PRIMORDIAL DENSITY PERTURBATIONS IN TEPID INFLATION

B. Lukács
Central Research Institute for Physics, H-1525 Bp. 114, Pf. 49, Budapest, Hungary
G. Paál
Konkoly Observatory of the Hungarian Academy of Sciences, H-1525 Bp. 114, Pf. 67, Budapest, Hungary

Abstract: Density fluctuations needed for galaxy formation may have thermal origin in a tepid inflation.

Our goal is to get rid of unnatural initial conditions and/or parameters of inflationary cosmologies while preserving their successes. Simple new inflationary models are capable to produce $\gtrsim 10^{87}$ entropy, $\gtrsim 10^{29}$ times expansion and to explain the flatness, horizon and monopole problems, but usually only at the expense of i) predicting too high local density perturbations; ii) requiring almost exactly critical global density within the present horizon; and iii) violating the cosmologic principle outside horizon.

Observe that the thermal fluctuations at the GUT transition temperature would be just in the order of magnitude $\partial e/e \sim 10^{-5}$ required for galaxy formation. Indeed, according to Ref. 1,

$$(\partial e/e) \approx V^{-1/2}(d^2 s/de^2)^{-1/2} \approx (8\pi/3)(N\pi/5)^{1/4}(T/M_{Pl})^{3/2} \qquad (1)$$

for a radiation field at horizon size. Substituting $N \approx 100$, $T_{GUT}/M_{Pl} \approx 10^{-4}$, $\partial e/e \approx 2.5 \times 10^{-5}$. However

a) usually inflation happens at deep supercooling when $\partial e/e \ll 10^{-5}$;

b) (1) is meant for the initial relative fluctuations at the first horizon crossing during inflation, still to be multiplied by $\approx e/(e+p)$ to get the final value at the second horizon crossing [2].

Both above problems are simultaneously resolved if there is no deep supercooling with violent reheating but rather a continuous entropy production from a delayed phase transition, so tepid inflation is needed. Then $\partial e/e$ does not decrease too much, and $e/(e+p) \approx e/Ts$ is not too high. Such models exist, cf. Ref. 3.

In these models the transition happens almost isothermally. Then S/S_i, R/R_i and $\partial e/e$ can be expressed by the temperatures of the transition T_0 and the phase equilibrium T_{eq}, with the following results.

Results and conclusions. For tepid inflation very simple and suggestive relations hold.

1) 10^{87} entropy and 10^{29} expansion appears at 92% supercooling for all reasonable Higgs parameters.

2) For this supercooling and GUT energy scales between 10^{14} and 10^{15} GeV favoured by low energy particle physics *there is no "fluctuation problem"*, since there always exist such Higgs number paramter values close to O(1) that $\partial e/e$ be a few times 10^{-5} for all relevant mass scales. Thus density perturbations may be due to thermal rather than quantum fluctuations; no very weakly coupled inflaton field is needed; the scalar field can be in thermal contact with the radiation; the thermal history of the Universe may be monotonous.

3) The amplification factor $e/(e+p)$ is O(100) and not 10^{20} of the standard cold inflation.

4) The thermodynamic coherence length of thermal fluctuations [1] $\sim 1/T_0 \ll l_{horizon}$, since $T_0 \gg T_{Hawking}$. Our phenomenologic picture corresponds to a "continuous creation" of coherent domains and a quasihomogeneous vacuum decay during the whole inflation. *Not a single coherent region is inflated to encompass the observable part of the Universe; $e \approx e_{crit}$ is not needed, the cosmologic principle may hold true.*

Acknowledgement. Thanks are due to B. Kampfer, R. H. Brandenberger and A. A. Starobinskii for valuable discussions.

References: [1] L. Diósi and B. Lukács: Phys. Lett. 112A, 13 (1985); Phys. Rev. 31A, 3415 (1985)
[2] R. H. Brandenberger: Rev. Mod. Phys. 57, 1 (1985)
[3] B. Kampfer, B. Lukács and G. Paál: Phys. Lett. B187, 17 (1987)

J. Audouze et al. (eds.), Large Scale Structures of the Universe, 514.