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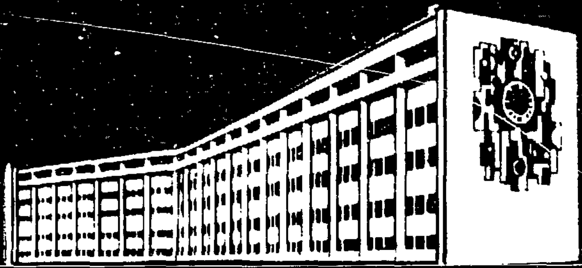
CLOSED WORLDS AND BARYON ASYMMETRY OF THE VISIBLE UNIVERSE



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Closed Worlds and Baryon Asymmetry of the Visible Universe

Yu.A.Beletsky

To explain the existence of galaxies and clusters of galaxies in the framework of standard big-bang cosmology it is necessary to admit initial perturbations of energy density on a background of Friedmann solution with the scale much bigger than the particle horizon [1,2] . Since we don't know the dynamical nature of these perturbations, they are usually looked upon as an initial condition for classical Einstein cosmology on some Cauchy hyperspace Σ_*[3] . The corresponding time label t_* ("threshold time" of Harrison [3] is much behind the Planck time $t_{Pl} \sim 10^{-43}$ and much ahead of the time of lepton annihilation and Helium formation $t_{He} \sim 10^{-4}$.

The existence of these large-scale perturbations ($L >> \Lambda_H(t_*)$) in the very early Universe can lead to the production of some kinds of primordial cosmological objects like black holes, semi-closed and closed worlds (exhaustive information and references on these objects can be found out in Frolov's review [5]).

In the simplest case one can get semi-closed world matching Schwarzschild solution (with gravitational or external mass m_{ex}) and a part of closed Friedmann solution (with its own or internal mass m_{in}). Fig.1 represents cross-section in angular variable of two-dimensional surface t =const, $\theta = \pi/2$ for semi-closed worlds with different value of coefficient of gravitational packing $\eta = \frac{m_{in} - m_{ex}}{m_{in}}$. Apparently these semi-closed worlds can change their η due to radiation or accretion. If the accretion of surrounding matter suppresses radiation and diminishes the mass defect $(\eta \to 0)$, then the semi-closed world becomes a black hole. Otherwise, both the classical radiation [6,7] and the quantum evaporation [5] will result in closed worlds.

For simplicity we will not below dwell upon the evolution of the primordial objects and consider them as the ones given by the spectrum of initial (on Σ_*) energy perturbations. Moreover, we will be interested only in the rise of closed worlds. In this case it is easy to get rather simple and general criterion connecting relative energy deviation $\delta = \Delta\varepsilon/\varepsilon$ and radius of perturbed region L when it closes up on itself. In the perturbed region the metric may be written as [3,4]

$$ds^2 = d\tau^2 - S^2(\tau)\left[\frac{dr^2}{1 - \varkappa r^2} + r^2 d\theta^2 + r^2 \sin^2\theta \, d\varphi^2\right], \qquad (1)$$

where $\varkappa$ is the perturbed total energy per unit mass and the time coordinate τ is the proper time as measured by comoving observers. It is clear that separate worlds will be formed if $r_b \varkappa = 1$ (here r_b the value of r on the boundary of the perturbation). Matching (1) with background Friedmann solution on Σ_*

$$ds^2 = dt^2 - R^2(t)\left[dr^2 + r^2 d\theta^2 + r^2 \sin^2\theta \, d\varphi^2\right] \qquad (2)$$

one gets the following chain of equations from definitions of particle horizon $\lambda_H = dR/d\left(\frac{dR}{dt}\right)$, and Schwarzschild's radius of perturbation $R_s = 2GM = \frac{8\pi G}{3} \varepsilon L^3$ (where $L = r_b S(\tau_*)$).

$$\delta = \frac{3\varkappa}{8\pi G \varepsilon R(t_*)} = \frac{3}{8\pi G \varepsilon L^2} = \frac{L}{R_s} = \frac{\Lambda_H^2(t_*)}{L^2} \qquad (3)$$

As it was assumed for $\delta << 1$ radius of perturbation should be much less than R_s and much more than the particle horizon. For constant density in perturbation one has $L^3/\Lambda_H^3 = b/b_H = m/m_H$ where b, m and b_H, m_H are initial (on Σ_*) numbers of baryons and masses within the horizon and in the perturbed region, respectively. From (3) it follows that all perturbations which exceed the critical value

$$\delta_c = \left(b_H/b\right)^{2/3} = \left(m_H/m\right)^{2/3} \tag{4}$$

form closed worlds and are separated from the initial topologically connected in Σ_* universe (below we will name it as protouniverse). The protouniverse breakes down into pieces until some effective time t_0 , when particle horizon exceedes typical dimension of perturbation. The corresponding hypersurface Σ_0^j of topologically connected j -th universe is indeed the Cauchy surface for its classical cosmology.

The spectrum of initial perturbation on Σ_0 is effectively cut off at $\delta > \delta_c$, what is usually supposed from the very outset [4,5,8] . Therefore, if the cut off is the only observable consequence of described topological decay, (as closed worlds are unobservable), then the surfaces Σ_* and Σ_0 are physically indistinguishable. We present here some arguments in favour of the point that such initial conditions of our visible Universe like baryon asymmetry and proximity of mean density to critical one are the consequences of topological decay of the protouniverse.

The question about baryon asymmetry arises due to the fact that although the local laws of physics are matter-antimatter symmetrical, our Universe is apparently dominated by matter. The second important fact is that the number of photon per baryon is about $1/\beta \sim 10^{8+9}$ so if the baryon number is conserved, then this number must be viewed merely as a little strange initial condition of the Universe.

The success of quantum chromodynamics and Weinberg-Salam gauge theory has motivated the attempts of grand unification. In all these unified schemes baryon number is not conserved and initially the baryon symmetric Universe can evolve a net of baryons [9] . Here we present scenario which can be easily combined with the ideas mentioned above, but which can independently explain the baryon asymmetry without breaking baryon conservation. In some respect similar idea as regards the primordial black holes was stated in [10] .

It is clear that the arguments in favor of baryon symmetry should refer to Σ_* , i.e. to the protouniverse. On the contrary, any universe on Σ^j_0 naturally loses baryon symmetry due to inhomogeneities of baryonic charge on Σ_* , and statistical fluctuations [11] (in the first approximation since gravitation does not distiguish baryon charge, fluctuations of baryon number can be regarded statistically independent of perturbations of energy). The value of this asymmetry even in the simplest case depends on spectrum of energy perturbations and equation of state which are almost completely unknown to us on Σ_0 and,moreover, nothing can be said of them before topological decay. On this stage one can adopt a model spectrum with some parameters and try to fit the arisen baryon asymmetry with other observed consequences. Here we will choose a bit another way and adopt a rather strong assumption. As we are short of information on scale of energy perturbations on Σ_* , we a priori cannot restrict their magnitude even by the magnitude of our visible Universe, i.e.,we cannot consider our Universe as the largest piece of the protouniverse. But we can suppose that our Universe is the most typical product of topological decay, i.e. such initial conditions on Σ_0 as baryon asymmetry and Hubble parameter [12,13] are the most probable (Cf. with antropic principle of Dicke-Carter). This assumption can be regarded as extended principle of Copernicus.

From the total number of baryons and baryon asymmetry of our Universe this principle allows us to find out the total number of particles in the protouniverse and the number of closed worlds formed as a result of topological decay.

Define baryon asymmetry of the j-th closed world as ratio of the difference of a number of baryons b_j and antibaryons $\tilde{b}_j$ to their total number

$$\xi_j = \frac{b_j - \tilde{b}_j}{b_j + \tilde{b}_j} = \frac{a_j}{n_j} . \qquad (5)$$

The protouniverse was charge-symmetric – $\xi_* = 0$, contained the total number of particles $2N_* = b_* + \tilde{b}_*$ and decayed into k piecies. As $N_* \gg n_j \gg k \gg 1$ we can simplify further and assume that all closed worlds contained equal number of particles $n_j = 2n = b + \tilde{b} = 2N_*/k$. Then the probability to have the given asymmetry ξ for statistically independent distribution of initial $2N_*$ particles into $k = N_*/n$ closed worlds is

$$P(\xi, n | k, N_*) = \frac{\binom{N_*}{b} \binom{N_*}{\tilde{b}}}{\binom{2N_*}{b+\tilde{b}}} = \frac{D(n,k)}{B(\xi,n,k)} , \qquad (6)$$

where

$$D(n,k) = (nk)!(nk)!(2n)![2n(k-1)]! \,/ (2nk)!$$

and

$$B(\xi,n,k) = [n(1-\xi)]![n(k-1+\xi)]![n(1+\xi)]![n(k-1-\xi)]!$$

According to the extended principle of Copernicus the protouniverse crumbled up with the most probable asymmetry which equals the observed one in our Universe $\xi = \xi_0$.

In the considered case it results in the equation

$$\frac{\partial}{\partial \xi} P(\xi, n | k, N_*) \Big|_{\xi = \xi_0} = 0 \qquad (7)$$

which relates ξ_0 with k and n_0. From (6) and (7) after simplifications we get $k \cong 4 n_0 \xi_0 \sim 10^{80}$ and $N_* = k n_0 \sim 10^{168}$

Fig.2 by analogy with Fig.1 conditionally demonstrates the evolution of the protouniverse from t_{Pl} till t_{He} (the initial stage - a, process of topological decay - b,c, and separeted closed worlds - d).

It should be noted that even without extended principle of Copernicus, but only admitting topological decay the baryon symmetry of arisen universe breakes, nevertheless, down. Moreover, if our Universe is the largest piece of the protouniverse, then the process of topological decay of the protouniverse effective diminishes the mean density of our Universe and approaches its value to the critical one. It means that in any case closed world formation to some extent makes the initial condition of our Universe (baryon asymmetry and parameter of deceleration) more appropriate for the origin of life [12,13].

In conclusion, we note that in the classical Einstein theory apparently impossible to describe topology change [14], so it is necessary to use quantum gravity to support the idea, that observed baryon asymmetry is a trace of topological decay.

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FIGURE CAPTIONS

Fig.1. Cross-section in angular variable of two-dimensional surface t = const. and $\theta = \pi/2$ for semi-closed worlds with different value of gravitational packing.

Fig.2. By analogy with Fig.1 conditional demonstration of the evolution of the protouniverse. The initial stage - a, process of topological decay - b,c and separeted closed worlds - d).

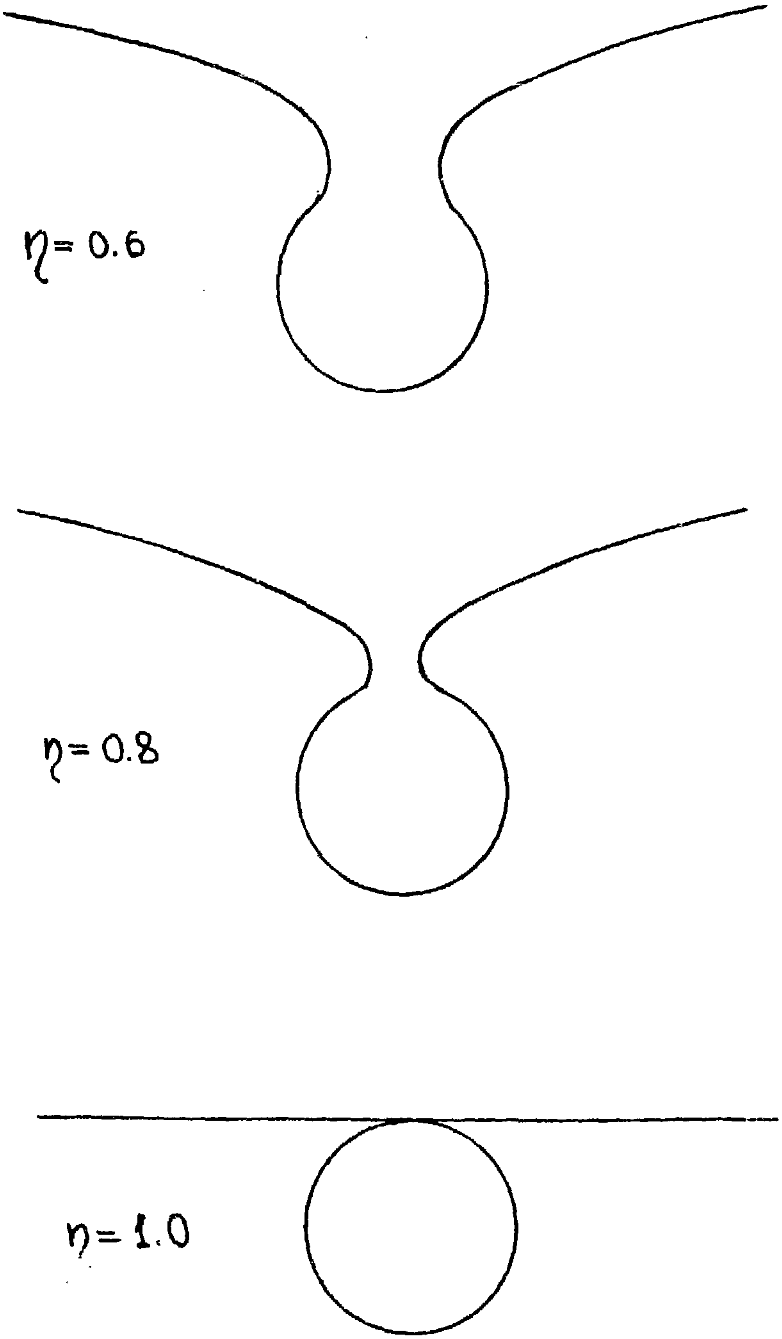

Fig.1.

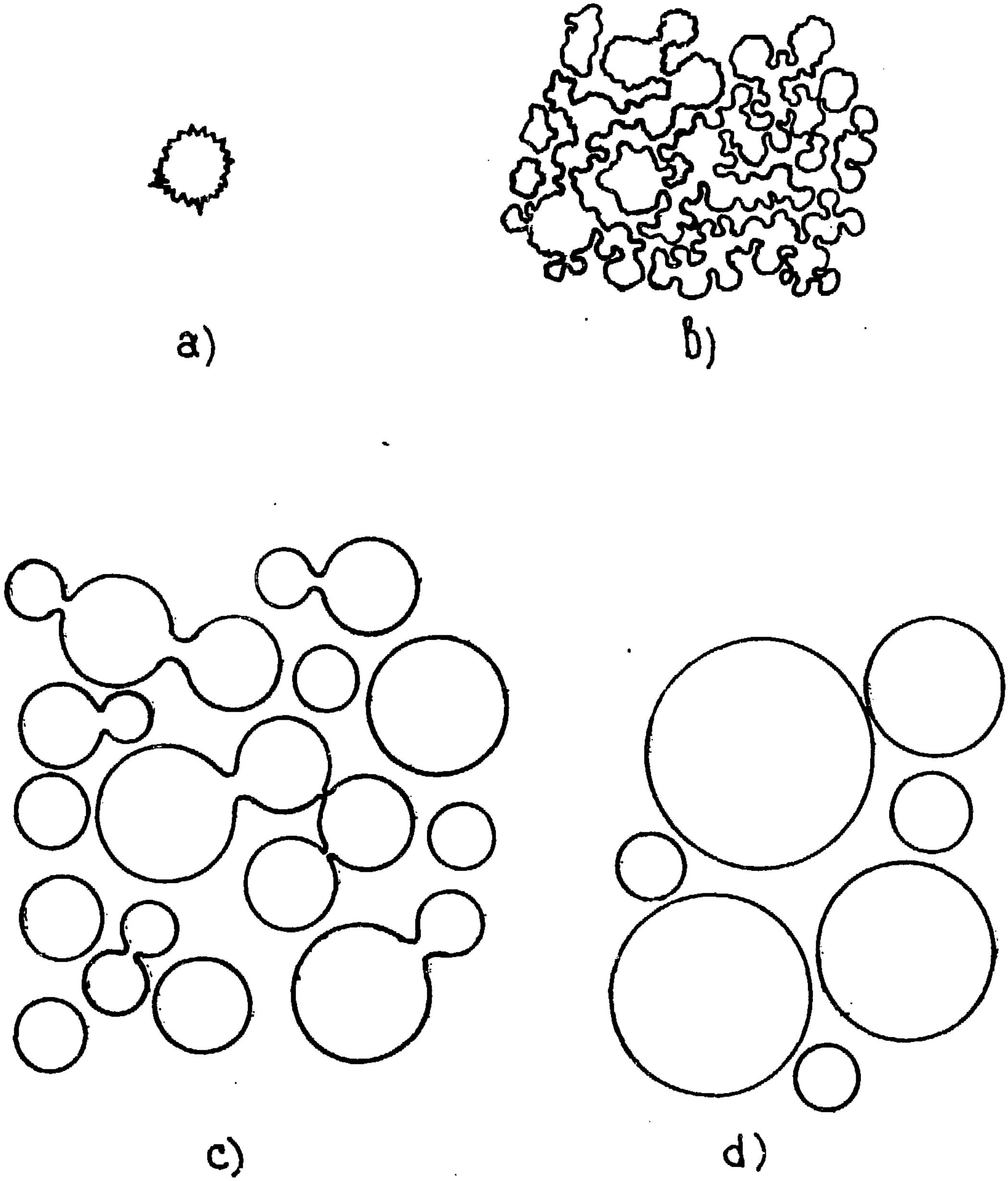

Fig.2.

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