THEORETICAL PHYSICS

INTERNATIONAL CENTRE FOR

CERN-86/74

IC/86/74
A new approach to understanding the universe and its potential consequences is presented. This approach utilizes the principles of symmetry and conservation laws to explore the implications of different models of the universe. It is shown that the universe evolution in the chaotic phase of the universe can lead to the emergence of new structures and phenomena. This work is important in the context of the current scientific understanding of the universe. The potential implications of these findings could lead to significant advances in our understanding of the universe's structure and evolution.
Here $M_p \sim 10^{19} \text{ GeV}$ is the Planck mass, $k$ is the curvature scalar, $\nu^2 \equiv G$ is the gravitational constant. A discussion of a theory of an interacting field $\Psi$ will be contained in a separate publication (5).

Evolution of a sufficiently homogeneous field $\Psi$ in a locally Friedmann universe with a scale factor $a(t)$ is governed by equations

$$\ddot{\Psi} + 3H\dot{\Psi} = -m^2 \Psi,$$

where $H = \frac{\dot{a}}{a}$, and

$$\dot{a}^2 + \frac{k}{a^2} = \frac{8\pi}{3M_p^2} \left( \frac{1}{2} \Psi^2 + \frac{m^2}{2} \Psi^2 \right).$$

Here $k = 1, 0$ for a closed, open, or flat universe respectively. At $\Psi > M_p$ solutions of eqs. (2), (3) rapidly approach the asymptotic regime

$$\Psi(t) = \Psi_o - \frac{mM_p}{2\sqrt{3} H M_p} t,$$

$$A(t) = A_o \exp \left( \frac{2\sqrt{3}}{M_p^2} \left( \Psi_o^2 - \Psi^2(t) \right) \right).$$

According to (4), (5), during a time $\tau < 2\sqrt{3} \Psi_0 \frac{m}{M_p}$, the value of the field $\Psi$ remains almost unchanged, and the universe expands quasiexponentially, $a(t + \tau) \approx a(t) \exp(H \tau)$, where

$$H = \frac{2\sqrt{3}}{M_p^2} \frac{m\Psi}{\sqrt{3} H M_p},$$

$H > T^{-1}$ for $\Psi > M_p$. The only possible constraint on the initial value of the field $\Psi$ at the beginning of the universe evolution is

$$\frac{m^2 \Psi_0^2}{2} \lesssim M_p^4.$$ Therefore a typical initial value of the field $\Psi$ is $\Psi_0 \sim \frac{M_p^2}{m^2}$ (I-4).

3. Quasiexponential expansion (inflation) (4), (5) makes the universe locally homogeneous and isotropic. However, inflation also leads to creation of long-wave fluctuations $\delta \Psi(x)$ of the classical field $\Psi$ (6-8). Fluctuations generated during a time $\Delta t = H^{-1}$ in our theory look as a distribution of the classical field $\delta \Psi(x)$ with a time-independent amplitude

$$\delta \Psi(\omega) \sim \frac{H(\omega)}{\sqrt{2/\pi}} \sim \sqrt{\frac{3}{2}} \frac{M_p}{\sqrt{3} M_p} \left( \Psi_0 - \frac{mM_p}{2\sqrt{3} H M_p} t \right).$$

and with initial wavelength $\Delta \ell \sim H^{-1}$. Later their wavelength exponentially grows as $a(t)$ (5), but at the same time new perturbations with the wavelength $\Delta \ell \sim H^{-1}$ are generated, etc. Inhomogeneities of the field $\Psi$ give rise to density perturbations $\delta \rho(x)$, which on a galaxy scale have a relative amplitude $\frac{\delta \rho}{\rho} \sim 10^{-4}$ (9, 10). This gives a desirable value $\frac{\delta \rho}{\delta \Psi} \sim 10^{-4}$ for $m \sim 10^{-5} M_p \sim 10^{14}$ GeV (6, 9, 3). The value of $\frac{\delta \rho}{\delta \Psi} \sim 10^{-4}$ logistically grows at large scales and becomes $O(1)$ at a scale $\ell \sim M_p^{-1} \exp(2\sqrt{3} M_p) \sim 10^{10} \text{ cm}$. Perturbations of the scalar field on such a scale are generated when the average field $\Psi$ (4) is of the order $\frac{M_p^4}{\sqrt{M_p^4}} \sim 10^4 M_p$. The physical meaning of this result is very interesting.

4. During a typical time $\Delta t = H^{-1}$ the average field $\Psi$ (4) decreases by

$$\Delta \Psi = \frac{mM_p}{2\sqrt{3} H M_p} = \frac{M_p^2}{3 H M_p} \Psi.$$ From (7), (8) it follows that $|\delta \Psi| \leq \Delta \Psi$ for $\Psi \leq \frac{M_p^2}{3 \sqrt{m^2 \Psi}}$ and $|\delta \Psi| \geq \Delta \Psi$ for $\Psi \geq \frac{M_p^2}{3 \sqrt{m^2 \Psi}}$. This means that the region $M_p \lesssim \Psi \lesssim \frac{M_p^2}{m^2 \Psi}$ is divided into two regions. At $\Psi \lesssim \frac{M_p^2}{3 \sqrt{m^2 \Psi}}$ evolution of the scalar field $\Psi$ everywhere with a good accuracy is described by eq. (4). However, at $\Psi \gtrsim \frac{M_p^2}{3 \sqrt{m^2 \Psi}} \approx 10^4 M_p$ (i.e., in the main part of the region $M_p \lesssim \Psi \lesssim \frac{M_p^2}{m^2 \Psi}$) only the average field $\Psi$ (averaged over the initial coordinate volume of the universe (5)) obeys eq. (4), and the role of fluctuations is very important.

Let us consider a domain of the universe of a size $\Delta \ell \gtrsim O(H^{-1}(\Psi))$ containing a sufficiently homogeneous field $\Psi \gg M_p \sqrt{M_p^4} \sim 10^4 M_p$. According to the "no hair" theorem for de Sitter space, inflation in such a domain proceeds independently of what occurs outside it (10),
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structure comes from topology and may lead e.g. to creation of a pair of mini-universes with opposite topological numbers.) Note, that this process may occur in the chaotic inflation scenario only, since only in this scenario inflation may occur at densities of the order of \( \phi^4 \) \((3,11)\).

As a result, the universe becomes divided into exponentially large number of domains, and all possible types of compactification and all possible types of metastable vacuum states should be realized in different domains of the universe. All those domains (mini-universes), in which inflation remains possible after their formation, later become exponentially large. It seems therefore that God not only could create the universe differently, but in His wisdom He created the universe which has been unceasingly producing different universes of all possible types.

According to this scenario, we live in the mini-universe of our type not for the reason that it is the only possible universe, but for the reason that there exist many different mini-universes, and life of our type cannot exist in domains with a different dimensionality and with different types of symmetry breaking \((3)\). This provides a justification of the anthropic principle in the inflationary cosmology.

A more detailed discussion of the problems touched upon in the present paper will be published elsewhere \((5,11)\).

ACKNOWLEDGMENTS

The author is grateful to A.S. Goncharov, G. Gelmini, D.A. Kirzhnits, L.A. Kofman, N.A. Markov, V.F. Mukhanov, T.L. Rozental and Ya.B. Zeldovich for valuable discussions. He would also like to thank Professor Abdus Salam, the International Atomic Energy Agency and UNESCO for hospitality at the International Centre for Theoretical Physics, Trieste.

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