IDENTIFICATION ATTEMPT OF THE MAIN STAGES OF HUMAN BEING GROWTH AND OF UNIVERSE EVOLUTION

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În ciuda cunoştinţelor şi datelor experimentale existente foarte limitate privind creşterea organismului uman (îndeosebi referitoare la fazele pre-natale), respectiv evoluţia Universului, lucrarea de faţă încearcă să identifice principalele etape ale creşterii organismului uman, respectiv expansiunea Universului. În acest scop, sunt utilizate unele "unelte" oferite de teoria fizică a Complexităţii, spre exemplu cele privind Clasele de Universalitate şi sunt admise unele ipoteze privind: a) comportarea asemănătoare a sistemelor complexe de diferite naturi, b) valabilitatea legilor de tip putere, etc. Rolul deosebit de important al fazelor de inflaţie este evidenţiat, iar modelele rezultate privind etapele de bază ale creşterii organismului uman, respectiv evoluţiei Universului, sunt prezentate în detaliu.

Despite the very limited knowledge and existing data about the human body growth and the Universe evolution, we try to identify the basic stages of human body growth and Universe expansion. For this purpose we use some tools offered by the physical theory of Complexity, such as e.g. the Universality classes, and we assume some hypotheses referring to the: a) similar behavior of complex systems of different nature, b) validity of power laws, etc. The outstanding role of the inflation growth is pointed out, and the result conjectures about the basic stages of human body growth and Universe evolution are reported.

Key words: Similitude models, Growth processes, Universality Classes, Human growth, Universe evolution, Complexity theory, Power laws, Inflation stages.

1. Introduction

The basic features of the human body growth between the teenager years and maturity were presented in [1], [2]. Their results were extended for the growth stages beginning from childhood to maturity in [3] and for aging stages in [4]. The

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purpose of the current work is to study the basic stages of the human body growth from its embryo and fetus stages up to maturity.

Given the complexity of the human body, it seems that this task is not still solved. An additional difficulty refers to the fact that the present biological studies do not indicate the confidence domains (or intervals, at least), even if they refer to some observed biological oscillations [5].

Taking into account these difficulties, it is necessary to identify and use the most efficient existing tools to achieve the desired identification.

The accomplished study pointed out that these tools are: a) the universality features, which accompany always the complexity, b) the comparison of the basic features of the different growth patterns for a proper choice of the representation space.

2. Classical Similitude Models of the Growth Processes

The modeling (starting from the experimental results) of the physical processes was examined in detail in the specialty literature [6], [7]. The analysis of the main types of present physical models points out to the presence of the following basic stages: a) the identification of the uniqueness parameters of the studied state (process), b) the identification of the characteristic similitude criteria [7], c) the finding of the set of irreducible similitude, d) the expression of all relations of interest for applications or scientific descriptions in terms of some similitude criteria, e) the test of the theoretical and experimental similitude models, f) the test of compatibility of the similitude models relative to the experimental results [8].

2.1. The general similitude growth equation

Starting from the differential equation of the growth (accommodation) of an arbitrary physical parameter Y(t):

$$\frac{dY}{dt} = \pi(t) \cdot Y(t), \quad \text{where:} \quad [\pi(t)] = \frac{1}{T} \tag{1}$$

(where the symbol [ ] stands for the physical dimension), one obtains the similitude growth equation:

$$\frac{dy}{d\tau} = p(\tau) \cdot y(\tau). \tag{2}$$

in terms of similitude criteria (functions):

$$\tau = \pi(0) \cdot t, \quad y(t) = \frac{Y(t)}{Y(0)}, \quad p(t) = \frac{\pi(t)}{\pi(0)}. \tag{3}$$

2.2 Auto-catalytic growth processes (Universality class U0)

Many results concerning the basic features of the growth processes in Physics [9], Biology [10] and even Cosmology [11] confirm the presence and relevance of auto-catalytic (exponential or Malthusian) growth processes. *The auto-catalytic growth equation* can be obtained from equations (2)-(4), for:

$$\pi(t) = const. = \frac{1}{\tau_{ac}} \ , \tag{4}$$

where τ_{ac} is a time constant: $y(t) = \exp(t/\tau_{ac}) \equiv \exp(\tau)$. (5)

From relations (3) and (5), one finds that in this case: $p(\tau) = 1$, hence: $\Phi(p) = -dp/dt = 0$, i.e. the auto-catalytic growth processes belong to the universality class U0 ($\Phi(p)$ does not depend on p).

2.3 The Gompertz's model (Universality class U1)

Assuming that: $\Phi(p) = -dp/dt = p$ (corresponding to the universality class U1), one obtains:

$$p(t) = e^{-\tau} \text{ and: } \ln y = -\exp(-\tau) + C \text{, hence: } y = \exp[C - \exp(-\tau)]. \tag{6}$$

From the condition: $y(0) = 1$, it results the similitude expression of the growth equation, according to Gompertz's model:

$$y = \exp[1 - \exp(-\tau)] \ . \tag{7}$$

The Gompertz's model [1a] is valid for some tumor growth processes [1b - e], [12], [13] as well as for the descriptions of some economical phenomena [14], population dynamics [15], etc.

2.4. Generalized West's model (Universality class U2)

The similitude expression of the generalized West's model [2], [3]:

$$y = [1 + b - b \cdot \exp(-\tau)]^{1/b}, \tag{8}$$

generalizes Eq. (8), because it leads to the similitude expression of the Gompertz's growth for $b \to 0$. Obviously, the growth rate is given in this case by the non-linear expression:

$$\frac{dy}{d\tau} = \frac{1+b}{b} \cdot y^{1-b} - \frac{1}{b} \cdot y \ . \tag{9}$$

We will point out also that the generalised West's model: (i) describes the growth processes of the living beings, in the range protozoa – plants – mammals, by means of the similitude equation (9), (ii) can be used for the tumours growth description, with values of the parameter p depending on the fractal nature of the biological channels (e.g. in angio-genesis) [13].

2.5 Proposed representation space of the growth processes

Starting from the typical similitude parameter y defined by relation (3), we propose the use of representations in the "phases space": $z = ln y$ and $\dot{z}$, because then: (i) the equation of the auto-catalytic (exponential) growth corresponds to a horizontal straight-line segment:

$$\dot{z} = s \text{ (constant)}, \quad \text{and:} \quad z = ln y = m + s.t\,, \tag{10}$$

(ii) the equation of the U1 (Gompertz) growth is (see also [3]):

$$\dot{z} = a_o + \alpha_1 (z - z_o), \text{ where: } a_o = \dot{z}_o\,,\ \alpha_1 < 0\,,\ z_o = \ln y_o\,, \tag{11}$$

(iii) the equation of the U2 (generalized West's type) growth is [3]:

$$\dot{z} = \left(1 + \frac{\beta}{\gamma \cdot a_o}\right) \cdot e^{\gamma z} - \frac{\beta}{\gamma}\ . \tag{12}$$

One finds [16] that the above indicated Universality classes are present in the description of many processes of physics, chemistry, biology or even sociological sciences, but since all plots of these Universality classes have negative (or null) slopes (in the phases space $\dot{z}, z$), while some stages of the human embryo growth present an evident positive slope (see Fig. 1), it follows that it is necessary to complete them with some stages specific to the growth initial stages.

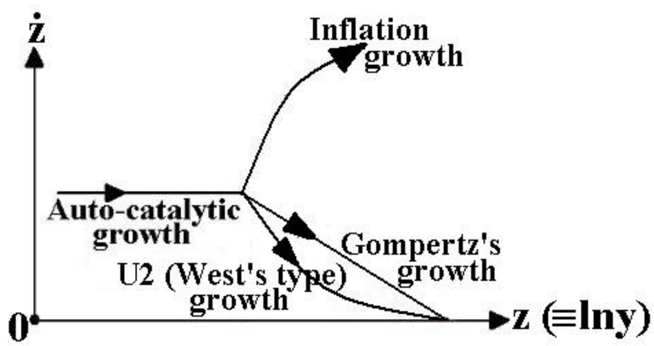

Fig. 1. Typical plots of the main types of growth stages

Taking into account that the Universality of the complex systems corresponds to similar evolutions, the analysis of the present theoretical models of the Universe evolution could be useful to complete the knowledge about the growth stages.

3. Brief Analysis of the Basic Versions of the Standard Model of Cosmology

The existing experimental data referring to the Universe evolution (expansion) were synthesized by some theoretical studies, the Guth - Linde model (see [17], [18]) of the inflationary Universe, following its Big Bang appearance, and are presently accepted even by some academic textbooks [19]. Thus is we present in Fig. 2 the basic features of the Universe evolution accordingly to it.

Taking into account the very large values of the inflation factor (up to $10^{10^{12}}$ times) for the Linde's version [18d] of the Standard Model of Cosmology (SMC), a $\log[\log(R/R_P)] = f(\log t)$ plot is necessary to represent the Linde's model [see Fig. 3, where $R_P\ (\cong 1.6 \cdot 10^{-35} m)$ is the Planck's radius, corresponding to the inflation beginning at the Planck's time $t_P\ (\cong 0.533 \cdot 10^{-43} s)$].

The zero-order approximation of the inflation stage description in this plot is the linear one:

$$\ln[\ln(R/R_P)] = m \cdot \ln\left(\frac{1}{\tau}(t - t_P)\right), \qquad (13)$$

where τ is the characteristic time of the Universe inflation, probably equal to the Planck's duration t_P, at least for the Linde's version of SMC.

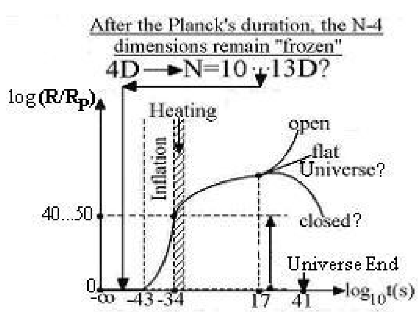

Fig. 2. The Guth version [17] of the Standard Model of Cosmology (SMC)

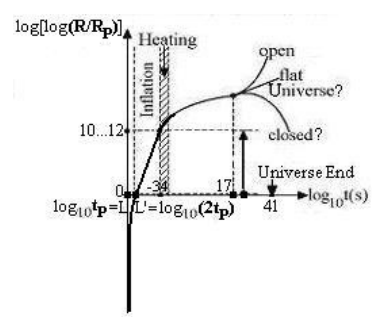

Fig. 3. Linear approximation of inflation stage of the Linde's version [18d] of SMC

From relation (13), one obtains:

$$z = \ln(R(t)/R_P) = \left[\frac{1}{\tau}(t - t_P)\right]^m, \text{ and: } R(t)/R_P = \exp\left[\frac{1}{\tau}(t - t_P)\right]^m, \qquad (13')$$

where $m = 1$ for the classical exponential (auto-catalytic) inflation [19a].

For the Universe age $t_{ie}\ (\sim 10^{-34} s)$ and radius R_{ie} corresponding to the inflation end, one finds:

$$\ln[\ln(R_{ie}/R_P)] = m \cdot \ln[(t_{ie} - t_P)/\tau] \; . \qquad (13")$$

The values of the inflation exponent *m* corresponding to the Linde's version of SMC (for $\tau = t_P$) and those of the characteristic time τ for the Guth's exponential inflation stage are synthesized by Table 1.

Table 1

Main numerical results concerning the parameters of equation (13"), describing the inflation stage of the Universe evolution

Inflation model	Inflation factor	$\ln\left(\frac{R_{ie}}{R_P}\right)$	$\tau\ (s)$	Exponent *m* of power law from rel. (16a)
Classical Guth's model	10^{40} [17]	92.103	10.854×10^{-38}	1 (auto-catalytic growth)
	10^{50} [19a]	115.13	8.686×10^{-38}	1 (auto-catalytic growth)
Chaotic inflation Linde's model	$10^{10^{12}}$ [18d]	2.3×10^{12}	$t_P = 0.533 \times 10^{-43}$	1.494
	$10^{10^{10}}$ [20b]	2.3×10^{10}	$t_P = 0.533 \times 10^{-43}$	1.252

One finds that the values of the inflation exponent *m* corresponding to the Linde's model are larger than 1. In this case, one obtains from relation (13'): $\dot{z} = \frac{m}{\tau} \cdot z^{(m-1)/m} = C \cdot z^n$, where: $n = \frac{m-1}{m} \in (0, 1)$ and: $C = \frac{m}{\tau} > 0$.

Finally, we mention some reasons to prefer the results referring to the Linde's inflation model: a) it leads to a power law (specific to the complex systems), b) the Linde's inflation characteristic time seems to coincide with the well-known parameter of the Universe beginning stage – the Planck duration, c) the inflation characteristic times corresponding to the Guth's model are not related to other known parameters of the Universe evolution.

4. Typical Plots of the Universal Types of Growth Stages

One finds so that the shape (in the phases space $\dot{z}, z$) of the: (i) *auto-catalytic growth* is that of a "horizontal" straight-line segment, (ii) *Gompertz growth* (U1) is that of a descending (of negative slope) straight- line segment, (iii) *generalized West's growth* (U2) is that of a relaxing (because $\gamma < 0$ [3]) exponential [see also Fig. 1]. Taking into account that the studied experimental data concerning the human growth (in its embryo and child phases, especially [21]-[23], see below) indicate the existence of some growth stages with positive slopes of the $\dot{z} = f(z)$ plots, we will name these stages as **phases of inflation growth** (Fig. 1).

We have to underline finally that the accomplished analysis has: a) identified only 4 universal types of growth stages, b) found that the basic features of the $\dot{z} = f(z)$ plots of these growth stages are absolutely distinct, their identification being possible even in the absence of experimental confidence domains (see Table 2).

Because:

$$\dot{z} = \frac{d}{dt}(\ln p) = \frac{\dot{p}}{p} \text{ , and: } \frac{d\dot{z}}{dz} = p \cdot \frac{d}{dp}\left(\frac{\dot{p}}{p}\right) = \frac{p}{\dot{p}} \cdot \frac{d}{dt}\left(\frac{\dot{p}}{p}\right) = \frac{\ddot{p}}{\dot{p}} - \frac{\dot{p}}{p} \text{ ,} \tag{15}$$

one finds that the inflation stages ($d\dot{z}/dz > 0$) and even the U0 Universality class (auto-catalytic growth) stages ($\dot{z} = const.$) correspond to very strong growth accelerations: $\ddot{p} > \dot{p}^2/p$ and: $\ddot{p} = \dot{p}^2/p$, respectively, produced by some specific (chemical, nuclear, etc) reactions, after the germination phase and in adolescence, especially. Of course, these growth stages correspond to some power laws similar to relation (13'):

$$p(t) = p_0 \exp\left(\frac{t}{\tau}\right)^m \text{ ,} \tag{16}$$

hence to: $$\ddot{p} \cdot p = \dot{p}^2 + \frac{m(m-1)}{\tau^m} \cdot t^{m-2} \cdot p \geq \dot{p}^2 \text{ , for: } m \geq 1 . \tag{16'}$$

One finds so that for the inflation stage, the growth acceleration $\ddot{p}$ increases faster than exponentially.

Table 2

Basic features of the $\dot{z} = f(z)$ plots of the universal types of growth stages

Type of the growth stage	Signs of the plot		Criterion of the compatibility acceptance
	slope	curvature	
U0 Universality class (auto-catalytic growth)	0	0	Oscillations of the $\dot{z} = f(z)$ representative points (RP) around the average of the $\dot{z}$ values
U1 Universality class (Gompertz's type)	< 0	0	Oscillations of the $\dot{z} = f(z)$ representative points (RP) around a descending straight-line
U2 Universality class (West's type)	< 0	> 0	Permanent negative slopes and monotonically decreasing values of the slope modulus for the pairs of successive $\dot{z} = f(z)$ repr. points
Inflation	> 0	< 0	Permanent positive slopes and monotonically decreasing values of the slope for the pairs of succes-sive $\dot{z} = f(z)$ representative points

5. Analysis of some Existing Results for Different Growth Processes

5.1 Basic stages of human growth

a) *Embryo Growth*

The average values (indicated by references [21a-c]) of the human embryo length L (mm), were used to calculate the values of the similitude parameter $z_L = \ln\{L\}_{0.1\,mm}$ and those of its growth rate: $\dot{z}_L(t) = \dfrac{L(t+\Delta t) - L(t-\Delta t)}{2 L_m \Delta t}$.

The obtained results were synthesized by Fig. 4.

b) *Fetal Growth*

The average values (indicated by references [21a - c]) of the human fetus mass (weight) m (g), were used to calculate the values of the similitude parameter $z_m = \ln\{m\}_g$ and of its growth rate: $\dot{z}_m = \dfrac{m(t+\Delta t) - m(t-\Delta t)}{\tilde{m} \cdot 2\Delta t}$, the obtained values being synthesized by Fig. 5.

c) *Baby Growth*

The average values (indicated by reference [23]) of the human baby length L (cm) and mass m (kg), were used to calculate the values of the similitude parameters $z_L = \ln\{L\}_{0.1\,mm}$ and $z_m = \ln\{m\}_g$, and of the similitude parameters growth rates: $\dot{z}_L = \dfrac{\Delta L}{L_m \Delta t}$ and $\dot{z}_m = \dfrac{\Delta m}{\tilde{m} \cdot \Delta t}$. The obtained results were synthesized by Fig. 6.

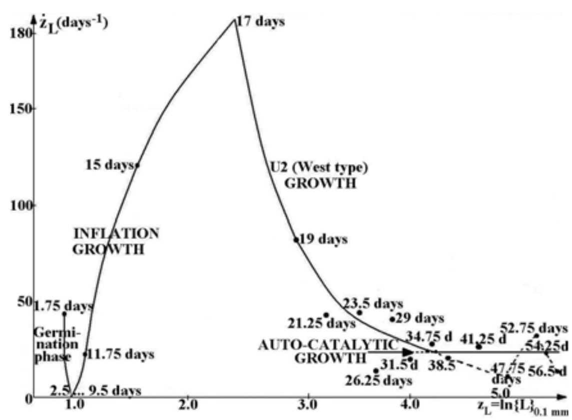

Fig. 4. Basic stages of the human embryo growth

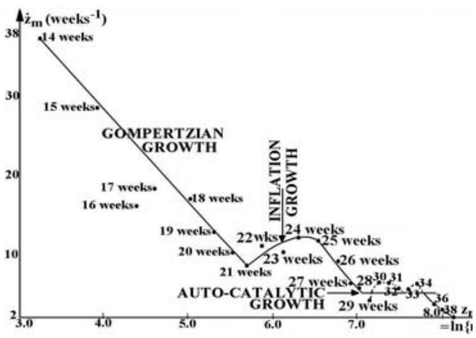

Fig. 5. Basic stages of the human fetus growth

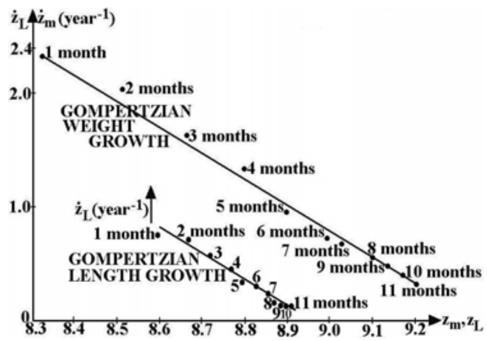

Fig. 6. Basic stages of the baby boy growth

d) ***Child and Teenager Growth***

Fig. 7 synthesizes the obtained results relative to the similitude parameters $z_H = \ln\{H\}_{0.1\,mm}$ and $z_m = \ln\{m\}_g$, and for these similitude parameters growth rates: $\dot{z}_H = \dfrac{\Delta H}{H_m \Delta t}$ and $\dot{z}_m = \dfrac{\Delta m}{\widetilde{m} \cdot \Delta t}$, starting from the average values (indicated by reference [23]) of the boys and teenagers height H (cm) and mass m (kg).

6. Conclusions

The analysis of the obtained results points out that:

a) because the basic features of the $\dot{z} = f(z)$ plots of the universal growth classes are absolutely distinct, the identification of the growth stages is possible even in the absence of the experimental confidence domains (see Table 2),

Fig. 7. Basic stages of the boy and teenager growth

b) the use of the similitude “phases space” ($z, \dot{z}$) allows the identification of: (i) the “germination” phase, (ii) the inflation growth processes, (iii) the auto-catalytic growth processes (the U0 universality class), (iv) the Gompertz’s growth (U1 universality class), (v) the U2 (West’s type) growth,

c) the most important growth stages (the inflation ones) seem to fulfill a power law of the type: $\dot{z} = C \cdot (z - z_i)^n$, which corresponds also to the linear plot (zero-order description) of the inflation stage in the Linde’s space $\log[\log(R/R_P)] = f(\log t)$ [18d] (n is a positive irrational number less than 1),

d) the U0 universality class (auto-catalytic) growth stages are always accompanied by some monotonic oscillations of the corresponding biologic states, indicated by their representative points in the ($z, \dot{z}$) space (see Figs. 4 and 5, as also [5]),

e) given that: (i) the same findings seem to be valid also for the Universe inflation stage, corresponding to the present theoretical models of the Universe evolution [17], [18], (ii) the Universe evolution involves also at least a second inflation stage (after its drastic deceleration after the inflation stage, the Universe is again accelerating now [24]), it seems that there are some similarities between the human growth and the Universe evolution [19c].

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