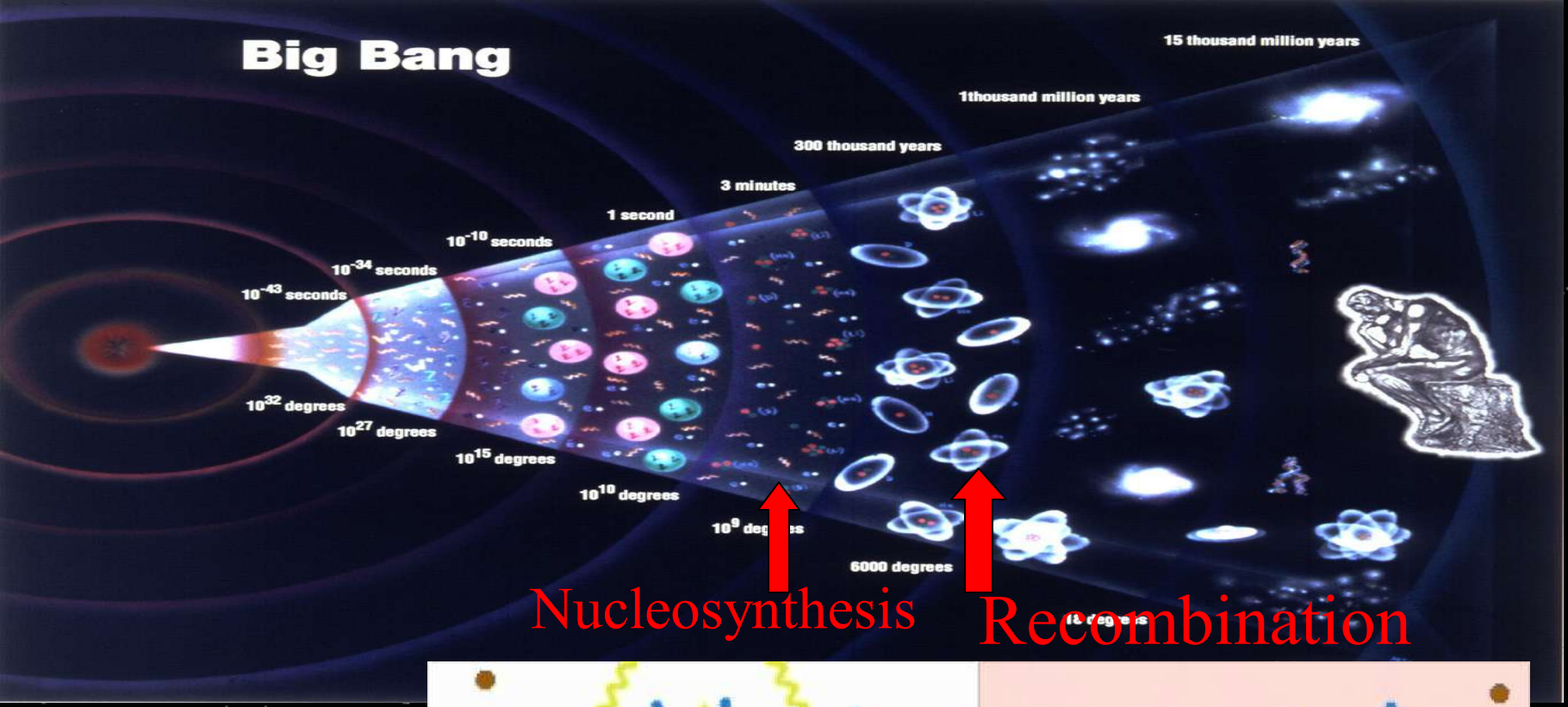


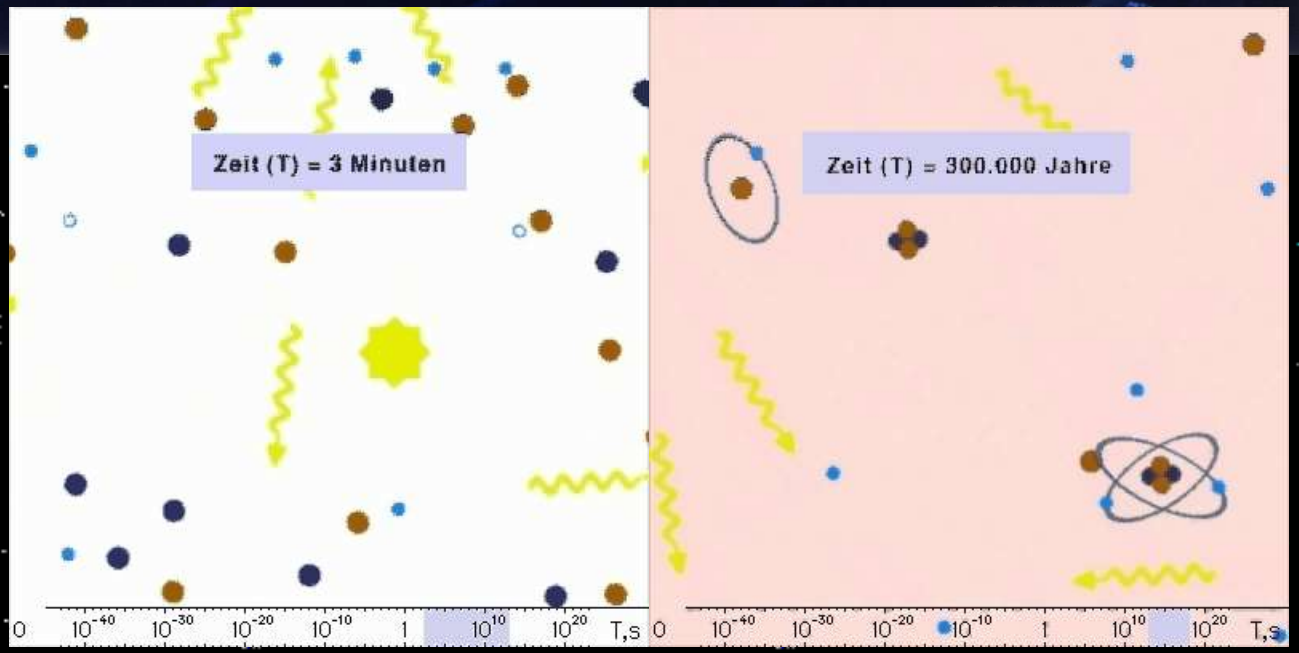


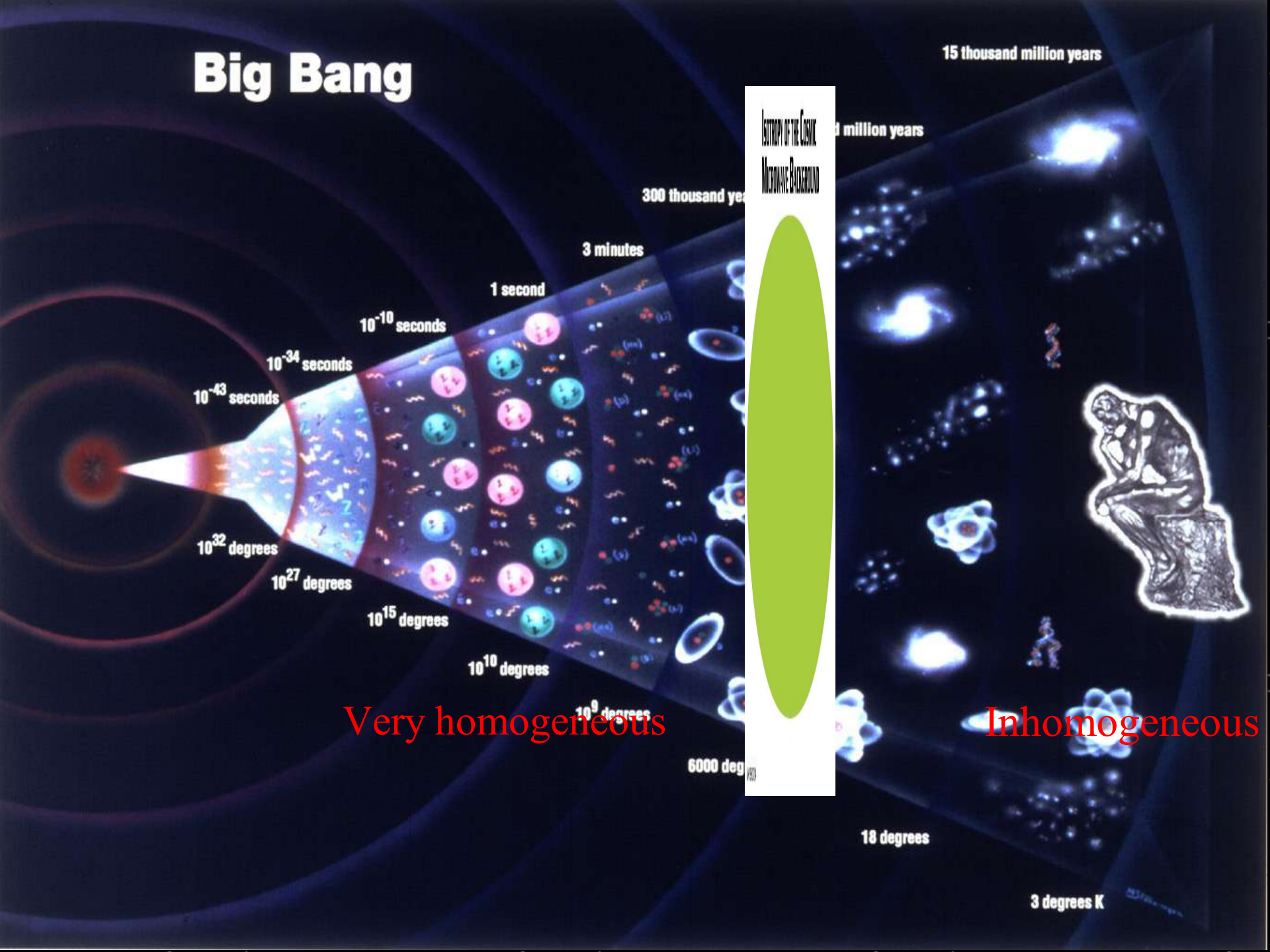
a

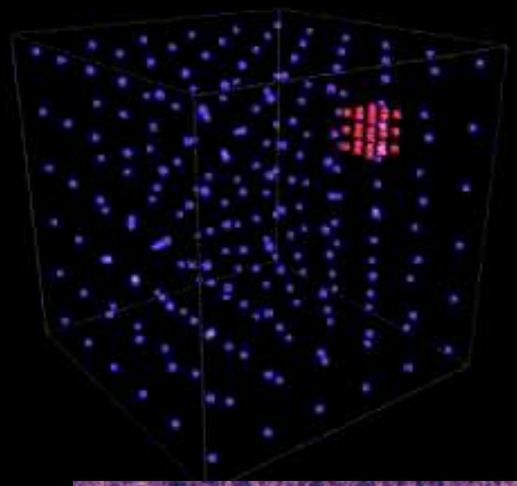
$$\lambda \propto a \quad \Rightarrow \quad T \propto \frac{1}{a}$$

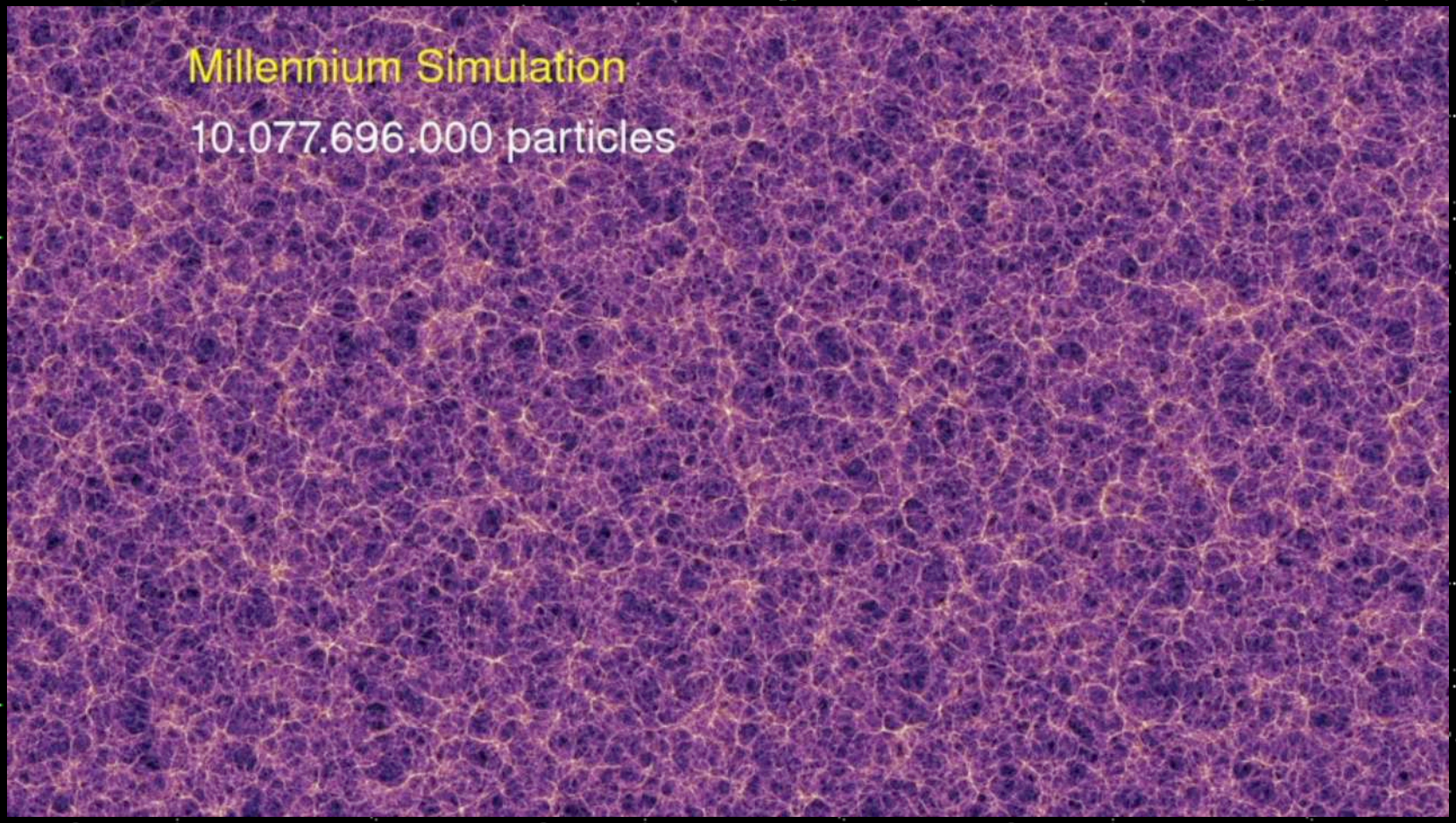
When the Universe was 1000 times smaller its temperature was about $2725°K$

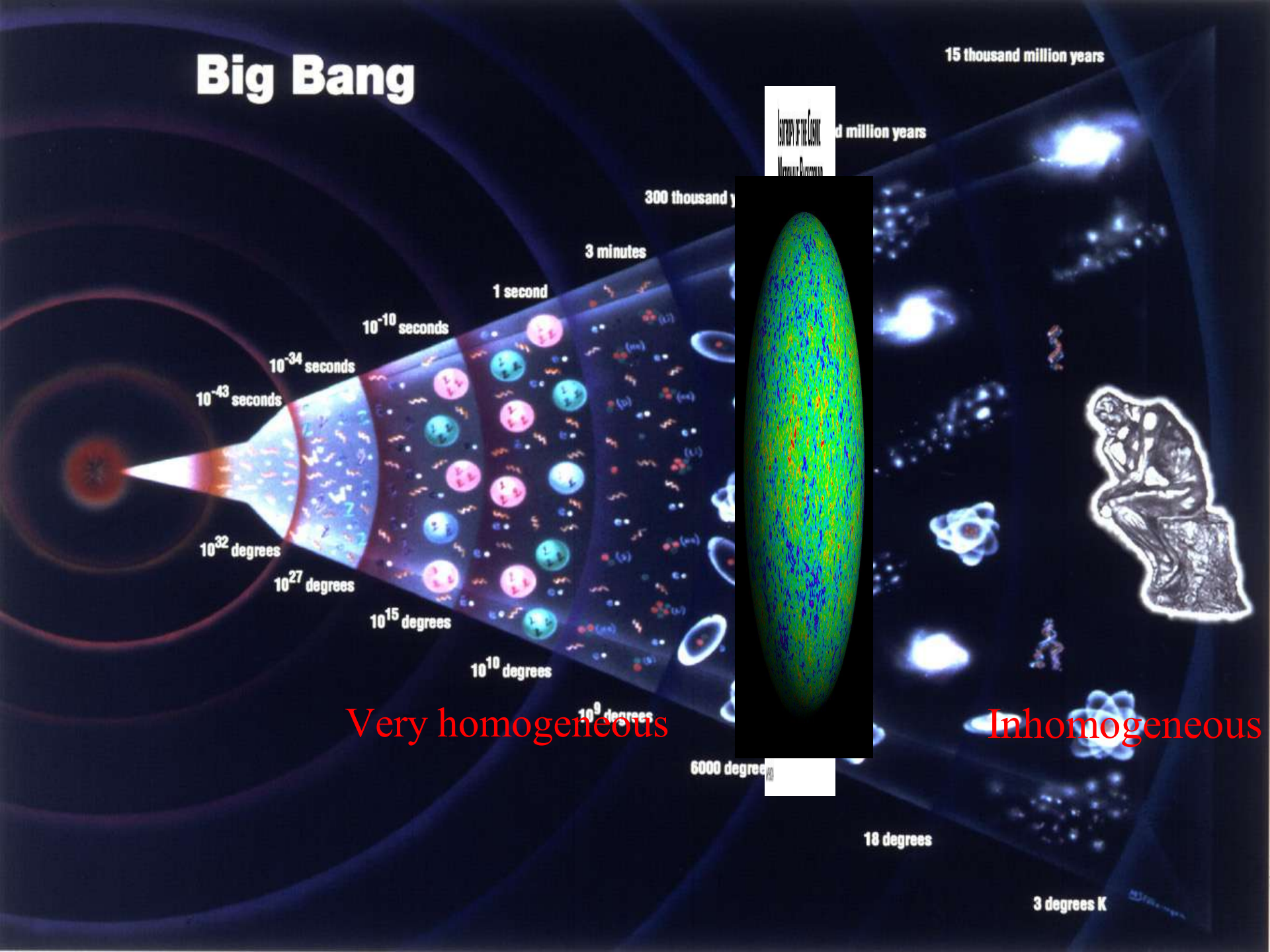

Big Bang
15 thousand million years
1thousand million years
300 thousand years
3 minutes
1 second
10^{-10} seconds
10^{-34} seconds
10^{-43} seconds
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
10^{9} degrees
6000 degrees
Nucleosynthesis
Recombination


Zeit (T) = 3 Minuten
Zeit (T) = 300.000 Jahre
0
10^{-40}
10^{-30}
10^{-20}
10^{-10}
1
10^{10}
10^{20}
T,s


Big Bang
15 thousand million years
Anisotropy of the Cosmic Microwave Background
300 thousand ye
3 minutes
1 second
10^-10 seconds
10^-34 seconds
10^-43 seconds
10^32 degrees
10^27 degrees
10^15 degrees
10^10 degrees
6000 deg
18 degrees
3 degrees K
Very homogeneous
Inhomogeneous




Millennium Simulation
10.077.696.000 particles


Big Bang
15 thousand million years
d million years
300 thousand
3 minutes
1 second
10^{-10} seconds
10^{-34} seconds
10^{-43} seconds
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
10^{9} degrees
6000 degrees
18 degrees
3 degrees K
Very homogeneous
Inhomogeneous

JETP Lett, Vol. 33, No.10, 20 May 1981

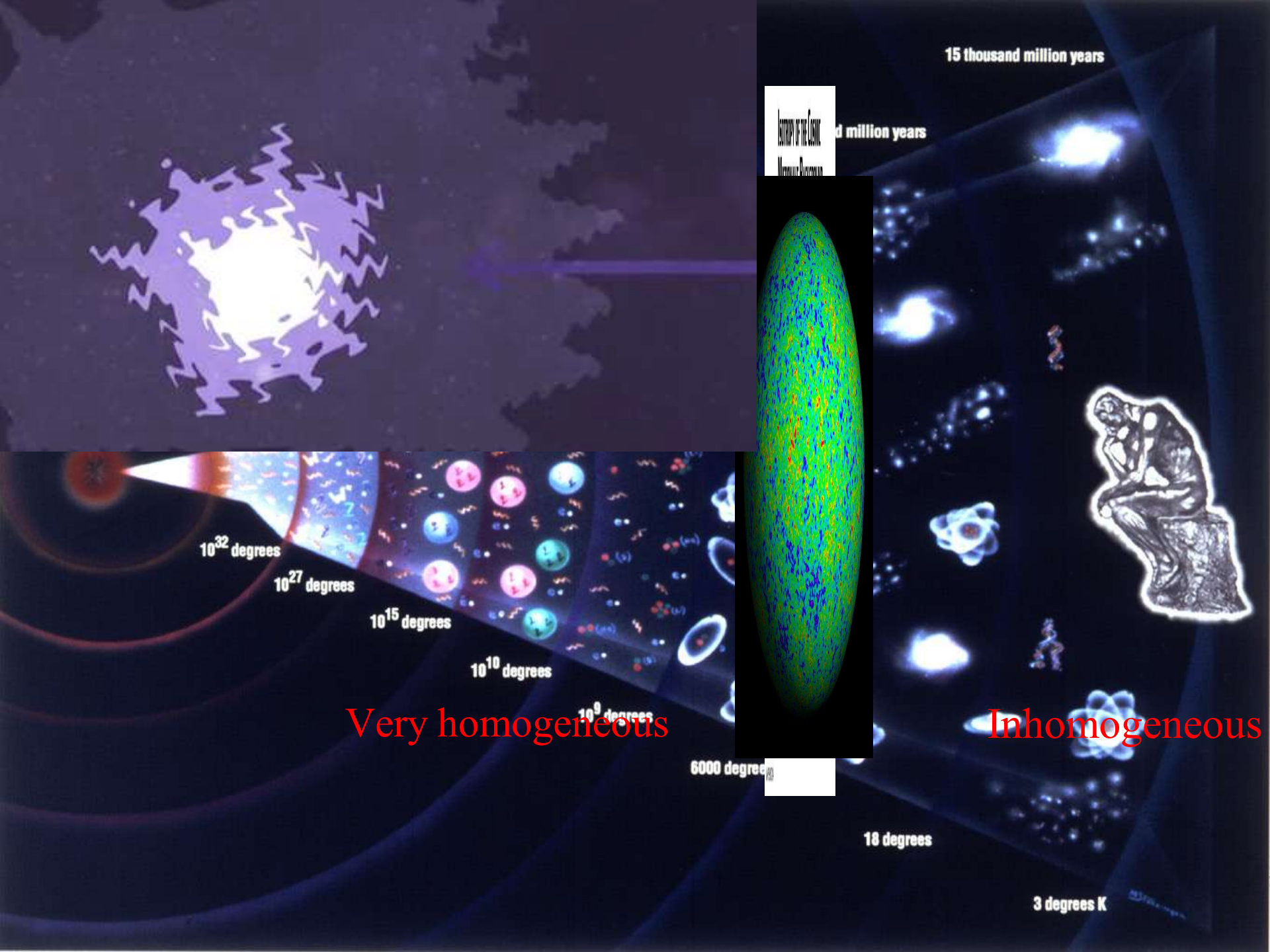
Quantum fluctuations and a nonsingular Universe

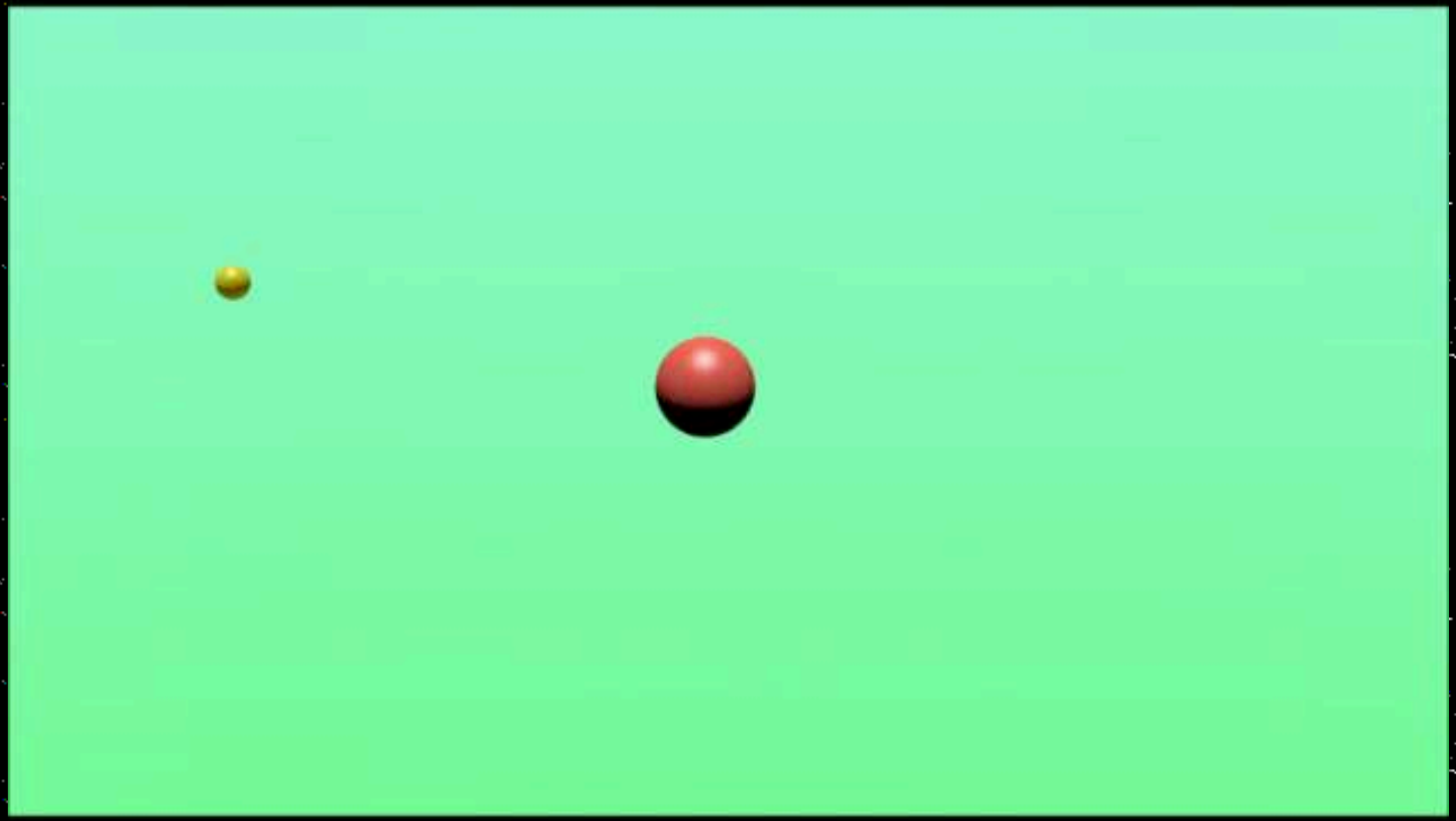
V.F.Mukhanov and G.V. Chibisov

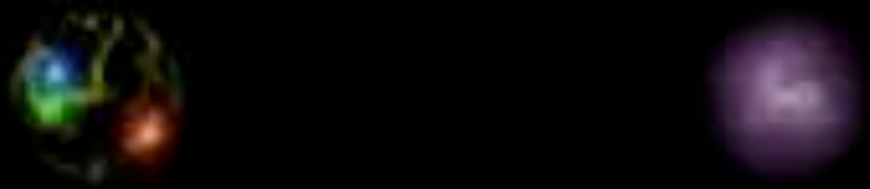
P. N. Lebedev Physics Institute, Academy of sciences of the USSR

(Submitted 26 February 1981; 15 April 1981)

Pis'ma Zh. Eksp. Theor. Fiz. 33, No.10, 549-553 (20 May 1981)


15 thousand million years
million years
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
6000 degrees
18 degrees
3 degrees K
Very homogeneous
Inhomogeneous




$\Delta x\, m \Delta v \geq \hbar$

$$\Delta p \Delta x \geq h$$

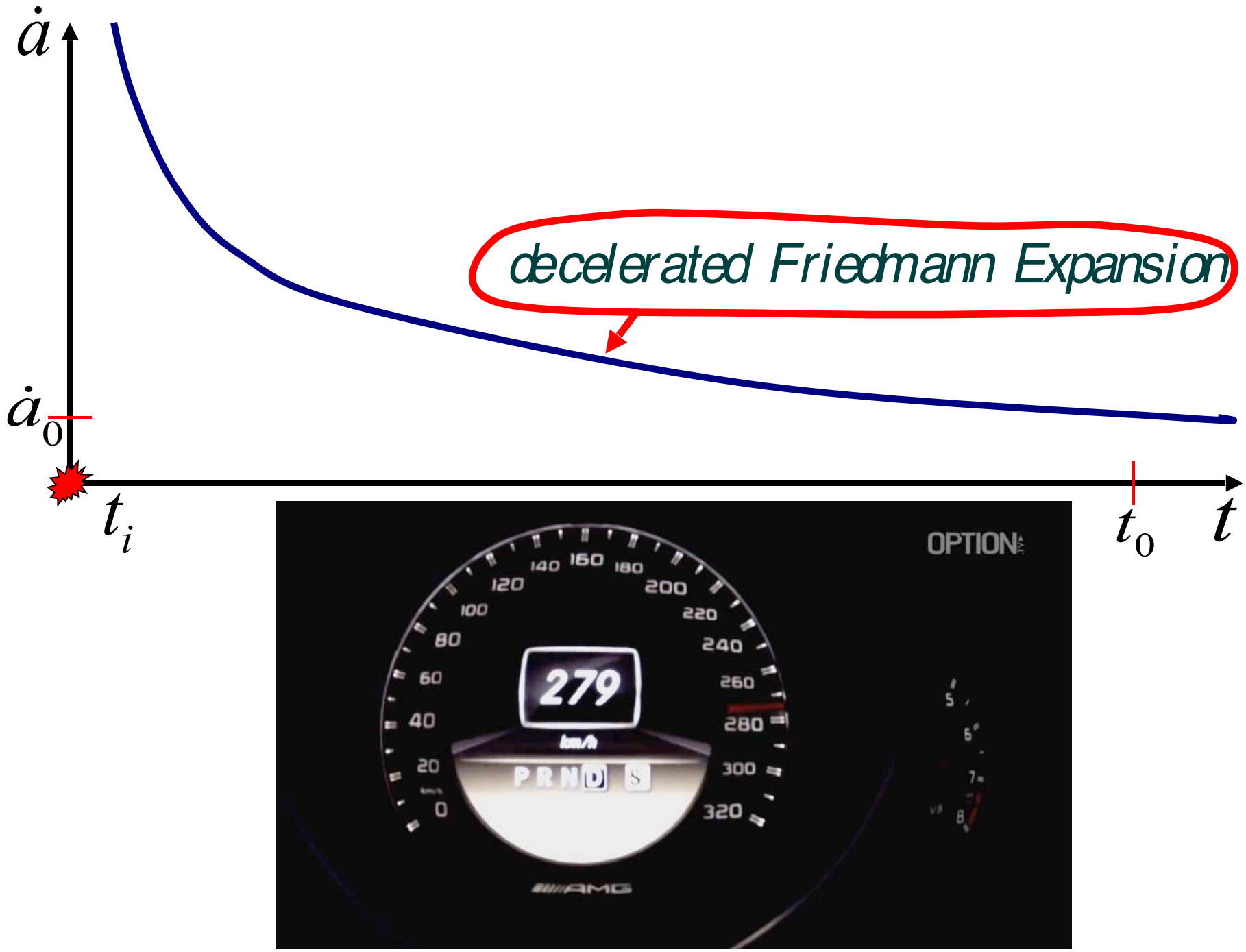
There always exist unavoidable Quantum Fluctuations

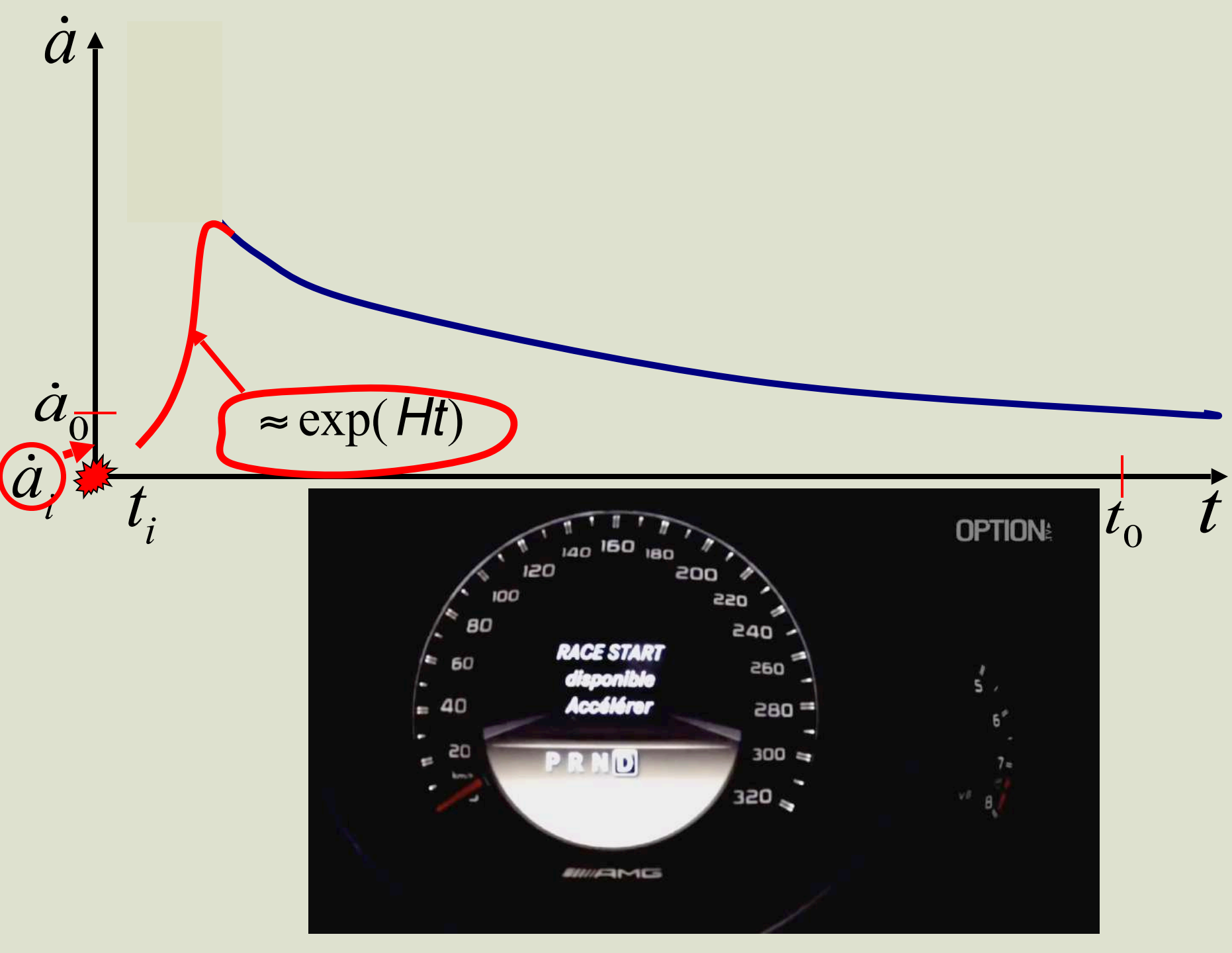
Quantum fluctuations in the density distribution are large (10^{-5})

only in extremely small scales (~ 10^{-33} cm),

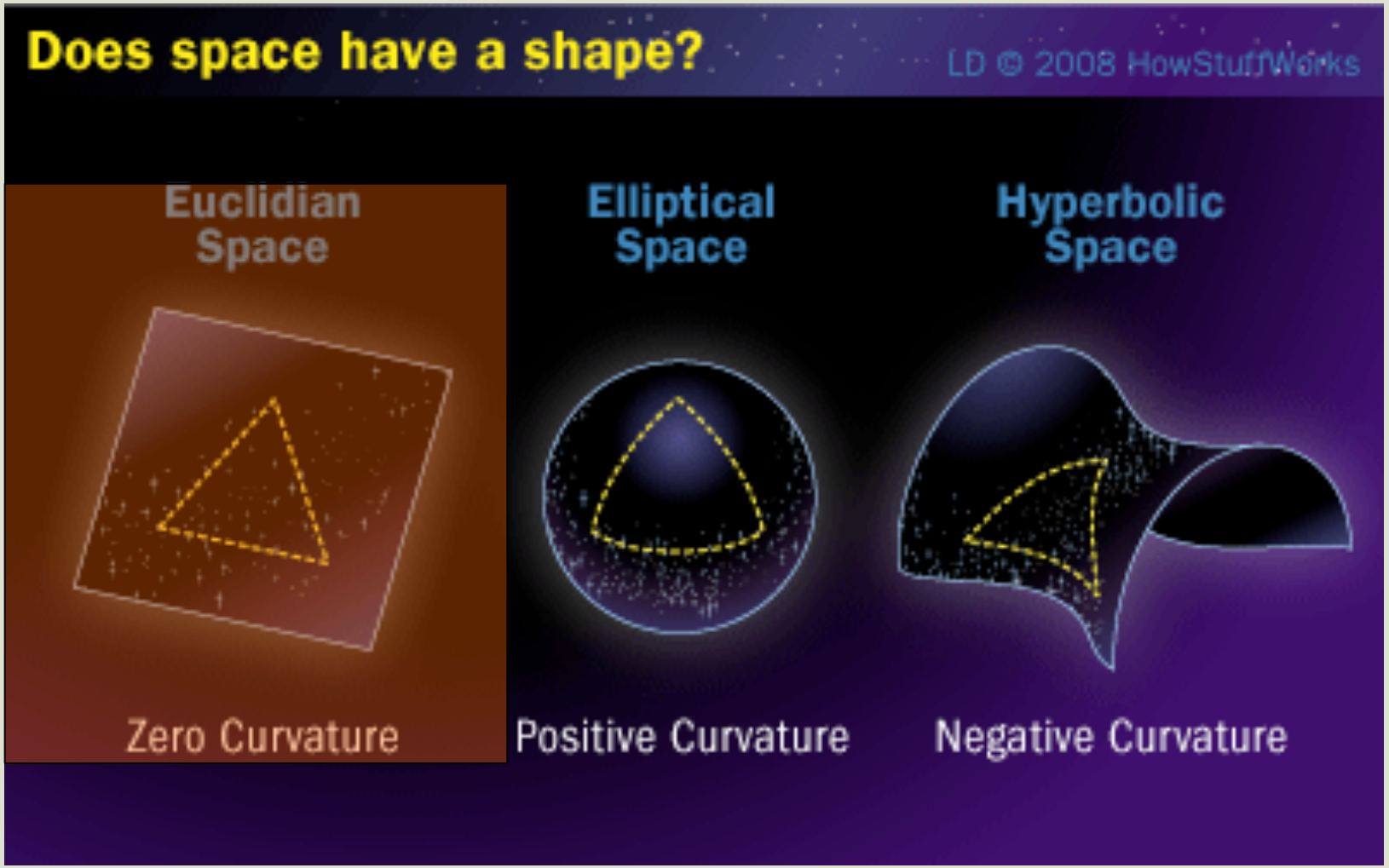
but very small (~ 10^{-58}) on galactic scales (~ 10^{25} cm)

Can we transfer the large fluctuations from extremely small scales to large scales???


$\dot{a}$
$\dot{a}_0$
t_i
t_0
t
decelerated Friedmann Expansion
OPTION
279
km/h
P R N D S
AMG


$\dot{a}$
$\dot{a}_0$
$\dot{a}_i$
t_i
t_0
t
$\approx \exp(Ht)$
OPTION
RACE START
disponible
Accélérer
P R N D
AMG

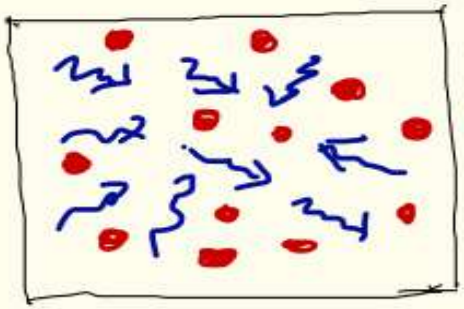
Predictions!!!

1) 

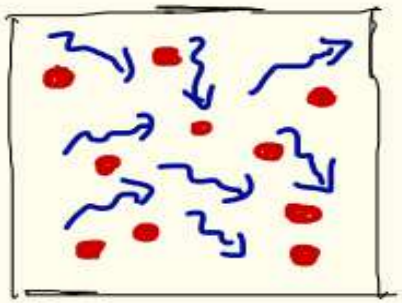
$$\Omega = 1$$

Perturbations (inhomogeneities) are:

2) Adiabatic (MC 1981)



100 photons
50 baryons



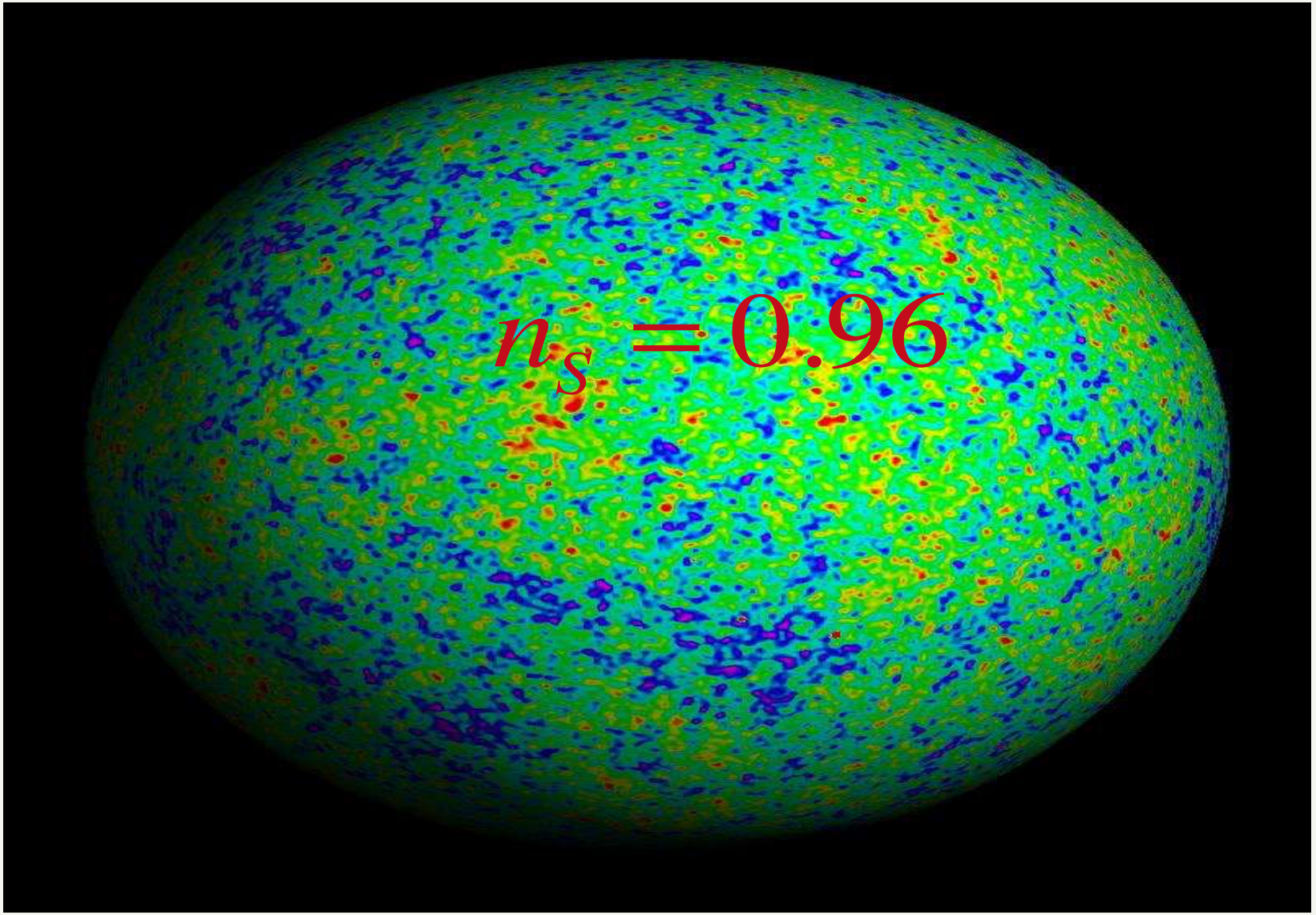
98 photons
49 baryons

~~49 - 2 = 47~~

3) Gaussian (MC 1981)

$$\Phi=\Phi_g + f_{NL}\Phi_g^2, \text{ where } f_{NL} = O(1) \text{ (MC, 81)}$$

4) have log spectrum (MC 1981)



$$\frac{female}{male} = 0.96$$

4) Have log spectrum (MC, 81; H, 82)

$$\Phi^2 \propto \ln^2(\lambda / \lambda_{CMB}) \propto \lambda^{1-n_S}$$

$$n_S = 1 - \frac{2}{\ln(\lambda_{gal} / \lambda_{CMB})} \approx 0.96!!!$$

L.P. 9/6/2003:

We are writing a proposal to get money to do our small angular scale CMB experiment. If I say that simple models of inflation require n_s=0.95+/-0.03 (95\% cl) is it correct?

I'm especially interested in the error. Specifically, if n_s=0.99 would you throw in the towel on inflation?

V.M. 9/8/2003

The "robust" estimate for spectral index for inflation is 0.92<n_s<0.97.

The upper bound is more robust than lower. The physical reason for the deviation of spectrum from the flat one is the nessesity to finish inflation....

If you find n_s=0.99 +/- 0.01 (3 sigma) I would throw in the towel on inflation.