ACTA UNIVERSITATIS CAROLINAE
2000 GEOGRAPHICA, XXXV, SUPPLEMENTUM, PAG. 225–238

Limits of global change of the cosmological environment since the origin of the Earth

JAN KALVODA

Faculty of Science, Charles University in Prague, Czech Republic

ABSTRACT

The aim of the paper is to set limits on changes of the cosmological environment in the epoch from the origin of the solar system to the present within the standard cosmological models. The minimum and the largest possible changes of the main cosmological observational and theoretical cosmological parameters are demonstrated. It is suggested that these limits of global change of physical conditions in the evolving universe are the essential cause of the long-term stable cosmological environment in the last 5 x 10^9 years.

Key words: Earth in the universe, global change, the environment

1. Definition of the topic

The changes and evolution of the natural environment of the Earth are mainly a consequence of physical, chemical and biological processes, respectively interactions of matter and energy on the planet, in the solar system and in the Galaxy. The evolving universe as a whole represents in the same time a global environment of these local events and phenomena. The physical state of this cosmological environment is secularly changing due to evolution of the universe from an extremely hot and dense state in the past to its present-day observed spacetime metric and large-scale structure. There appears a question about how rapidly and to what extent the physical conditions in the universe as a whole have been changing during the periods of the history of the Earth and the solar system – that is during the last $5\text{x}10^9$ years of the up-to-now evolution of the large-scale structure of the universe. The principal aim of the paper is therefore to set limits on changes of the cosmological environment in the epoch from the origin of the solar system and the Earth to the present within the standard cosmological models. For this topic the following were taken into consideration: the knowledge of the age of the universe, galaxies and stars, data about ranges of present-day values of the main cosmological parameters, the Hubble expansion rate H_o, the deceleration parameter q_o and cosmological constant λ, the physical state of matter and radiation in the extremely short period after its origin, and also further observations and theoretical findings about the evolution of the universe as a whole and its local inhomogeneities such as our Earth, solar system and Galaxy.

2. The age of the Earth related to the age of the universe

The radiometric age of our Galaxy was recently estimated at (12 – 18) x 10^9 years (Norris 1994, Chaboyer et al. 1996) and the photometrically best found age of the metal-poor globular cluster M92 at (15.8 ± 2.1) x 10^9 years (Bolte, Hogan 1995). However, Salaris et al. (1997) reconsidered the age determination of three of the oldest globular clusters in our Galaxy (M68, M15 and M92) and concluded that they are only (12 ± 2) x 10^9 years old. According to Peebles et al. (1991, 1994) the oldest stars, quasars and protogalaxies were being formed in the period t = (1 – 2) x 10^9 years where t is the age of the universe. With regard to the age of metal-poor globular clusters in our Galaxy (12 ± 2) x 10^9 years (Salaris et al. 1997, Chaboyer et al. 1998), the lowest age of the universe is estimated within the limits 11 x 10^9 years $\leq t_0 \leq$ 16 x 10^9 years.

Therefore, are at least (13.5 ± 2.5) x 10^9 years between the present stage of the evolution of the universe and the period $t \approx 3 \times 10^5$ years when radiation separated from matter. Galaxies and other structural units of the universe could have been formed after a certain time of its evolution probably by gravitational contraction of primordial inhomogeneities of matter as such they were recently discovered in an isotropic cosmic microwave background radiation. This isotropic cosmical radiation with the present temperature $T_0 = 2.73$ K (Penzias, Wilson 1965, Dicke et al. 1965) which has the radiation spectrum of Planck's black body, is physically identified to the relics of the extremely dense and hot stage of the expanding universe in the past. The present temperature of the relic radiation T_0 approximately corresponds to 5 x 10^8 photons with density of energy of 3.5 x 10^5 eVm^{-3} (Weinberg 1972). The Earth is moving with regard to the relic isotropic cosmic microwave background radiation at a speed of (360 ± 20) km s^{-1} in the direction $\alpha = 11.2$ h and $\delta = -7°$ (Smoot et al. 1992, Partridge 1995).

The solar system originated (4.8–4.9) x 10^9 years ago, including the lighting up of the Sun as a star by nuclear reactions (4.7–4.8) x 10^9 years ago, and the planet Earth was formed (4.5–4.6) x 10^9 years ago (Dambrymple 1991). Conditions for the origin of terrestrical life already existed (3.8–4.2) x 10^9 years ago (Emiliani 1992) when the Earth differentiated into mantle and core, and degassed, so the early ocean and atmosphere originated. A large but declining flux of asteroideal impacts on the young Earth surface ceased about (4.0–3.8) x 10^9 years ago (Chang 1994) and life took firm hold probably in the marine environment. The Issua greenstone belt of southwestern Greenland indicates surface temperatures of the Earth below 100 °C and its lower formation consists of amphibolite with layers of ironstones also containing organic carbon as evidence for life before 3.8 x 10^9 years (Mojzsis et al. 1996). Isotopically light kerogen, found in carbonaceous argillites, siltstones and cherts of the Theespruit formation in the lower part of the Onwerwacht group in the Mpumalanga is the product of chemical activity of Eobionts (3.4–3.7) x 10^9 years ago. The microfossils of procaryotes are filamentous Cyanobacterium in shallow marine sediments of the Warrawona group in northwestern Australia (3.5 x 10^9 years old) as well as Archaeopheroides Eobacterium (3.2 x 10^9 years old) of the Swaziland sequence in Mpumalanga's Fig-Tree formation.

The range of sustainibility of life in palaeogeographical conditions of the very complex environmental systems of the near-surface spheres of the Earth has been very narrow. Life remained almost exclusively unicellular for a full period of 3 x 10^9 years (Bengtson 1994). Bacteria are older than 3.5 x 10^9 years, Eucaryot fauna originated in the period (2.2–1.9) x 10^9 years, but simple multicellular algae only evolved approximately 1.2 x 10^9 years ago and the oldest known metazoan Edicaran fauna is 10^9 years old. A generically very rich evolution of life went on in a noticeably shorter period of the history of the Earth. It is incontestable that chemical elements indispensable or necessary for the origin and evolution of life originated both in the early stages of the universe evolution (H, He, D, Li), and in supernovae (e.g. O, C, N and Fe) or other stars of the local group of galaxies (Davies, Koch 1991, Dunlop 1994) and mainly of our Galaxy.

The flow of cosmic time t in the basic reference cosmological system of the relic isotropic microwave background radiation is very close to the radiometric time measured on the Earth. The progress of radiometric time t_r, which determines the time remoteness of geodynamic events in the Earth's history, is synchronous with the progress of cosmic time t at relativistic and other types of corrections of the order of only 10^{-3} (Kalvoda 1987). Within the framework of standard cosmological models the evolution of the universe as a whole in the period of the existence of the Earth and solar system can thus be characterized by the values of the principal cosmological parameters in the radiometrically measured time

$$t_r = t_0 - t \qquad (1)$$

where t_0 is the present age of the universe and t its age at the time of the origin of the radiometrically dated rocks of the upper part of the Earth's crust, meteorites or other objects in the solar system. Corresponding to every moment of the geological time scale is a certain set of cosmological parameters that characterize the varying global spacetime geometry of the universe.

3. Global changes of cosmological environment

The standard cosmological models incorporate the general relativity theory and the cosmological principle that postulates a large-scale homogeneity and isotropy of the universe (comp. Misner et al. 1973, Bičák 1974 and others). The expansion of the universe is indicated by the relation between the redshift in the spectra of galaxies and quasars and their distances which is expressed by the Hubble expansion rate

$$H = \frac{\dot{a}(t)}{a(t)} \qquad (2)$$

The expansion factor a(t) characterizes the radius of universe curvature and it is determined by the dynamic equations following from the Einstein gravitation law

$$\frac{\dot{a}^2}{a^2}+\frac{kc^2}{a^2}-\frac{\lambda}{3}=\frac{8\pi G\rho}{3} \tag{3}$$

$$\frac{2\ddot{a}}{a}+\frac{\dot{a}^2}{a^2}+\frac{kc^2}{a^2}-\lambda=-\frac{8\pi Gp}{c^2} \tag{4}$$

where c is the speed of light in a vacuum, G is the gravitation constant, l is cosmological constant (in standard models λ = 0), k is the index of curvature (+1, 0, –1) of homogeneity hypersurfaces of the universe, the dots denote derivations with respect to time; pressure p and density of matter and radiation ρ are bound by the equation of state. The law of energy conservation implies for matter density ρ_m and radiation ρ_r

$$\rho_m(t)\sim\frac{1}{a^3(t)} \tag{5}$$

$$\rho_r(t)\sim\frac{1}{a^4(t)}. \tag{6}$$

The change in the rate of universe expansion is determined by the deceleration parameter

$$q=-\frac{\ddot{a}(t)\,a(t)}{\dot{a}^2(t)}\ . \tag{7}$$

In standard cosmological models the characteristic linear dimension of the universe a(t) is the cube root of its volume V(t), the ratio Va^{-3} remaining constant for all t > 0. Therefore, the dynamics of the universe can be expressed by the introduction of the actualistic ratio of its characteristic parameters a(t) in the past and at the present time

$$\delta=\frac{a_t}{a_0}=\frac{1}{1+z}\ , \tag{8}$$

where z is the observational parameter of the cosmological redshift of radiation spectrum from very distant galaxies and quasars.

The values of the actualistic parameter of universe expansion δ as a coefficient of proportionality between global (mean) physical conditions of the universe in the past and of the universe state as observed today were calculated (Kalvoda 1987) in relation to the radiometrically measured time t_r. From the dynamic equations of Einstein's gravitational law (3, 4) in a form appropriate for the era of matter dominance over radiation follows (Weinberg 1972, Peebles 1993 and others)

$$\left(\frac{\dot{a}_t}{a_0}\right)^2=H_0^2\left[1-2q_0+2q_0\left(\frac{a_0}{a_t}\right)\right]. \tag{9}$$

Therefore, the formula for radiometrically measured look-back time in the equation (1) is

$$t_r = H_0^{-1}\left[\int_0^1\left(1-2q_0+\frac{2q_0}{x}\right)^{-\frac{1}{2}}dx - \int_0^\delta\left(1-2q_0+\frac{2q_0}{x}\right)^{-\frac{1}{2}}dx\right]. \qquad (10)$$

There are four variants of the solution of the equation (10) according to the values of the deceleration parameter q_0 which are demonstrated in detail by Kalvoda (1987, 1999). The values of observational cosmological parameters H_0 and q_0 are so far known from astronomical tests only to be within certain limits of observation (Sandage 1972, Peebles 1980, Kennicutt et al. 1995, Ballinger et al. 1996): 30 km s^{-1} Mpc^{-1} $\leq H_0 \leq$ $\leq$ 80 km s^{-1} Mpc^{-1} and $0.1 \leq q_0 \leq 1.0$. The present age of the universe t_0 and the relation of the actualistic parameter of the expansion of the universe δ to the radiometrically measured atomic time t_r are calculated and graphically expressed within these limits of H_o and q_o according to the equation (10) in Table 1 and Fig. 1.

Table 1. The present age of the universe t_0 within the framework of standard cosmological models in relation to the values of observational cosmological parameters H_0 and q_0 (the cosmological constants being $\lambda = 0$) according to the formula $t_0 = H_0^{-1}\int_0^1(1-2q_0+\frac{2q_0}{x})^{-\frac{1}{2}}dx$ in the range near to the limits of observed values of the Hubble expansion rate 30 km s^{-1} Mpc^{-1} $\leq H_0 \leq$ 80 km s^{-1} Mpc^{-1} and the deceleration parameter $0.1 \leq q_0 \leq 1.0$. Values in brackets are excluded by astrophysical determination of the minimum possible age of the universe $t_0 = (13.5 \pm 2.5) \times 10^9$ years.

q_0 H_0 (km s^{-1} Mpc^{-1})	0.1	0.2	0.3	0.4 t_0(10^9 years)	0.5	0.6	0.7	0.8	0.9	1.0
30	27.5	25.3	23.8	22.7	21.7	20.9	20.2	19.6	19.1	18.6
40	20.6	19.0	17.9	17.0	16.3	15.7	15.2	14.7	14.3	13.9
50	16.5	15.2	14.3	13.6	13.0	12.5	12.1	11.8	11.4	11.2
60	13.8	12.7	11.9	11.3	(10.9)	(10.5)	(10.1)	(9.8)	(9.5)	(9.3)
70	11.8	(10.9)	(10.2)	(9.7)	(9.3)	(9.0)	(8.7)	(8.4)	(8.2)	(8.0)
80	(10.3)	(9.5)	(8.9)	(8.5)	(8.1)	(7.8)	(7.6)	(7.4)	(7.2)	(7.0)

Observations also show (Misner et al. 1973, Peebles 1993, Gribbin, Rees 1995, Coles, Ellis 1997) that the present mean density of matter ρ_{mo} and radiation ρ_{ro} in the universe are in orders of 10^{-26} kg m^{-3} and 10^{-30} kg m^{-3} respectively. The values T, ρ_m and ρ_r in different periods of cosmic time t related to their present-day values, represent global changes of physical conditions of the cosmological environment from the early stages of the universe's evolution to the present.

Establishing the course of the curve $\delta(t_r)$ is conditioned by a precision of mutually independent observations of present values of H_o and q_o (Fig. 1). Precise determi-

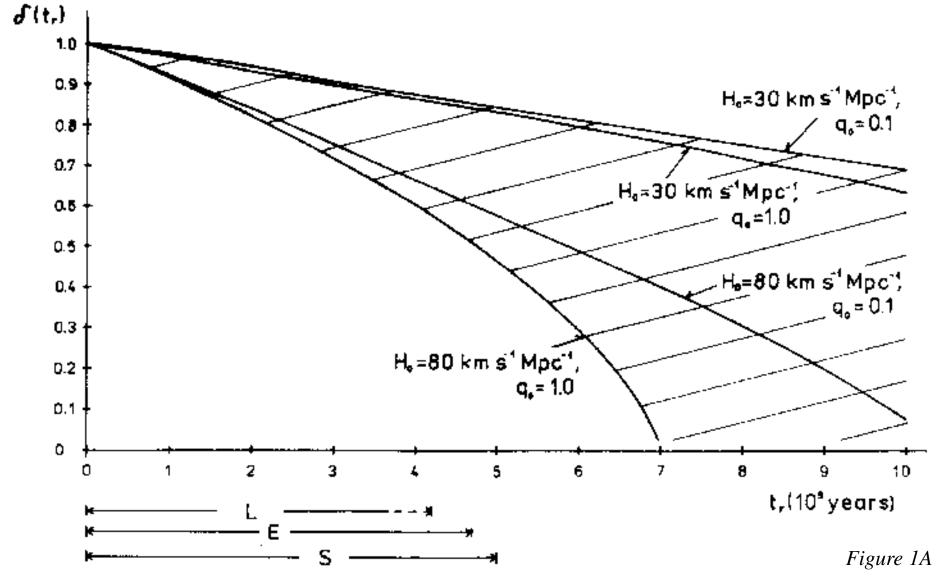

Figure 1A

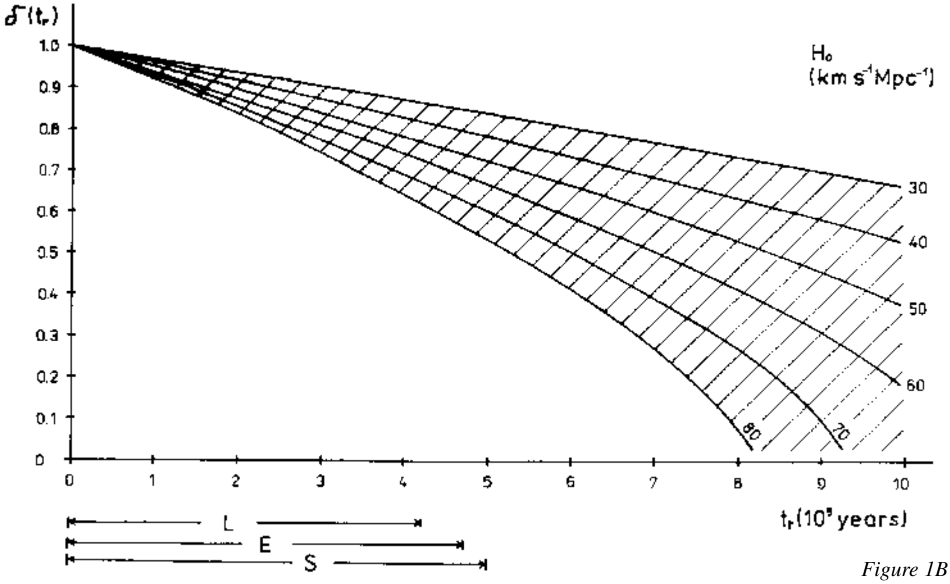

Figure 1B

Figure 1: Set of the values of the actualistic parameter of universe expansion d in radiometrically measured time tr within the framework of standard cosmological models with $\lambda = 0$ and within A) the ranges of observations of H_0 (30 to 80 km s^{-1} Mpc^{-1}) and q_0 (0.1 to 1.0), B) the Einstein – de Sitter model of the universe ($k = 0$, $q_0 = 0.5$, $\lambda = 0$) with H_0 from 30 to 80 km s^{-1} Mpc^{-1}. Figs 1, 2 and 3 are prepared according to the calculations and graphs in the papers of Kalvoda (1987 and 1999).

Key: S – period of the existence of Sun (4.8–5.0 x 10^9 years), E – period of the Earth's geological history (4.7–4.8 x 10^9 years), L – period of life evolution on the Earth (3.8–4.2 x 10^9 years).

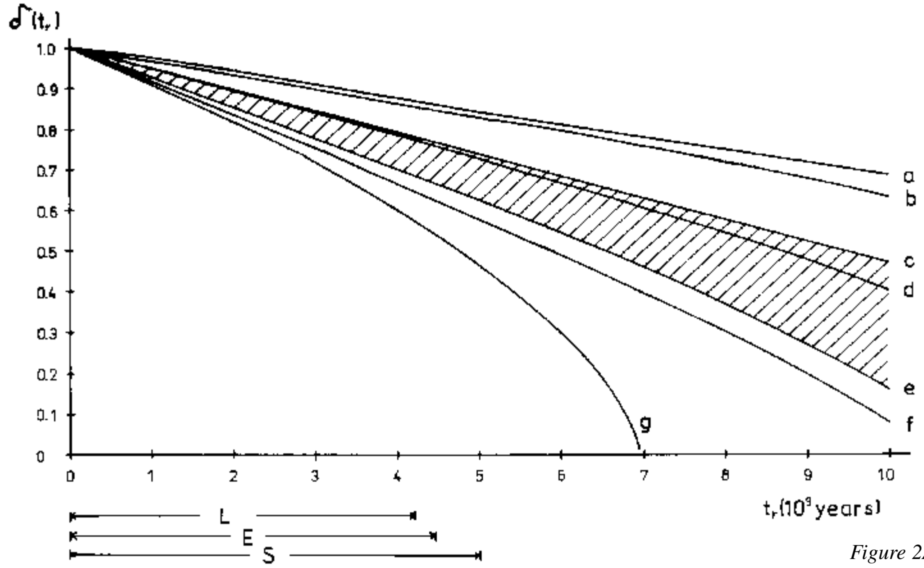

Figure 2A

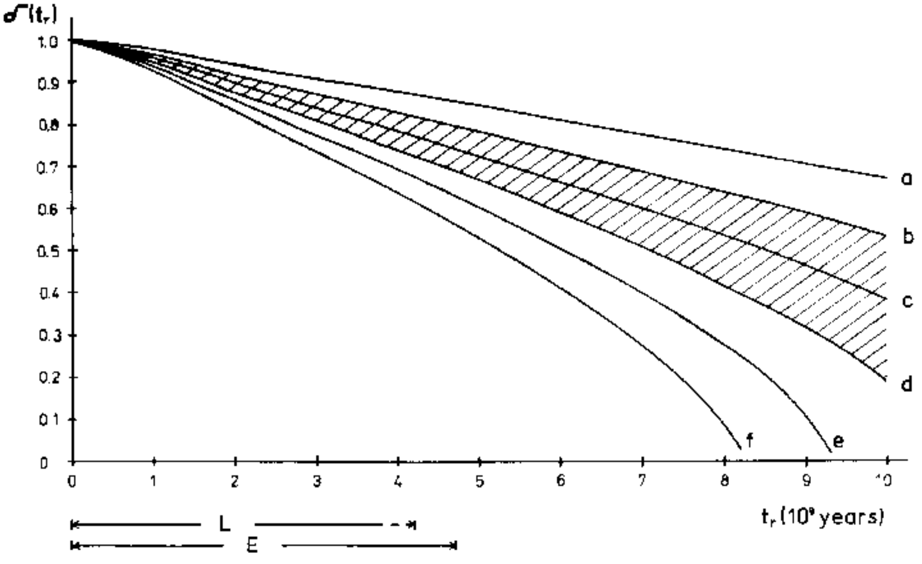

Figure 2B

Figure 2: Determination of the area in which the real curve of the actualistic parameter of the universe's expansion $\delta(t_r)$ at a minimum possible age of the universe $t_0 = (13.5 \pm 2.5) \times 10^9$ years (see hatching) can extend within the framework of A) standard cosmological models with $\lambda = 0$ and B) the Einstein - de Sitter model of the universe ($k = 0$, $q_0 = 0.5$, $\lambda = 0$), in closer ranges of astronomical observations $H_0 = 30 - 80$ km s^{-1} Mpc^{-1} under the conditions $\delta \leq 0.01$ for various given times t_r.
Key to Fig. 2A

Key to Fig. 2A

Indication of curve $\delta(t_r)$	t_0 (10^9 years)	H_0 (km s^{-1} Mpc^{-1})	q_0
a	27.5	30	0.1
b	18.6	30	1.0
c	16.5	50	0.1
d	13.6	50	0.4
e	10.9	70	0.2
f	10.3	80	0.1
g	7.0	80	1.0

Key to Fig. 2B

Indication of curve $\delta(t_r)$	t_0 (10^9 years)	H_0 (km s^{-1} Mpc^{-1})
a	21.7	3
b	16.3	40
c	13.0	50
d	10.9	60
e	9.3	70
f	8.2	80

For other symbols see Fig. 1.

nation of the position and the course of the curve of the actualistic parameter $\delta(t_r)$ as a coefficient of proportionality between physical characteristics of the state of the universe as a whole in the past and at present leads to a more precise establishment of the global changes ofphysical conditions in the evolving universe as a whole in the period when events forming the history of our Galaxy, solar system and Earth were going on. In accordance with astrophysical theories of the evolution of stars and galaxies (see e.g. Peebles 1993, Norris 1994, Coles, Lucchin 1995), it is possible to expect not only a higher energetic activity of the Galaxy in the younger stages of its evolution, including a higher mean frequency of explosions of supernovas (Hippelein et al. 1995, Arnett 1996), but also, as a consequence of the universe's expansion, a higher intensity of radiation from very distant and extremely strong sources. These phenomena of cosmological origin could have influenced, for instance, the secular changes of solar emissions connected with the Sun's evolution, and, therefore, also the geodynamic processes in the history of the Earth. The correlation of the course (for instance of the sheerness) of the curve $\delta(t_r)$ with radiometric dating of the course of events in the history of the Earth and solar system excludes or reduces the factuality of the sequence of combinations H_0 and q_0 also in larger limits of the astronomical observations of them (Kalvoda 1987, 1999), and therefore also the present mean densities of matter ρ_{mo} and radiation ρ_{ro} and the age of the universe t_0.

A consequence of the lower model age of the universe t_0 is a higher range between the global physical conditions in the universe as a whole in the ancient history

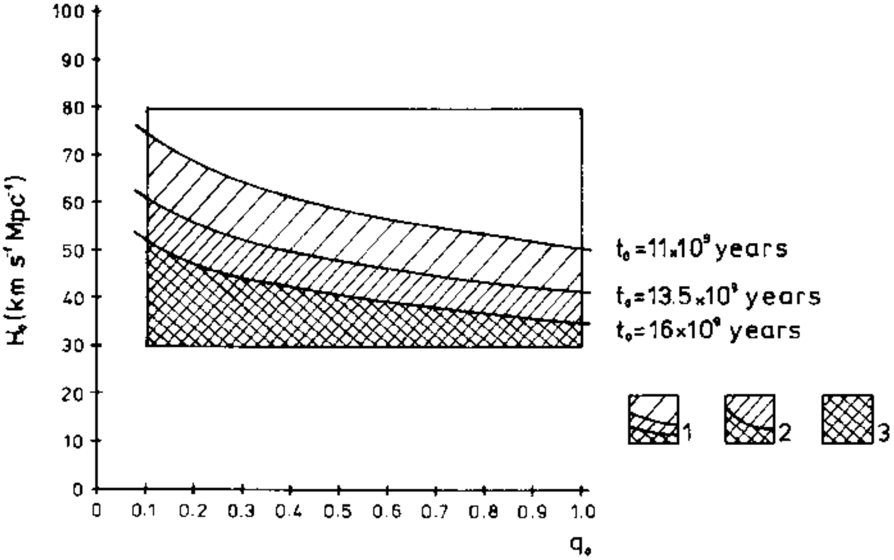

Figure3: The selection and exclusion of various combinations of H_0 and q_0 within the limits of astronomical observations (area of oblong) in standard cosmological models with $\lambda = 0$ by the minimum possible age of the universe in the range 11×10^9 years $\leq t_0 \leq 16 \times 10^9$ years. Possible combinations of H_0 and q_0 for minimum age $t_0 = 11, 13.5$ and 16×10^9 years are shown by (1), (2) and (3) type of hatching.

Table 2: Changes of temperature of the relict isotropic radiation T, of the average density of matter r_m and average density of radiation r_r in the universe in relation to the actualistic parameter of expansion $\delta = \frac{a_t}{a_0} = \frac{1}{1+z}$ (within limits $0.5 \leq \delta \leq 1$, a_t resp. a_0 is the characteristic linear dimension of the universe and z is the cosmological redshift), expressed for $T_0 = 2.73$ K, $\rho_{mo} = 10^{-26}$ kg m^{-3} and $\rho_{ro} = 10^{-30}$ kg m^{-3} and in ratios

$$\frac{T}{T_0}, \frac{\rho_m}{\rho_{m_0}}, \frac{\rho_r}{\rho_{r_0}}$$

δ	T(K)	$\frac{T}{T_0}$	ρ_m(kg m^{-3})	$\frac{\rho_m}{\rho_{m_0}}$	ρ_r(kg m^{-3})	$\frac{\rho_r}{\rho_{r_0}}$
1.00	2.73	1.00	10^{-26}	1.00	10^{-30}	1.00
0.98	2.78	1.02	$1.06\text{x}10^{-26}$	1.06	$1.08\text{x}10^{-30}$	1.08
0.93	2.92	1.07	$1.23\text{x}10^{-26}$	1.23	$1.31\text{x}10^{-30}$	1.31
0.90	3.03	1.11	$1.37\text{x}10^{-26}$	1.37	$1.52\text{x}10^{-30}$	1.52
0.85	3.22	1.18	$1.64\text{x}10^{-26}$	1.64	$1.94\text{x}10^{-30}$	1.94
0.80	3.41	1.25	$1.95\text{x}10^{-26}$	1.95	$2.44\text{x}10^{-30}$	2.44
0.75	3.63	1.33	$2.35\text{x}10^{-26}$	2.35	$5.53\text{x}10^{-30}$	5.53
0.70	3.90	1.43	$2.92\text{x}10^{-26}$	2.92	$4.16\text{x}10^{-30}$	4.16
0.60	4.55	1.67	$4.63\text{x}10^{-26}$	4.63	$7.72\text{x}10^{-30}$	7.72
0.50	5.46	2.00	$8.00\text{x}10^{-26}$	8.00	$1.60\text{x}10^{-29}$	16.00

of the Earth (and solar system or Galaxy) and these conditions at present. If the lowest possible present age of the universe might be only $t_0 = (13.5 \pm 2.5) \times 10^9$ years, the curve of the actualistic parameter of expansion of the universe $\delta(t_r)$ runs within the limits depicted in Fig. 2. These data substantially exclude all variants of standard models of the universe with a cosmological constant $\lambda = 0$, where H_0 is higher then 75 km s^{-1} Mpc^{-1} (Fig. 3) and below this value also those possibilities where the deceleration parameter q_0 has (also within the limits of its observations, see Tab. 1) a too high value.

Within the framework of standard cosmological models with $\lambda = 0$ and with regard to the results of astrophysical determination of present-day values of the Hubble expansion rate H_0 = 30–80 km s^{-1} Mpc^{-1}, the deceleration parameter q_0 = 0.1–1.0 and the minimum possible age of the universe $t_0 = (13.5 \pm 2.5) \times 10^9$ years there is shown the maximum range to which the global metric of spacetime and the physical conditions of the evolving universe in the period from the origin of the Earth and the solar system have changed. For the period $t_r = 5 \times 10^9$ years (Fig. 2A), the limits of the value of the actualistic expansion rate of the universe $\delta(t_r)$ have been calculated to be 0.6–0.8. These maximum limits correspond to 1) a temperature range of isotropic cosmic microwave background radiation T of between 1.25–1.67, 2) a mean density of matter ρ_m in the range 1.95–4.63, 3) a mean density of radiation ρ_r of 2.44–7.72, all of the ranges being multiples of present values. The characteristic dimension of the expanding universe a was maximally 1.25–1.67 times lower and its volume V was 1.95–4.63 times lower than now. Therefore, for $\delta(t_r) = 0.6$ in the period 5×10^9 years ago, the largest possible values of T, ρ_m and ρ_r (Table 2) were 4.55 K, 4.63×10^{-26} kg m^{-3} and 7.72×10^{-30} kg m^{-3}.

The smallest possible changes of physical conditions in the universe as a whole can be derived within the standard cosmological model with $\lambda = 0$ for the combination of the lowest values of cosmological parameters in the limits of independent observations $q_0 = 0.1$ and H_0 = 30 km s^{-1} Mpc^{-1}, when $t_0 = 27.5 \times 10^9$ years. For the period $t_r = 5 \times 10^9$ years, the actualistic parameter of the universe expansion is then $\delta(t_r) = 0.85$, which corresponds to the values T = 3.22 K, $\rho_m = 1.7 \times 10^{-26}$ kg m^{-3} and $\rho_r = 1.95 \times 10^{-30}$ kg m^{-3}, that is respectively, 1.18, 1.63 and 1.92 times more than at present. However, $t_r = 5 \times 10^9$ years ago, the characteristic dimension of the expanding universe a was maximally 1.18 times smaller and its volume V then 1.63 times smaller than at present.

The general scenario of cosmological evolution is usually tested in the framework of the Einstein - de Sitter model ($k = 0$, $\lambda = 0$) with a $q_0 = 0.5$ expansion and $to = \frac{2}{3} H_0^{-1}$.

Moreover, the equation (10) has in this type of standard model very simple solutions

$$t_r = \frac{2}{3} H_0^{-1} (1 - \delta^{\frac{3}{2}}) \tag{11}$$

$$\delta = (1 - \frac{3}{2} H_0 t_r)^{\frac{2}{3}} \cdot \tag{12}$$

The Einstein - de Sitter model seeded from the earlier inflation stage of the universe (10^{-43} sec ≤ t ≤ 10^{-32} sec) with primordial fluctuations recently detected (Smoot, Davidson 1993, Bernardis et al. 1994) in the scale-invariant spectrum of the cosmic microwave background radiation with the present-day temperature $T_0 = 2.73$ K. After the inflation stage of exponential expansion (Guth 1981, Linde 1995) the universe is expanding at precisely the velocity to sustain that expansion indefinitely with the deceleration parameter $q_0 = 0.5$.

The astrophysical extent of determination of the minimal age of universe $t_0 = = (13.5 \pm 2.5) \times 10^9$ years corresponds in the Einstein – de Sitter model to the maximal present value of the Hubble expansion rate in limits 40 km s^{-1} $Mpc^{-1} < H_0 <$ 60 km s^{-1} Mpc^{-1}. It applies for $t_r = 5 \times 10^9$ years, that

δ(tr)	t_o(years)	H_o (km s^{-1} Mpc^{-1})	T(K)	ρ_m (kg m^{-3})	ρ_r (kg m^{-3})
0.67	11.00×10^9	59.50	4.08	3.32×10^{-26}	4.96×10^{-30}
0.75	13.50×10^9	48.50	3.64	2.37×10^{-26}	3.16×10^{-30}
0.79	16.00×10^9	41.00	3.46	2.03×10^{-26}	2.57×10^{-30}

According to the Einstein – de Sitter model, the maximum limits of the value of the actualistic expansion rate of the universe δ for $t_r = 5 \times 10^9$ years (Fig. 2B) have been calculated to be 0.67–0.79. These limits correspond to a range of T 1.27–1.50, ρ_m 2.03–3.32, ρ_r 2.57–4.96 times higher, and a 1.27–1.50, V 2.03–3.32 times lower than at present.

For $t_r = 10^9$ years, which is approximately the period of the evolution of multicellular life, limits of $\delta(t_r)$ in standard cosmological models with all the above stated parameters (comp. Fig. 2) are 0.98 for the minimum and 0.93 for the largest global change of physical conditions in an expanding universe. These values correspond (Table 2) to a range of T 1.01–1.07, ρ_m 1.06–1.23, ρ_r 1.08–1.31 times higher, and a 1.02–1.07, V 1.06–1.23 times lower than at present.

4. Conclusions

Radiometric dating of 1) rocks and the evolution of life on the surface of our planet, 2) the age of the Earth and the solar system, and 3) the oldest globular clusters in Galaxy, and the minimum possible age of the universe $t_0 = (13.5 \pm 2.5) \times 10^9$ years based on nucleocosmochemistry and the large-redshift astrophysics, exclude in standard cosmological models with $\lambda = 0$ many combinations of H_0 and q_0 within closer limits of their independent observations (Fig. 3). That is one of the reasons why in cosmology open models, in particular, of the universe with both $0.1 \leq q_0 \leq 0.5$ and acceptable non-zero values of the cosmological constant λ are intensively explored and tested (Weinberger 1989, Kraus, Turner 1995). However, in the cosmological models with $\lambda \neq 0$ the calculated ages of the universe and also values of δ related to time t_r, are in general higher than in models with $\lambda = 0$. Therefore, the value of $\delta = 0.85$ for $t_r = 5 \times 10^9$ years in the above described standard cosmological models is a suitable example of the possible minimum global change of physical conditions in the universe as a whole (Table 2). The value of $\delta = 0.6$ indicates probably the largest possible changes of the cosmological environment during the last 5×10^9 years (Fig. 2) and represents that 1) the characteristic dimension of the expanding universe a and its volume V were maximally 1.67 and 4.63 times lower than now; 2) a temperature of isotropic cosmic microwave background radiation T, a mean density of matter ρ_m and a mean density of radiation ρ_r were maximally 1.67, 4.63 and 7.72 times higher than now. These limits of global change of physical conditions in the evolving universe are the essential cause of the long-term relatively stable cosmological environment in the epoch from the origin of the solar system and the Earth to the present.

Acknowledgments

The work was carried out under the auspices of the Research Centre for Earth Dynamics, the Czech Republic.

References

ARNETT D. (1996): Supernovae and Nucleosynthesis. – Princeton Series in Astrophysics (Princeton University Press), 598 p., Princeton, New Jersey.

BALLINGER W. E., PEACOCK J. A., HEAVENS A. F. (1996): Measuring the Hubble constant with redshift surveys. – Mon. Not. R. Astron. Soc., 282, 877–888, Oxford, London.

BENGTSON S. (1994, ed.): Early Life on Earth. – Nobel Symposium (84th: 1982, Karlshoga, Sweden), Columbia University Press, 630 p., New York, Chichester.

BERNARDIES P. DE, MAOLI R., MASI S., MELCHIORRI B., MELCHIORRI F., SIGNORE M., TOSTI D. (1994): Microwave Background Anisotropies: Future Plans. – In: J. L. Sanz, E. Martínez-Gonzáles, L. Cayón (eds.): Present and Future of the Cosmic Microwave Background. (Springer Verlag), Lect. Not. Phys., 429, 233 p., 188–207, Berlin, Heidelberg, New York.

BIČÁK J. (1974): Struktura a vývoj vesmíru. – Českosl. Čas. Fyz. A, 24, 5, 425–445, Praha.

BOLTE M., HOGAN C. J. (1995): Conflict over the age of the Universe. – Nature, 376, 6540, 399–402, London.

CHABOYER B., DEMARQUE P., KERNAN P. J., KRAUS L. M. (1996): A lower limit on the age of the Universe. – Science, 271, 5251, 957–61, Washington.

CHABOYER B., DEMARQUE P., KERNAN P. J., KRAUS L. M. (1998): The age of globular clusters in light of Hipparchos: restoring the age problem? – Astroph. J., 494, 96–110, Chicago.

CHANG S. (1994): The planetary setting of prebiotic evolution. – In S. Bengtson (ed.): Early Life on Earth. Nobel Symposium (84th: 1982, Karlshoga, Sweden), Columbia University Press, 630 p., 10–23, New York, Chichester.

COLES P., LUCCHIN F. (1995): Cosmology: the origin and evolution of cosmic structure. – John Wiley and Sons, Chichester, 449 p., New York.

COLES P., ELLIS G. F. R. (1997): Is the Universe Open or Closed? The Density of Matter in the Universe. – Cambridge Lecture Notes in Physics, 7, 236 p., Cambridge University Press, Cambridge.

DABRYMPLE G. B. (1991): The age of the Earth. – Stanford University Press, 474 p., Stanford (California).

DAVIES R. E., KOCH R. H. (1991): All the observed universe has contributed to life. – Phil. Trans. R. Soc. London, B, Biol. Sci., 334, 391–404, London.

DICKE R. H., PEEBLES P. J. E., ROLL P. G., WILKINSON D. T. (1965): Cosmic-blackbody radiation. – Astroph. J., 142, 414–419, Chicago.

DUNLOP J. S. (1994): The cosmological evolution of active Galaxies. – In: W. Wamsteker, M. S. Longair, Y. Kondo (1994): Frontiers of space and ground-based astronomy. – Astrophysics and Space Science Library (Kluwer Acad. Publ.), 87, 395–407, 705 p., Dordrecht, Boston, London.

EMILIANI C. (1992): Planet Earth: cosmology, geology, and the evolution of life and environment. – Cambridge University Press, 718 p., Cambridge.

GRIBBIN J., REES M. J. (1995): The stuff of the Universe: dark matter, mankind and anthropic cosmology. – Penguin, 302 p., London.

GUTH A. H. (1981): Inflationary Universe: A possible solution to the horizon and flatness problems. – Phys. Rev., D23, 2, 347–356, New York.

HIPPELEIN H., MEISENHEIMER K., RÖSER H. J. (1995, eds.): Galaxies in the young universe: proceeding of a workshop held at Ringberg Castle, Tegernsee, Germany, 22–28 September 1994. – Lect. Not. Phys., 463, 314 p., Berlin, London.

KALVODA J. (1987): The dynamic of the Universe evolution in the epoch of Earth's history. – Čas. Mineral. Geol. 32, 1, 87–103, Praha.

KALVODA J. (1999): The dynamics of the universe evolution since the origin of the Earth – Universitatis Ostraviensis Acta Facultatis Rerum Naturalium, Geographia – Geologia, 7, 7–28, Ostrava.

KENNICUTT R. C. J. R., FREEDMAN W. L., MOULD J. R. (1995): Measuring the Hubble constant with the Hubble space telescope. – Astron. J., 110, 4, 1476–1491, New York.

KRAUS L. M., TURNER M. S. (1995): The cosmological constant is back. – General Relativity and Gravitation, 27, 11, 1137–1144, London, New York.

LINDE A. (1995): Lectures on inflationary cosmology. – In: N. Sanchéz, A. Zichichi (eds.): Current Topics in Astrofundamental Physics: The Early Universe, Kluwer Acad. Publ., 465 p., 39–97, Dordrecht, Boston, London.

MISNER CH. W., THORNE K. S., WHEELER J. A. (1973): Gravitation. – 1279 p., San Francisco.

MOJZSIS S. J., ARRHENIUS G., MC KEEGAN K. D., HARRISON T. M., NUTMAN A. P., FRIEND C. R. L. (1996): Evidence for life on earth before 3,800 million years ago. – Nature, 384, 6604, 55–59, London.

NORRIS J. E. (1994): The Age Structure of the Older Parts of the Galaxy. – In: L. Blitz, P. Teuben (eds.): Unsolved problems of the Milky Way. International Astronomical Union, Proc. 169th Symp., Kluwer Acad. Publ., 725 p., 353–366, Dordrecht, Boston, London.

PARTRIDGE R. B. (1995): 3K: the cosmic microwave background radiation. – Cambridge Astrophysics Series, 25, Cambridge University Press, 373 p., Cambridge.

PEEBLES P. J. E. (1980): The Large-Scale Structure of the Universe. – Princeton University Press, 422 p., Princeton.

PEEBLES P. .J. E. (1993): Principles of physical cosmology. – Princeton University Press, 718 p., Princeton.

PEEBLES P. J. E., SCHRAMM D. N., TURNER E. L., KRON R. G. (1991): The case for the relativistic hot Big Bang cosmology. – Nature, 352, 6338, 769–776, London.

PEEBLES P. J. E., SCHRAMM D. N., TURNER E. L., KRON R. G. (1994): The evolution of the Universe. – Scient. Amer., 271, 4, 29–33, New York.

PENZIAS A. A., WILSON R. W. (1965): A measurement of excess antenna temperature at 4080 Mc/s. – Astroph. J., 142, 419–421, Chicago.

SALARIS M., DEGL'INNOCENTI S., WEISS A. (1997): The age of the oldest globular clusters. – Astroph. J., 479, 665–672, Chicago.

SANDAGE A. (1972): The redshift-distance relation, II. The Hubble diagram and its scatter for first-ranked cluster galaxies a formal value for q_0. – Astroph. J., 178, 1–24, Chicago.

SMOOT G. F. ET AL. (1992): Structure in the COBE Differential Microwave Radiometer First Year Maps. – Astroph. J. 396, L1–L5, Chicago.

SMOOT G., DAVIDSON K. (1993): Wrinkles in time. – Little Brown and Company, 311 p., London.

WEINBERG S. (1972): Gravitation and cosmology. – 657 p., New York, London, Sydney, Toronto.

WEINBERG S. (1989): The cosmological constant problem. – Rev. Mod. Phys., 61, 1, 1–23, New York.

LIMITY GLOBÁLNÍCH ZMĚN KOSMOLOGICKÉHO PROSTŘEDÍ OD VZNIKU ZEMĚ

Résumé

Změny a vývoj přírodního prostředí Země jsou důsledkem zejména fyzikálních, chemických a biologických procesů resp. interakcí hmoty a energie ve sluneční soustavě a Galaxii. Vyvíjející se vesmír jako celek je zároveň sekulárně se měnícím globálním prostředím těchto lokálních událostí a jevů. V práci jsou vypočteny observační a teoretické limity změn kosmologického prostředí v epoše od vzniku Země do současnosti v rámci standardních kosmologických modelů.

Radiometrické datování 1) hornin a vývoje života na povrchu naší planety, 2) stáří Země a sluneční soustavy, 3) nejstarších kulových hvězdokup v Galaxii a nejnižšího možného stáří vesmíru $t_0 = (13{,}5 \pm 2{,}5) \times 10^9$ let vylučují ve standardních kosmologických modelech s $\lambda = 0$ mnoho kombinací H_0 a q_0 v užších mezích jejich nezávislých pozorování (obr. 3). To je jedním z důvodů, proč jsou v kosmologii zkoumány a testovány zvláště otevřené modely vesmíru, a to jak s $0{,}1 \le g_0 \le 0,\ 5$, tak s přijatelnou nenulovou hodnotou λ. Vypočtená stáří vesmíru t a také hodnoty aktualistického parametru expanze vesmíru δ v radiometricky měřeném čase t_r jsou v kosmologických modelech s $\lambda \neq 0$ obecně vyšší než v modelech s $\lambda = 0$. Proto je hodnota $\delta = 0{,}85$ pro $t_r = 5 \times 10^9$ let ve standardních kosmologických modelech uspokojivým příkladem minimálních globálních změn fyzikálních podmínek ve vesmíru jako celku (tab. 2). Hodnota $\delta = 0{,}6$ indikuje pravděpodobně největší možné změny kosmologického prostředí v posledních 5×10^9 letech (obr. 2) a ukazuje, že 1) charakteristický rozměr expandujícího vesmíru a jeho objem byly maximálně 1,67, resp. 4,63krát menší než nyní, 2) teplota reliktového isotropního kosmického mikrovlnného záření, průměrná hustota hmoty a průměrná hustota energie ve vesmíru byly maximálně 1,67, 4,63 a 7,72krát vyšší než v současné době. Tyto limity globálních změn fyzikálních podmínek ve vyvíjejícím se vesmíru jsou podstatnou příčinou sekulárně poměrně stabilního kosmologického prostředí v epoše od vzniku sluneční soustavy a Země do současnosti.