Introduction: From the History of Humankind to Big History

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Leonid E. Grinin and Andrey V. Korotayev

Our Yearbook 'History and Mathematics' has already celebrated its 10th anniversary and has confidently entered its second decade. In this regard it will be quite reasonable to try to extend the scope of its research field. Therefore, this issue is designed in an unusual manner while still preserving the relevance for our approach (see about it below). It also makes sense to remind the reader of the various aspects that were touched upon in the previous issues.

The first issue of the Yearbook entitled 'Analyzing and Modeling Global Development' came out in 2006 (see Grinin, de Munck, and Korotayev 2006). This volume initiated a series of edited volumes dedicated to various aspects of the application of mathematical methods to the study of history and society. It comprised articles that apply mathematical methods to the study of various epochs and scales: from deep historical reconstruction to the pressing problems of the modern world. On the other hand, all the articles of this issue were dedicated to the analysis, periodization, or modeling of global development. It was shown that the mathematical modeling of historical macroprocesses suggests a fresh approach to the periodization issue. The authors studied these problems from different perspectives (technological, economic, demographic, sociostructural, cultural-psychological, linguistic). New quantitative insights on the dynamics of contemporary processes were presented. These insights allowed the authors to make a number of important forecasts on this basis.

The second issue was entitled 'Historical Dynamics and Development of Complex Societies'. It demonstrated that the application of mathematical methods not only facilitates the processing of historical information, but can also give to a historian a deeper understanding of historical processes (see Turchin *et al.* 2006).

The third issue of the Yearbook 'Processes and Models of Global Dynamics' presented a qualitative and quantitative analysis of global historical, political, economic and demographic processes, as well as their mathematical models (see Grinin *et al.* 2010).

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The fourth issue 'Trends and Cycles' was devoted to cyclical and trend dynamics in society and nature; special attention was paid to economic and demographic aspects, in particular to the mathematical modeling of the Malthusian and post-Malthusian traps' dynamics (see Grinin and Korotayev 2014).

The fifth issue 'Political Demography & Global Ageing' brought together a number of interesting articles by scholars from Europe, Asia, and America. They examined such an important modern historical macroprocess as global ageing from a variety of perspectives (see Goldstone, Grinin, and Korotayev 2015).

The sixth (Anniversary) issue 'Economy, Demography, Culture, and Cosmic Civilizations' revealed the extraordinary potential of the application of mathematical methods to the study of historical processes (see Grinin and Korotayev 2017).

The common feature of all our Yearbooks, including the present volume, is the usage of formal methods and social studies methods in their synthesis to analyze different historical phenomena.

The present Yearbook (which is the seventh in the series) is subtitled 'Big History Aspects'. This issue is devoted to the problems of evolutionary development of the world. In no way will it be a digression from the direction which we have initially defined for our Yearbook, but just an extension of the scope of the research.

As Karl Marx and Friedrich Engels wrote in their *German Ideology*, 'We know only a single science, the science of history… the history of nature and the history of men' (Marx and Engels 1976 [1846]: 34). Since that time the history of nature went even further back into the past, but the approach has not changed. On the contrary, at present the idea of historicism penetrated almost every scientific field. At the same time the search for common foundations of this endless in its diversity world has intensified. One of the directions of this interdisciplinary search for the unity of the world in its diversity is Universal Evolutionism (Big History).

In the paper 'Big History Trends and Patterns' an American astrophysicist **Eric J. Chaisson** writes, 'In the 20th century, several independent efforts came forth virtually simultaneously, as Sagan (1980), Jantsch (1980), Reeves (1981), and Chaisson (1981) all advanced the idea of complex systems naturally emerging with the pace of natural history'. Due to the efforts of scientists from different countries, there appeared a field of study which literally unified the history of nature and people. This is the Big (or Universal) History which explores the history of the Universe and humankind from the Big Bang to the present day (including our future). In regard to this approach, we wrote,

> One of the clearest manifestations of the evolutionary approach is the form of universal evolutionism that considers the process of evolution as a continuous and integral process – from the Big Bang all the way down to the current state of human affairs and beyond. Universal evolutionism implies that cosmic, chemical, geological, biological, and social types of

> macroevolution exhibit forms of genetic and structural continuity <...> The significance of this approach (which has both the widest possible scope, and a scientific basis) is evident. It strives to encompass within a single theoretical framework all the major phases of the Universe, from the Big Bang to the forecasts for the entire foreseeable future, while showing that the present state of humankind is a result of the self-organization of matter (Grinin, Markov *et al*. 2009: 8–9).

Thus, Evolutionistics that we develop in our works and Yearbooks (‘Эволюция’ and ‘Evolution’) is considered as an interdisciplinary common field (as well as intended combination of history and mathematics), which shows the unity of the world in its diversity. And what is better than mathematics at all times proved this unity of the world? Thus, we think that the integration of Big History's and mathematical dimensions in our Yearbook is fully justified and reasonable.

The present Yearbook consists of four sections.

Section I ‘Patterns of Big History’ includes the article by **Eric J. Chaisson** (‘Big History Trends and Patterns’). According to the author, evolution – ascent with change of Nature's many varied systems – has become a powerful unifying concept throughout the sciences. In its broadest sense, cosmic evolution, which includes the subject of Big History, comprises a holistic explanatory narrative of countless changes within and among organized systems extending from the Big Bang to humankind. This interdisciplinary scenario has the potential to unite physical, biological, and social sciences, thereby creating for people of all cultures at the start of the new millennium a consistent, objective, and comprehensive worldview of material reality.

The second article of this ***Section*** (‘Potential Nested Accelerating Returns Logistic Growth in Big History’) by **David J. LePoire** presents the models for the interpretation of Big History. This interpretation includes the increasing rates of the evolutionary events and phases of life, humans, and civilization. These three phases, previously identified by others, have different information processing mechanisms (genes, brains, and writing). The accelerating returns aspect of the new model replicates the exponential part of the progress as the transitions in these three phases started roughly 5 billion, 5 million, and 5,000 years ago. Each of these three phases might be composed of a further level of about six nested transitions with each transition proceeding faster by a factor of about three with corresponding changes in free energy flow and organization to handle the increased generation rate of entropy from the system.

The article by **Antony Harper** (‘A Toy Model Mechanism for Greater-Than-Exponential Human Population Growth’) proposes an underlying mechanism which generates this greater-than-exponential growth. The mechanism is represented by a toy model of two differential equations of interacting populations, the interactions of which enhance the reproductive abilities of the other population. The end result of this enhancement due to positive human interaction, a quintessential characteristic of our species, is a pattern of growth motivated by a greater-than-exponential rate of growth. It should be noted that the model proposed here is one of many potential models and not the sole, the only, possible model.

Section II is devoted to cosmic evolution. It mainly consists of the contributions connected with the hypotheses about prehistory of our Universe, therefore it is subtitled 'Hypotheses of Deep Big History'. It opens with **David Baker's** paper ('10^{500}. The Darwinian Algorithm and a Possible Candidate for a "Unifying Theme" of Big History'). This article postulates another aspect of the long sought-after 'unifying theme' of Big History, in addition to the rise of complexity and energy flows. It looks briefly at the manifestation of the 'Darwinian algorithm', that is to say an algorithm of random variation and non-random selection, in many physical processes in the Universe: cosmology, geology, biology, culture, and even the occurrence of universes themselves. This algorithm also seems to gradually open more forms of variation and more selection paths over time, leading to a higher level of free energy rate density, or what we know as 'complexity'. In fact the complexity of the object under discussion seems to correspond to the available number of selection paths. The article closes with a bit of philosophical reflection on what the Darwinian algorithm and the rise of complexity could possibly mean for humanity and the future of the cosmos.

The article by **Tom Gehrels** ('The Chandra Multiverse') extends the already colossal time horizons of Big History in a truly fantastic way. While reading this article, it is difficult to avoid exclaiming something like: 'This is a really BIG history!' Of course, this is a hypothesis, with which many might not agree. But this is a very bold hypothesis that extends the Big History horizon by many orders of magnitude. According to Gehrels, equations of Planck and Chandrasekhar lead to the conclusion that our universe is a member of a quantized system of universes, which he calls the 'Chandra Multiverse'. It is a trial-and-error evolutionary system. All universes have the same critical mass and finely tuned physics that our universe has. The origin and demise of our universe is described. In our astronomical environment, everything ages and decays; even the proton may have a limited half-life. The decay products of all the universes expand into the inter-universal medium (IUM), clouds form in the IUM, from which new universes are started. When the density at the center of our proto-universe cloud reached proton density, then photons, protons and neutrons were re-energized. A Photon Burst marks the beginning of our universe at 10^{-6} sec (1037 Planck times) later than a Big Bang, and the evolution of forces, sub-atomic particles and finely tuned physics occurs in the Chandra Multiverse. This theory of the multiverse also makes identification of dark energy and dark matter possible.

The section concludes with the contribution by **Leonid E. Grinin** ('Was There a Big Bang?'). The idea that our Universe emerged as a result of the extraordinary power of the Big Bang from singularity (*i.e.*, a state of an infinitely small quantity and infinitely high concentration of matter) is still very popular today. It was one of the main postulates of the Big Bang theory that completely formed in the 1960s–1970s. However, at present this idea as well as the Big Bang theory is outdated, although it is still shared by many scientists. Being widespread since the end of the 1970s the Inflation theory appears more modern. The main reason for the emergence of the Inflation theory was that the Big Bang theory could not satisfactorily explain a number of the contemporary parameters of the Universe.

The Inflation theory makes still widespread views of the Big Bang theory archaic as regards the following points: 1) the history of the Universe started with the Big Bang; 2) it started with the singularity. According to the Inflation theory, the Big Bang was not the beginning and the moment of the origin of the Universe, but it was preceded by at least two epochs: inflation and post-inflationary heating. That is, the Big Bang or precisely the hot Big Bang is just a phase transition from the state of cold inflation to the hot phase. Since the Inflation theory does not consider the Big Bang as the initial phase there emerges an intricate problem of the role of the Big Bang in the process of the formation the Universe as a whole. The paper considers the confusion with the Big Bang notion, a number and sequence of 'bangs' and why the theory can dispense easily without the notion the Big Bang. The advantages and disadvantages of the Inflation theory are discussed in this contribution.

Section III 'Biological Aspects' opens with the paper by **Edmundas Lekevičius** ('Ecological Darwinism or Preliminary Answers to Some Crucial though Seldom Asked Questions'). The author asserts that evolutionary regularities might be deduced from basic principles describing how life functions, most notably part-whole relationships and control mechanisms. Lekevičius suggests adding the concept of functional hierarchy to the concept of the struggle for existence: no solitary individual or species is functionally autonomous. Life as we know can exist only in the form of a nutrient cycle. Only two purely biotic forces – 'biotic attraction' and 'biotic repulsion' – act in the living world. The first one maintains and increases diversity and organizes solitary parts into systems integrated to a greater or lesser degree. The second one, in the form of competition, lessens biodiversity but at the same time provides life with necessary plasticity. On that basis, tentative answers to the following questions are given: (1) Why does life exhibit such a peculiar organization with strong integration at lower levels of organization and weak integration at higher ones?; (2) Why did particular species and guilds appear on the evolutionary stage at that particular time and not at any other?; (3) Why was the functional structure of ecosystems prone to convergence despite a multitude of stochastic factors?

In their contribution ('Relationship between Genome Size and Organismal Complexity in the Lineage Leading from Prokaryotes to Mammals'**) Alexander V. Markov, Valery A. Anisimov, and Andrey V. Korotayev** emphasize that there is a direct relationship between the level of organization and the minimal genome size (MGS) in the lineage leading from prokaryotes to mammals, in which the tendency towards increasing complexity is especially clear. The dynamics of MGS in this lineage can be adequately described by the model of hyperexponential growth. This implies the existence of nonlinear positive feedbacks that account for the acceleration of MGS growth. The nature of these feedbacks is discussed, including the formation of new genes by means of recombination of the fragments of existing genes, formation of 'niches' for new genes in the course of evolution of gene networks, and the expansion of regulatory regions. Hyperexponential growth of different variables related to the level of organization of the biosphere and society (biodiversity, MGS, size and complexity of organisms, world population, technological development, urbanization, *etc.*) suggests that the evolution of the biosphere and humanity in the direction of increasing complexity is a self-accelerating (autocatalytic) process.

Section IV 'History and Future of Social Systems' gives a series of forecasts. It opens with the paper by **Andrey V. Korotayev and Leonid E. Grinin** ('A Mathematical Model of Influence of the Interaction between Civilization Center and Barbarian Periphery on the World-System Development'). This article offers an analysis and mathematical modeling of the influence of one of the major factors of the World System macrodynamics throughout most part of its history (since the 'urban revolution') – the factor of interaction of civilizations with their barbarian periphery. The proposed mathematical model is intended to describe possible influence of interaction between civilizational core of the World System and its barbarian periphery on the formation of the specific curve of the world urbanization dynamics. It imitates completion of the phase transition, behavior of the system in the attraction basin and beginning of the phase transition to the attraction basin of the new attractor and is aimed to identify the role of the factor of interaction between the civilizational core and barbarian periphery in the formation of attractor effect during the completion of phase transition, that is for clarification of the reason why there was observed not only slowdown of growth rates of the main indicators of the World System development after completion of phase transitions during its development, but also their falling with the subsequent temporary stabilization near some equilibrium level. Achievements of modern barbarology, including complexity of barbarian periphery itself and its heterogeneity are considered. The basic principle of the proposed dynamic model is that sizes, power and level of complexity in realization of external policy functions in nomadic unions (empires) closely correspond to sizes, power and level of political culture and activity of the core states with which nomads constantly had to do (this point has been established in works of the known experts in nomadic studies). Various alternatives are shown in the model, when depending on power and size of one of the two components of the system 'civilization – barbarian periphery' studied by the authors, another one also changes significantly as it has to respond to the challenge properly, or can make less efforts without feeling threat or resistance. This principle is observed throughout the long period of the history of the World System. It is shown that interaction between the civilization center and barbarian periphery really can explain some characteristic features of the World System dynamics in the 4th millennium BCE – the 2nd millennium CE. The ways of further development of the model are outlined.

According to **William R. Thompson** ('Energy, Kondratieff Waves, Lead Economies, and Their Evolutionary Implications'), one approach to interpreting Kondratieff waves, associated with the leadership long cycle research program, emphasizes the role of intermittent but clustered technological innovations primarily pioneered by a lead economy, with various significant impacts on world politics. This approach is further distinguished by asserting that the K-wave pattern is discernible back to the 10th century and the economic breakthrough of Sung Dynasty China. While K-wave behavior has numerous and widespread manifestations, the question raised in this essay is whether explanatory power is improved by giving a greater role to energy and energy transitions in the K-wave process(es). Eight specific implications are traced, ranging from the interaction of technological innovations and energy to cosmological interpretations. In general, the answer to the raised question is affirmative, with one caveat on whether emphasizing new fuels and engines is a hallmark of the hydrocarbon era or a new and evolving feature of K-waves.

Leonid E. Grinin and Anton L. Grinin in their contribution ('Technological Dimension of Big History and the Cybernetic Revolution') consider the history of technological development in terms of production (or technological) revolutions. The analysis of its current state and forecasts is made with respect to Big History. Technologies have been playing a significant role in the history of humankind from the very origin of *Homo sapiens*. Numerous facts show that already after 50,000 BP technologies were developed in various fields: from hunting and cooking to primitive painting. Agriculture, building, transportation and many other human achievements could not have happened without certain technologies. Thus, one can argue that technologies play a very important role in Big History. Technologies played a special role in the collective learning which is defined as the sixth threshold of increasing complexity. This *Homo Sapiens'* achievement which happened at the beginning of the Upper Paleolithic was probably one of the most important events in the whole human history, and sometimes is termed as the Human revolution (*e.g.*, Shea 2006). Today we are at the threshold of another important transition which is often called 'post-human revolution', which could bring quite radical changes to society and even transform the human biological nature.

In his paper ('Global Society as Singularity and Point of Transition to the New Phase of Social Evolution') **Sergey V. Dobrolyubov** considers social evolution as a process consisting of three phases: Adaptive, Structural and Cognitive, which are separated by two phase transitions or by two singularities – the Neolithic and the Global. The mechanism of social evolution at these phases is different and is based on different institutional means of cognition and competition. At the current structural phase, competition of individuals leads to inequality, and competition of societies leads to extension of societies. Social inequality and exploitation of the periphery become institutional tools for the development. The expansion of societies and evolutionary limitations of its growth lead to life cycles of societies. The maximum size of society increases in the process of evolution and tends to cover all humankind. The Global Society is a final point of structural evolution, and transition to it is singularity. It will be a metamorphosis of the society's nature. The mechanism of further social evolution at the cognitive phase will rely directly on individual's need for cognition and self-realization, and not on the special social institutions. Mathematical model of the primary transformations dynamics at the structural phase is described by the equation $T(n) = -11214 + 1893n$, where $T(n)$ – is the moment of evolutionary transformation, and n – is the ordinal number of transformation. Global singularity is predicted by this model in AD 3930.

The Section concludes with the article by **Antony Harper** ('The Punctuated Equilibrium Macropattern of World System Urbanization and the Factors that Give Rise to that Macropattern'). This paper is about the World System evolution as it is reflected in the pattern of urbanization over the last 5,000 years. It will be shown that the pattern of urbanization as part of the immensely complex world system exhibits non-linearity in that it is neither smooth nor continuous but rather is punctuated by periods of rapid change interspersed between periods of stasis. This pattern was first described in biological systems by Eldridge and Gould (1972) for speciation, and much of the pattern of urbanization reflects the characteristics of punctuated equilibrium first described by those two authors. Specifically, this paper will investigate the phenomenon of punctuated equilibrium reflected in both the macro-pattern of urbanization over historic time, *i.e.* the evidence for punctuated equilibrium as reflected by data on urbanization and on the level of state development, and possible mechanisms for such punctuated behavior including the general model of self-organized criticality as developed by Per Bak (1996), the role of hypercycle formation in punctuated equilibrium, the role of aromorphic processes, and the interaction between population, carrying capacity, and level of technology as represented by a very general math model.

We hope that the present issue of the Yearbook will be interesting and useful both for historians and mathematicians, as well as for all those dealing with various social and natural sciences.

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