НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ

The 21st Century Singularity in the Big History Perspective: Global Population and the Planetary Acceleration Rate

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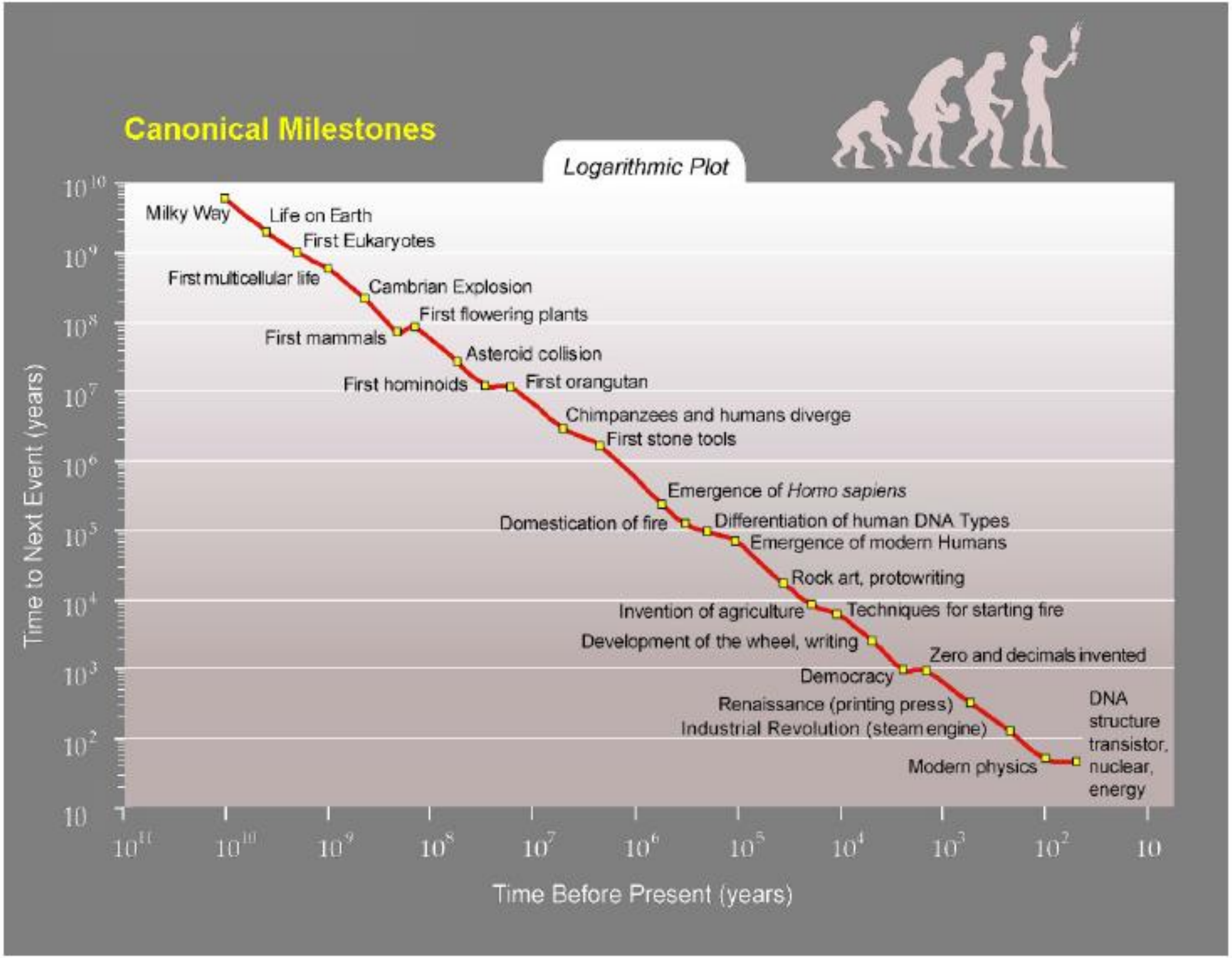
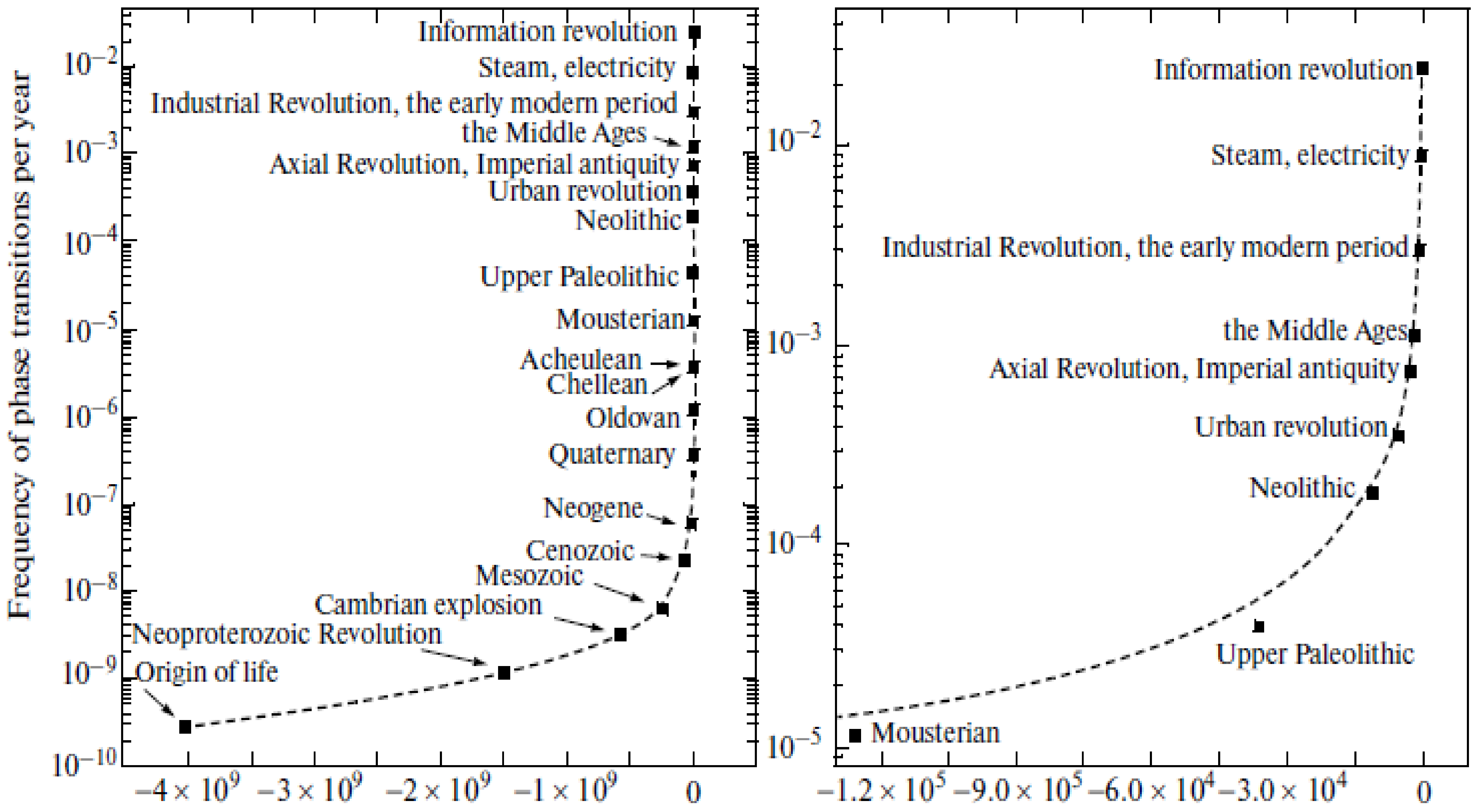
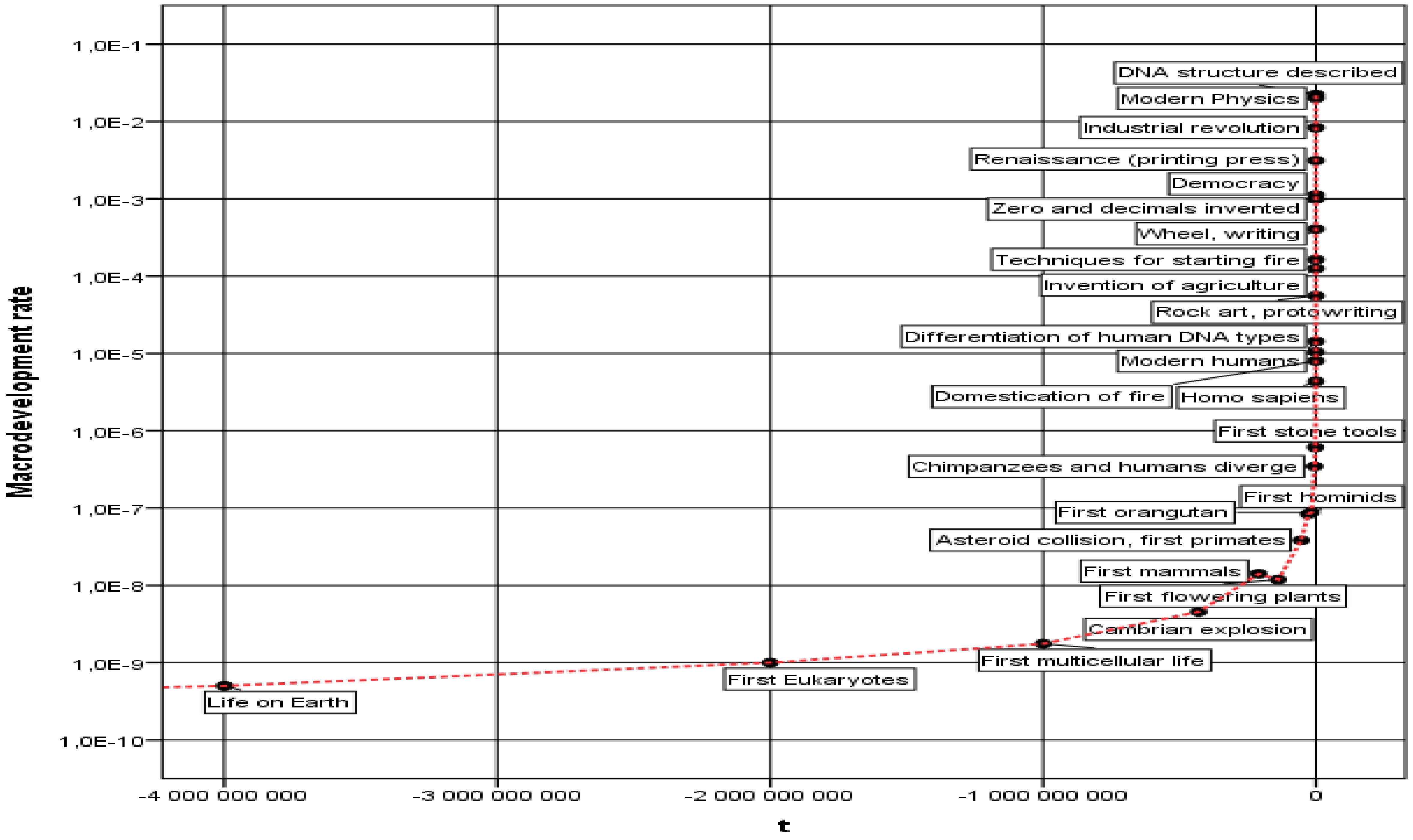

Canonical Milestones
Logarithmic Plot
Milky Way
Life on Earth
First Eukaryotes
First multicellular life
Cambrian Explosion
First flowering plants
First mammals
Asteroid collision
First hominoids
First orangutan
Chimpanzees and humans diverge
First stone tools
Emergence of *Homo sapiens*
Domestication of fire
Differentiation of human DNA Types
Emergence of modern Humans
Rock art, protowriting
Invention of agriculture
Techniques for starting fire
Development of the wheel, writing
Zero and decimals invented
Democracy
Renaissance (printing press)
Industrial Revolution (steam engine)
Modern physics
DNA structure transistor, nuclear, energy
Time to Next Event (years)
Time Before Present (years)
10^{10} 10^9 10^8 10^7 10^6 10^5 10^4 10^3 10^2 10
10^{11} 10^{10} 10^9 10^8 10^7 10^6 10^5 10^4 10^3 10^2 10

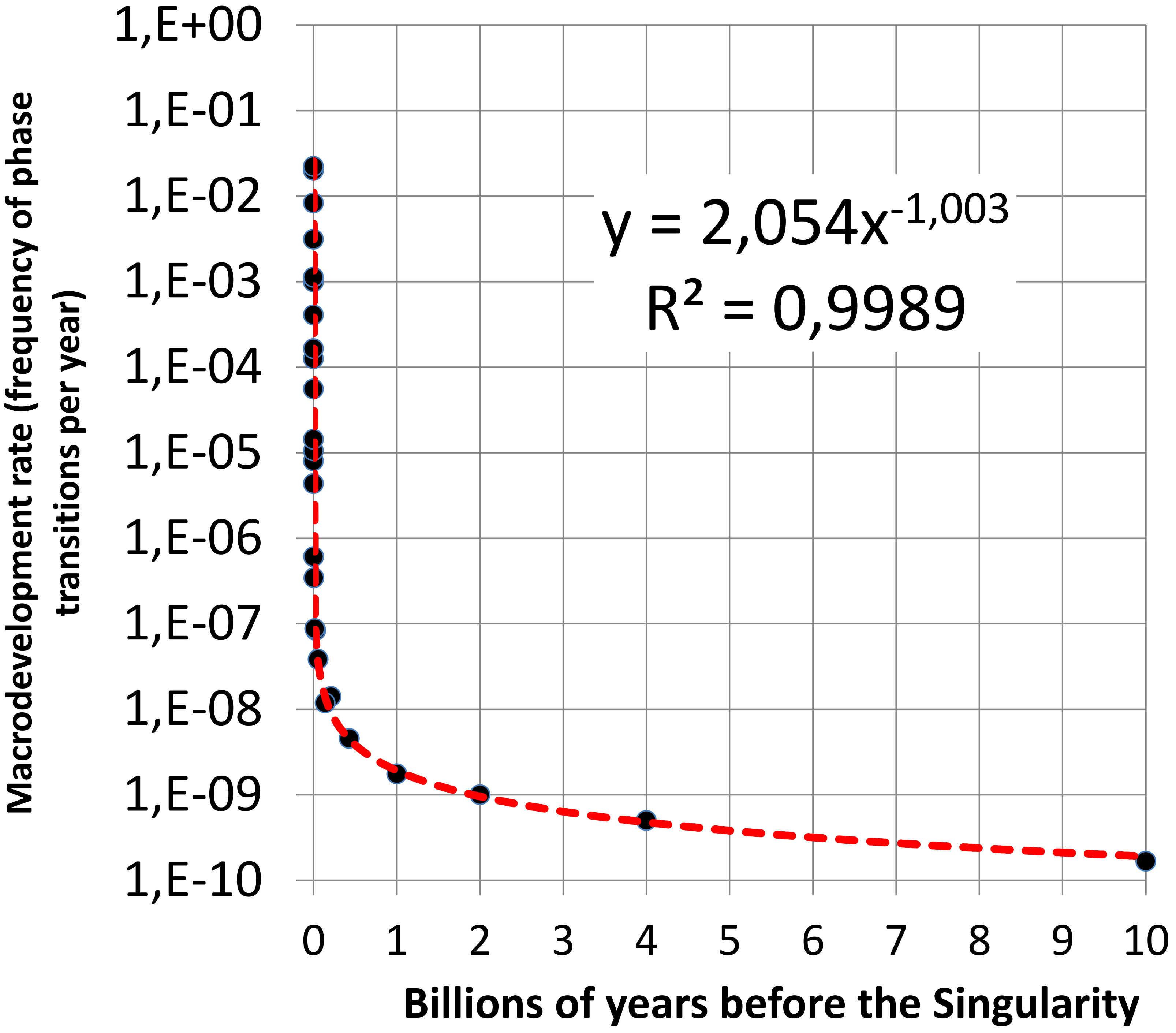
Fig. 6



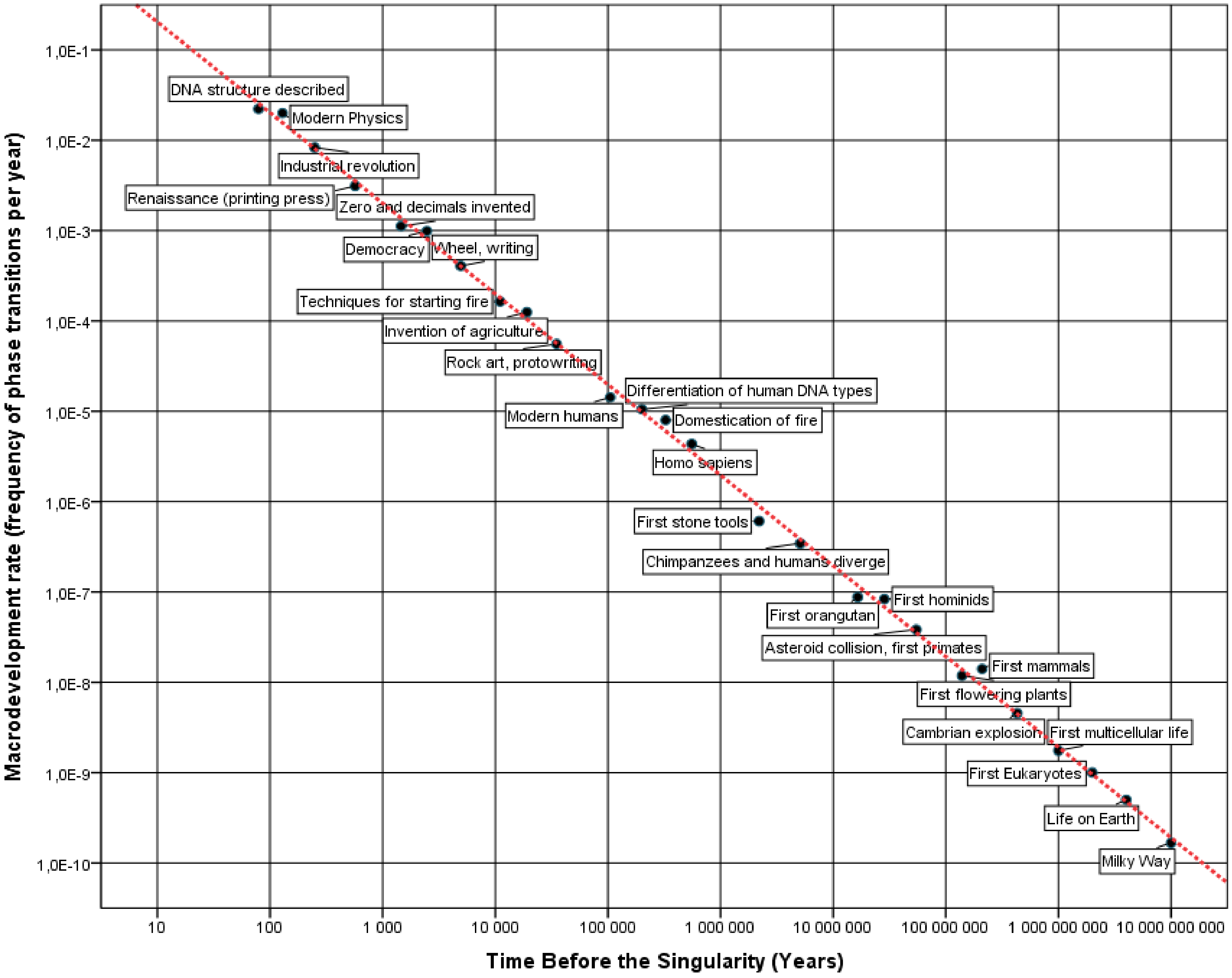
Frequency of phase transitions per year
Information revolution
Steam, electricity
Industrial Revolution, the early modern period
the Middle Ages
Axial Revolution, Imperial antiquity
Urban revolution
Neolithic
Upper Paleolithic
Mousterian
Acheulean
Chellean
Oldowan
Quaternary
Neogene
Cenozoic
Mesozoic
Cambrian explosion
Neoproterozoic Revolution
Origin of life
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
-4×10^9
-3×10^9
-2×10^9
-1×10^9
0
-1.2×10^5
-9.0×10^5
-6.0×10^4
-3.0×10^4



Macrodevelopment rate
1,0E-1
1,0E-2
1,0E-3
1,0E-4
1,0E-5
1,0E-6
1,0E-7
1,0E-8
1,0E-9
1,0E-10
-4 000 000 000
-3 000 000 000
-2 000 000 000
-1 000 000 000
0
t
DNA structure described
Modern Physics
Industrial revolution
Renaissance (printing press)
Democracy
Zero and decimals invented
Wheel, writing
Techniques for starting fire
Invention of agriculture
Rock art, protowriting
Differentiation of human DNA types
Modern humans
Domestication of fire
Homo sapiens
First stone tools
Chimpanzees and humans diverge
First hominids
First orangutan
Asteroid collision, first primates
First mammals
First flowering plants
Cambrian explosion
First multicellular life
First Eukaryotes
Life on Earth



Singularity date = 2029 CE



Macrodevelopment rate (frequency of phase transitions per year)
1,0E-1
1,0E-2
1,0E-3
1,0E-4
1,0E-5
1,0E-6
1,0E-7
1,0E-8
1,0E-9
1,0E-10
DNA structure described
Modern Physics
Industrial revolution
Renaissance (printing press)
Zero and decimals invented
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First orangutan
Asteroid collision, first primates
First mammals
First flowering plants
Cambrian explosion
First multicellular life
First Eukaryotes
Life on Earth
Milky Way
10
100
1 000
10 000
100 000
1 000 000
10 000 000
100 000 000
1 000 000 000
10 000 000 000
Time Before the Singularity (Years)

$$y = k/x$$

$$\boldsymbol{y = \frac{2.054}{x^{1.003}}}$$

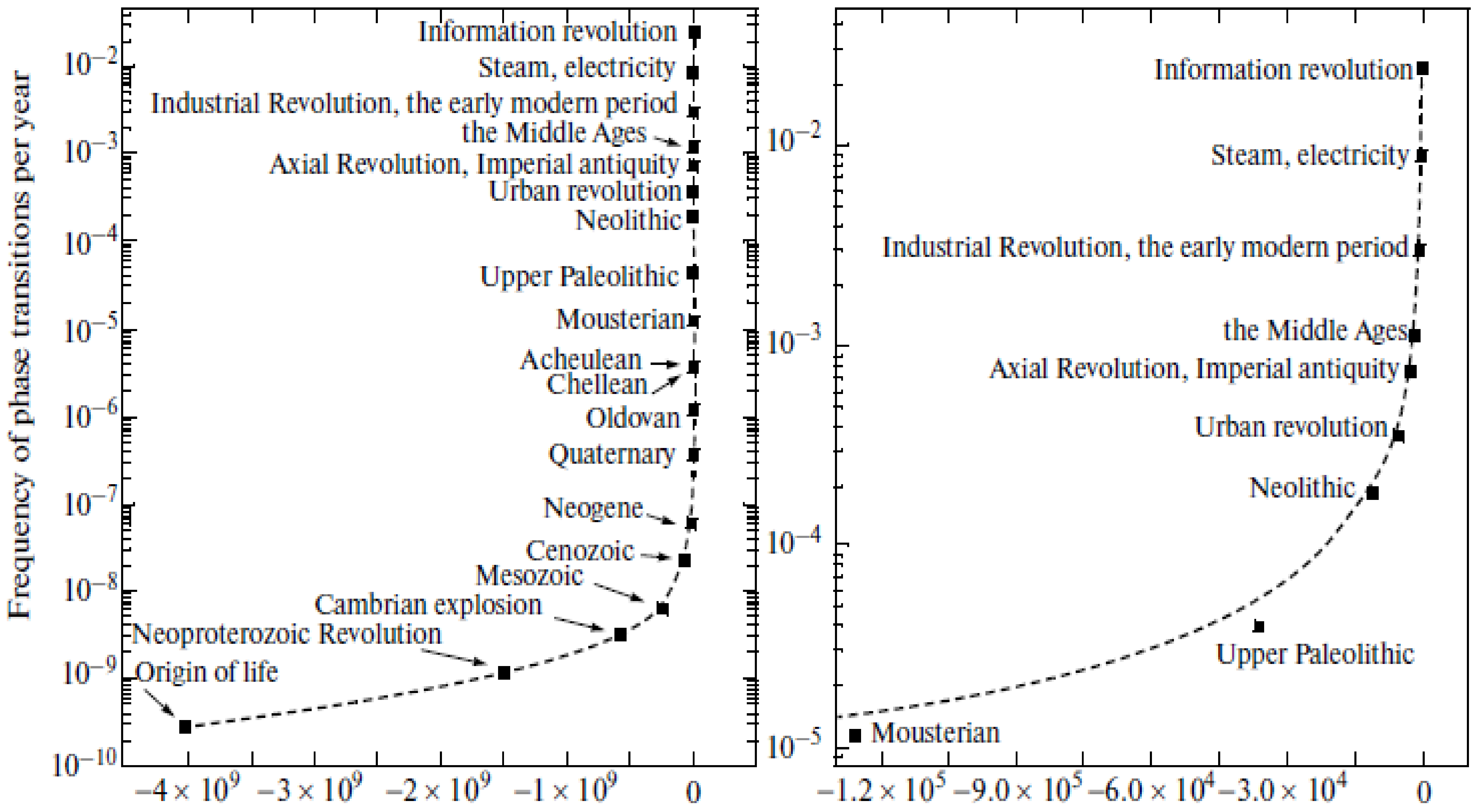
$$\boldsymbol{y = \frac{2.054}{x}}$$

$$\boldsymbol{y = \frac{2.054}{x}}$$

$x = t^* - t$

$$\boldsymbol{y_t = \frac{2.054}{2029 - t}}$$

$$\boldsymbol{y_t = \frac{C}{t^* - t}}$$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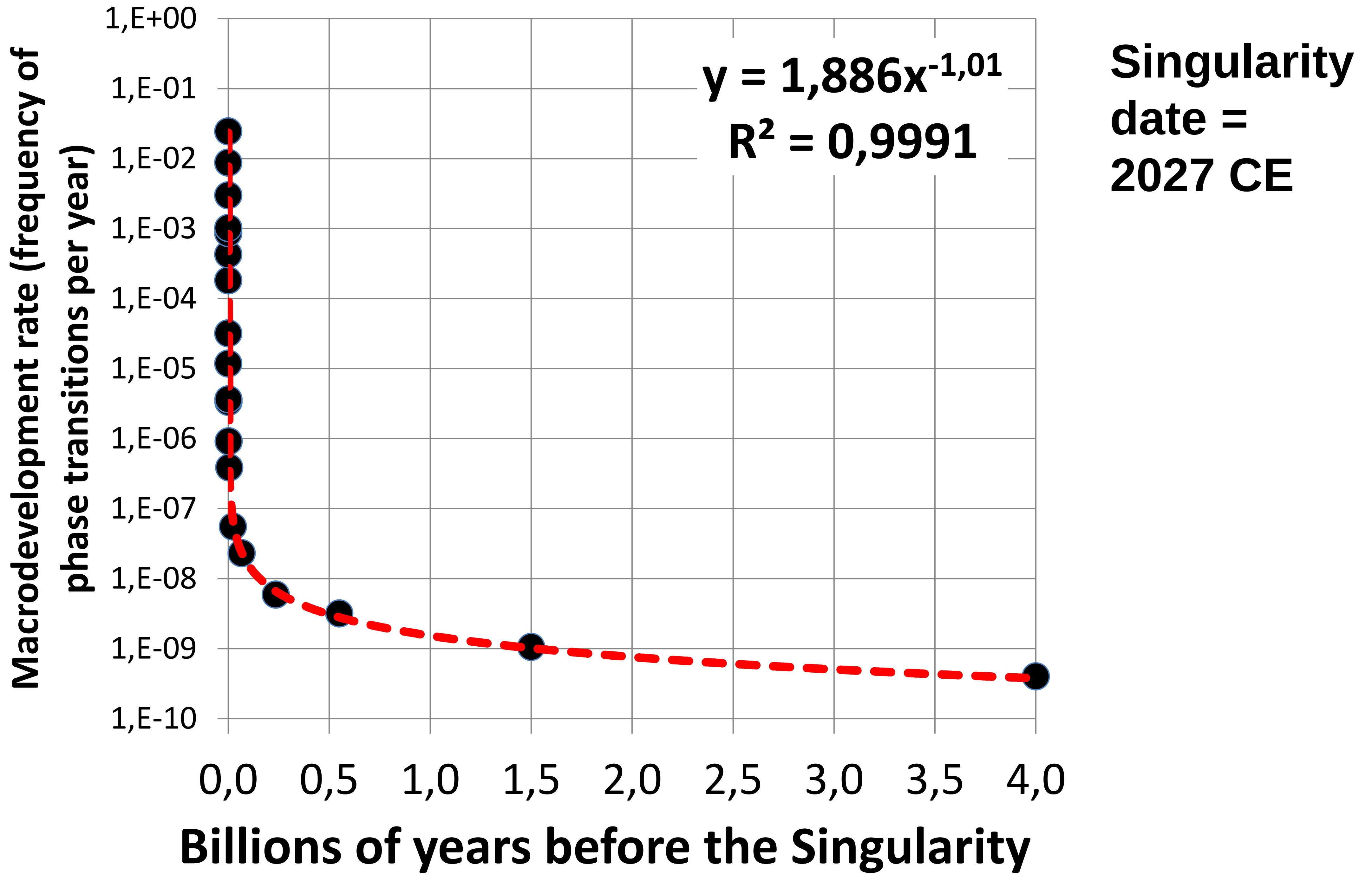
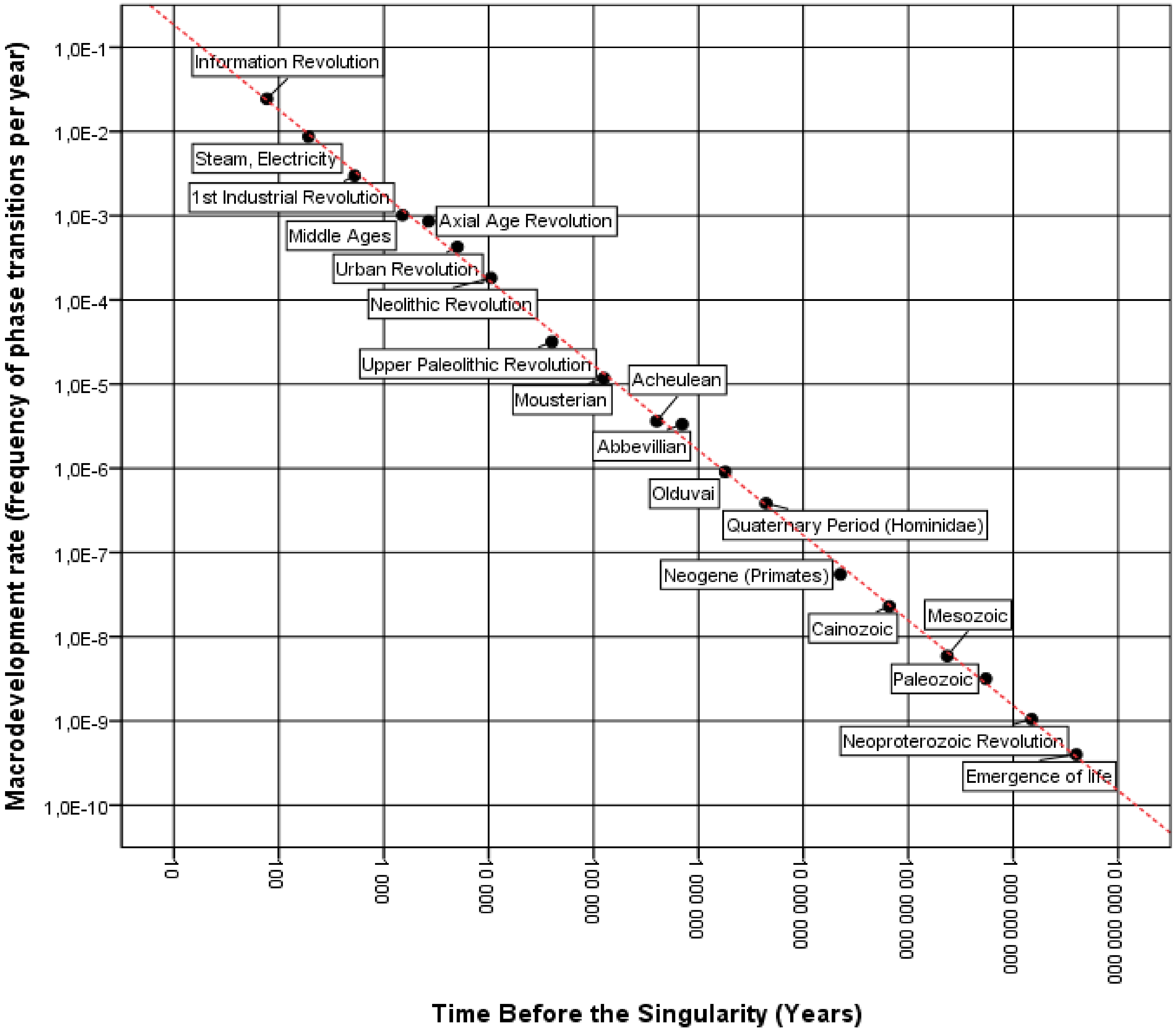
Information revolution
Steam, electricity
Industrial Revolution, the early modern period
the Middle Ages
Axial Revolution, Imperial antiquity
Urban revolution
Neolithic
Upper Paleolithic
Mousterian
Acheulean
Chellean
Oldowan
Quaternary
Neogene
Cenozoic
Mesozoic
Cambrian explosion
Neoproterozoic Revolution
Origin of life
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
-4×10^9
-3×10^9
-2×10^9
-1×10^9
0
-1.2×10^5
-9.0×10^5
-6.0×10^4
-3.0×10^4



y = 1,886x^-1,01
R² = 0,9991
Singularity date = 2027 CE
Macrodevelopment rate (frequency of phase transitions per year)
1,E+00
1,E-01
1,E-02
1,E-03
1,E-04
1,E-05
1,E-06
1,E-07
1,E-08
1,E-09
1,E-10
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
Billions of years before the Singularity



Macrodevelopment rate (frequency of phase transitions per year)
1,0E-1
1,0E-2
1,0E-3
1,0E-4
1,0E-5
1,0E-6
1,0E-7
1,0E-8
1,0E-9
1,0E-10
Information Revolution
Steam, Electricity
1st Industrial Revolution
Axial Age Revolution
Middle Ages
Urban Revolution
Neolithic Revolution
Upper Paleolithic Revolution
Acheulean
Mousterian
Abbevillian
Olduvai
Quaternary Period (Hominidae)
Neogene (Primates)
Mesozoic
Cainozoic
Paleozoic
Neoproterozoic Revolution
Emergence of life
10
100
1 000
10 000
100 000
1 000 000
10 000 000
100 000 000
1 000 000 000
10 000 000 000
Time Before the Singularity (Years)

$$y = \frac{1.886}{x^{1.01}}$$

$$y = \frac{1.886}{x}$$

$$y_t = \frac{1.886}{2027 - t}$$

$$y_t = \frac{C}{2027 - t}$$

Von Foerster showed that between 1 and 1958 CE the world's population (*N*) dynamics can be described in an extremely accurate way with an astonishingly simple equation:

$$N_t = \frac{C}{(t*-t)^{0.99}}$$

where N_t is the world population at time t, and C and t_0 are constants, with t_0 corresponding to an absolute limit ("singularity" point) at which N would become infinite.

Parameter t_0 was estimated by von Foerster and his colleagues as 2026.87, which corresponds to November 13, 2026; this made it possible for them to supply their article with a public-relations masterpiece title:

"Doomsday: Friday, 13 November, A.D. 2026"

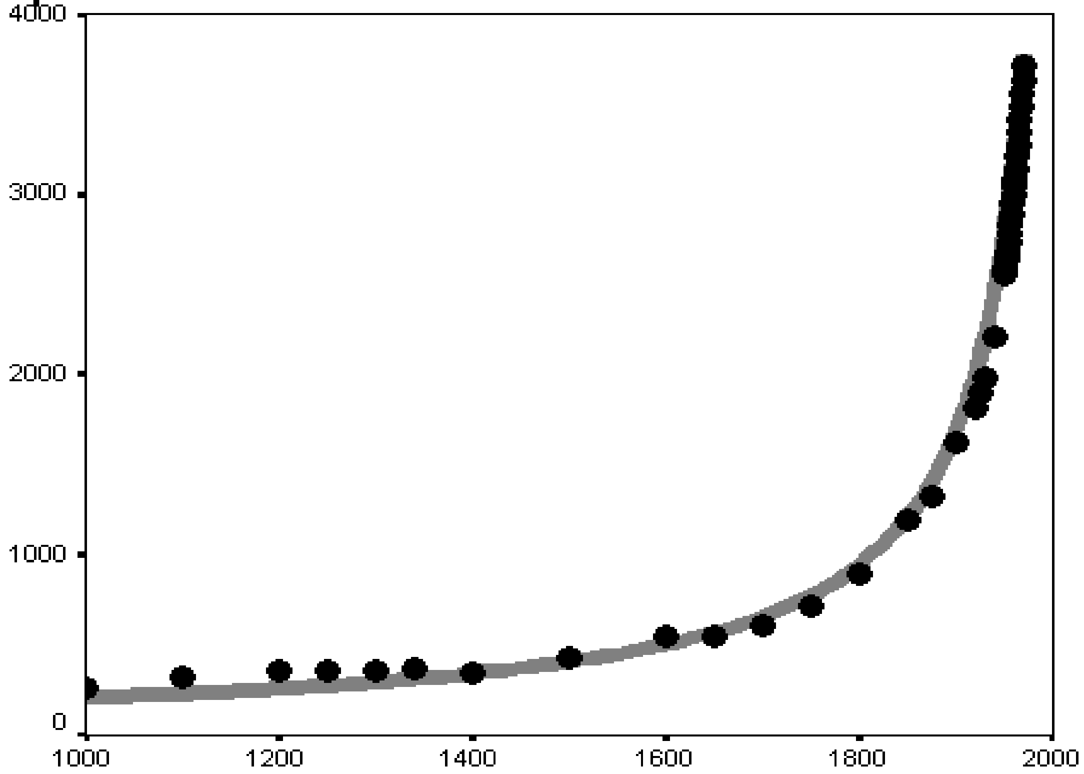
What is especially important for us is that, as was the case with equation (1) above, the denominator’s exponent (0.99) turned out to be only negligibly different from 1, and as has been shown by von Hoerner (1975) and Kapitza (1992, 1999), it can be written more succinctly as

$$N_t = \frac{C}{t^* - t}$$

2026.87 ≈ 2027

$$N_t = \frac{C}{2027 - t} \qquad \frac{dN}{dt} = \frac{N^2}{C}$$

The overall correlation between the curve generated by von Foerster's equation and the most detailed series of empirical estimates looks as follows:



$$N_t = \frac{C}{2027 - t}$$

The formal characteristics are as follows:
R = 0.998; R^2 = 0.996; $p = 9.4 \times 10^{-17} \approx 1 \times 10^{-16}$.

Thus, von Foerster's equation accounts for an astonishing 99.6% of all the macrovariation in world population, from 1000 CE through 1970, as estimated by McEvedy and Jones (1978) and the U.S. Bureau of the Census (2006).

Note also that the empirical estimates of world population find themselves aligned in an extremely neat way along the hyperbolic curve, which convincingly justifies the designation of the pre-1970s world population growth pattern as "hyperbolic".

$$y_t = \frac{c_1}{(2027-t)^{1.01}}$$

$$y_t = \frac{dn}{dt} = \frac{c_1}{2027 - t}$$

$$N_t = \frac{c_2}{(2027-t)^{0.99}}$$

$$N_t = \frac{c_2}{2027-t}$$

To my mind, all these indicate the existence of sufficiently rigorous global macroevolutionary regularities (describing the evolution of complexity on our planet for a few billion of years), which can be surprisingly accurately described by extremely simple mathematical functions, as well as the presence of a global planetary macroevolutionary development acceleration pattern described by a very simple equation:

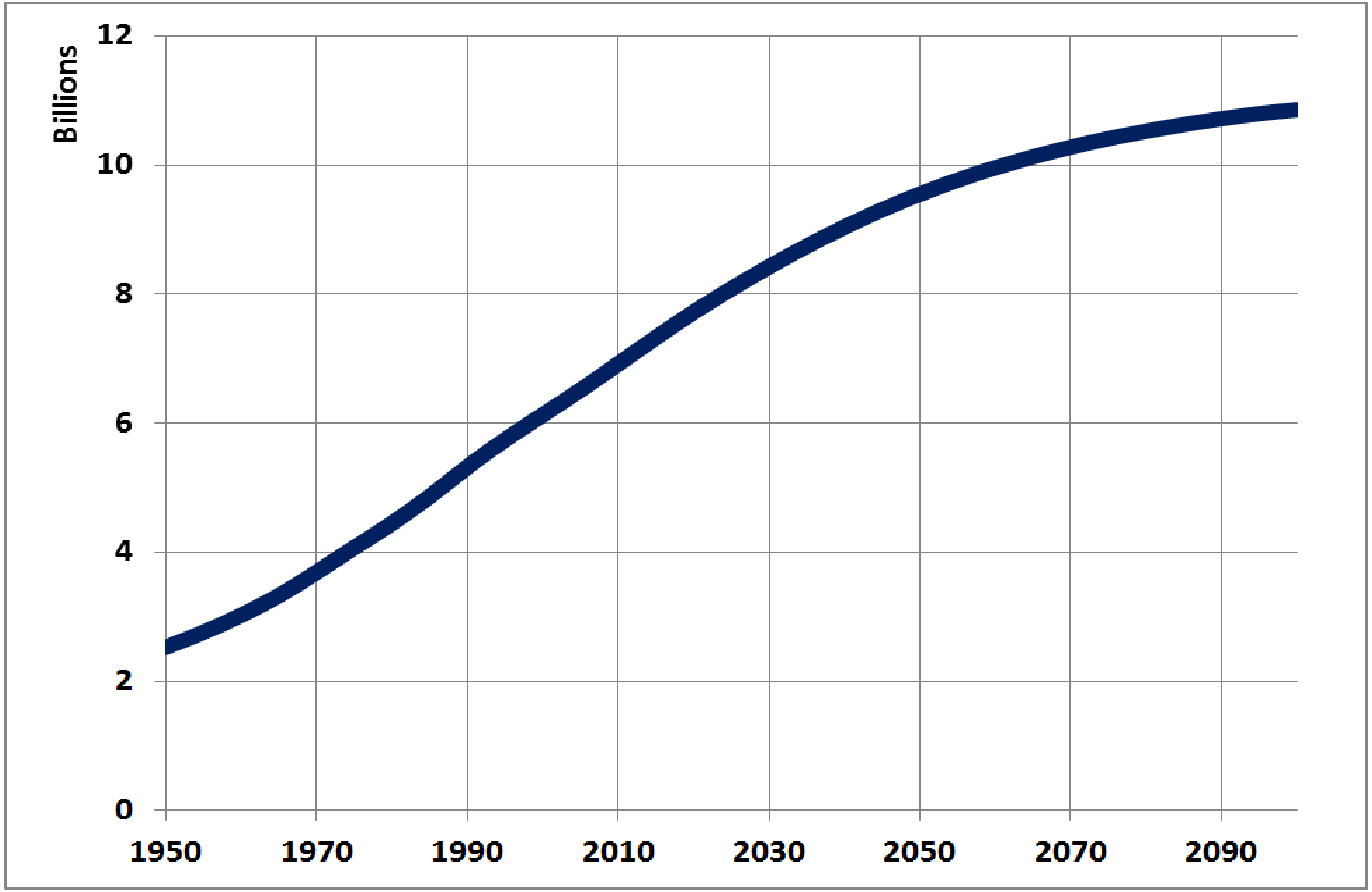
$$\frac{dy}{dt} = \frac{y^2}{C}, \qquad (6)$$

where C is a parameter in the following hyperbolic equation:

$$y_t = \frac{C}{t^* - t}, \qquad (5)$$

where t^* is the singularity date.

World population dynamics (billions), empirical estimates of the UN Population Division for 1950–2015 with its middle forecast till 2100



Thus, our analysis appears to indicate the existence of sufficiently rigorous global macroevolutionary regularities (describing the evolution of complexity on our planet for a few billion of years), which can be surprisingly accurately described by extremely simple mathematical functions.

At the same time this analysis suggests that in the region of the singularity point there is no reason, after Kurzweil, to expect an unprecedented (many orders of magnitude) acceleration of the rates of technological development.

There are more grounds for interpreting this point as an indication of an inflection point, after which the pace of global evolution will begin to slow down systematically in the long term.

$$y_t = \frac{c_1}{(2027-t)^{1.01}}$$

$$y_t = \frac{dn}{dt} = \frac{c_1}{2027 - t}$$

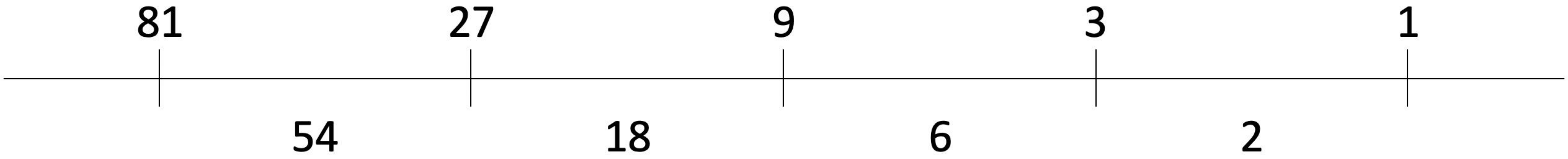
$$N_t = \frac{c_2}{(2027-t)^{0.99}}$$

$$N_t = \frac{c_2}{2027-t}$$

Alexey Fomin draws attention to the regularity discovered by Sergey Kapitsa (1996) - during the social phase of Big History, the population of the Earth between each pair of biospheric revolutions increased by approximately the same number of times (according to Fomin's calculations, somewhere around 2.8).

$$N = \frac{C_1}{t_0 - t} = \frac{C_1}{t_{ts}}$$

Dates of phase transitions, thousands of years before the Singularity, log scale



Period of time till the next phase transition, t_{tnt} (thousands of years)

$$y = \frac{dn}{dt} = \frac{1}{t_{tnt}}$$

Now, let us demonstrate this more formally. Since the movement from one biospheric revolution to another is accompanied by an increase in population N by the same factor of α and an increase in the index of global complexity n by one unit, we obtain:

$$N = k \cdot \alpha^n, \qquad (1)$$

where k is a coefficient of proportionality between N and α^n.[43]

Taking into account that

$$N_t = \frac{C_2}{2027-t}, \qquad (2)$$

we arrive at:

$$k \cdot \alpha^n = \frac{C_2}{2027-t}. \qquad (3)$$

$$k \cdot \alpha^n = \frac{C_2}{2027-t}. \tag{3}$$

This implies the following:

$$ln\,(k \cdot \alpha^n) = ln\left(\frac{C_2}{2027-t}\right), \tag{4}$$

$$ln\,(k) + ln\,(\alpha^n) = ln\left(\frac{C_2}{2027-t}\right), \tag{5}$$

$$ln\,(k) + nln\,(\alpha) = ln\left(\frac{C_2}{2027-t}\right), \tag{6}$$

$$n = \frac{ln\left(\frac{C_2}{2027-t}\right) - ln\,(k)}{ln\,(\alpha)}. \tag{7}$$

Differentiating expression (25), we obtain:

$$\frac{dn}{dt} = \frac{1}{ln\,(\alpha)} \cdot \frac{1}{2027-t}, \tag{8}$$

or

$$\frac{dn}{dt} = \frac{C_1}{2027-t}, \tag{9}$$

where $C_1 = 1/\ln(\alpha)$.[44]

Thus, we obtain analytically that if the world population (N) grows hyperbolically according to the law $N_t = C_2 / 2027 - t$, whereas the ratio $N = k{\cdot}\alpha^n$ is observed between the index of global complexity (n) and the population of the Earth (N), then the global complexity growth rate (dn/dt) will increase according to the same hyperbolic law ($x = C / 2027 - t$) as the population of the Earth.

It should be noted that this is not in bad agreement with many mathematical models of hyperbolic growth of the world population, as such models tend to consider the hyperbolic growth of the world population as a result of the functioning of the positive feedback mechanism of the second order between demographic growth and technological development, when technological development (most vividly manifested precisely as “biospheric revolutions” – e.g., the Neolithic Revolution, or the Industrial Revolution) significantly accelerated the growth rate of the population, which (by virtue of the principle "the more people, the more inventors”) through collective learning mechanisms accelerated onset of each successive “biospheric revolution” (that usually corresponded to a new major technological breakthrough). In particular, this correlates very well with an idea that was developed long ago by Taagepera (1976, 1979), Kremer (1993), Podlazov (2000, 2017), and Tsirel (2004) who demonstrated that the global technological growth rate is to be proportional to the global population, and who explained the hyperbolic growth of the world population through this point.

11. The Upper Palaeolithic revolution – $40 \cdot 10^3$ years ago. *Homo sapiens sapiens* became the leader of cultural evolution. Development of advanced hunter instruments – spears, snares. Imitative art is widespread.
12. Neolithic revolution [Agrarian revolution[10]] – $12–9 \cdot 10^3$ years ago. Appropriative economy [foraging] had been replaced by productive economy [food production].
13. Urban revolution (the beginning of the Ancient world) – 4000–3000 B.C. Appearance of state formations, written language and the first legal documents.
14. Imperial antiquity, Iron age, the revolution of the Axial time – 750 B.C. The appearance of a new type of state formations – empires, and a culture revolution. New kinds of thinkers such as Zaratushtra, Socrates, Budda, and others.
15. The beginning of the Middle Ages – 500 CE. Disintegration of Western Roman Empire, widespread Christianity and Islam, domination of feudal economy.
16. The beginning of the Modern Age, the first industrial revolution [the initial phase of the Industrial revolution] – 1500 CE. Appearing of manufacture, printing of books, the Modern History culture revolution etc.
17. The second industrial revolution (steam and electricity) [the beginning of the stage of maturity and expansion of the trade-industrial production principle] – 1830. Appearance of mechanized industry, the beginning of globalization in the information field (telegraph was invented in 1831), etc.
18. Information revolution, the beginning of the postindustrial epoch [the initial phase of the Cybernetic Revolution] – 1950. The main part of population of industrial countries work in the field of information production and utilization or in the service field, not in the material production".

- As one can see, in the description of seven out of eight “biospheric” revolutions identified by Panov, he explicitly mentions major technological breakthroughs associated with them. The same is more or less true with respect to the Modis – Kurzweil series (Modis 2002, 2003; Kurzweil 2005).
- Thus, for the both series with respect to the period after 40,000 BCE canonical milestones / complexity jumps / global phase transitions / biospheric revolutions corresponded very strongly to major technological breakthroughs – thus, for both series, for the social phase the growth rate of planetary complexity reflects to a very large extent the macro technological growth rate.

- For example, Michael Kremer describes the following reasons why he expects a high correlation between the demographic and technological dynamics:
- the “high population spurs technological change because it increases the number of potential inventors… All else equal, each person's chance of inventing something is independent of population. Thus, in a larger population there will be proportionally more people lucky or smart enough to come up with new ideas" (Kremer 1993: 685); thus, "the growth rate of technology is proportional to total population" (Kremer 1993: 682).

$$y_t = \frac{dn}{dt} = \frac{C_1}{2027 - t} \qquad N_t = \frac{C_2}{2027 - t}$$

$$\frac{dn}{dt} = k * N$$

- Thus, already the theory developed by Taagepera, Kremer, Podlazov, and Tsirel would allow to expect that for the human part of the Big History we should find a rather high correlation between the size of the world population and the global evolutionary macrodevelopment rate.
- However, I am sure that Taagepera, Kremer, Podlazov, and Tsirel themselves will be a bit surprised to see that their theoretical expectation finds such a strong support ($r = 0.997$, $p < 0.001$) for a test employing an apparently rather imperfect proxy of the global technological growth rate

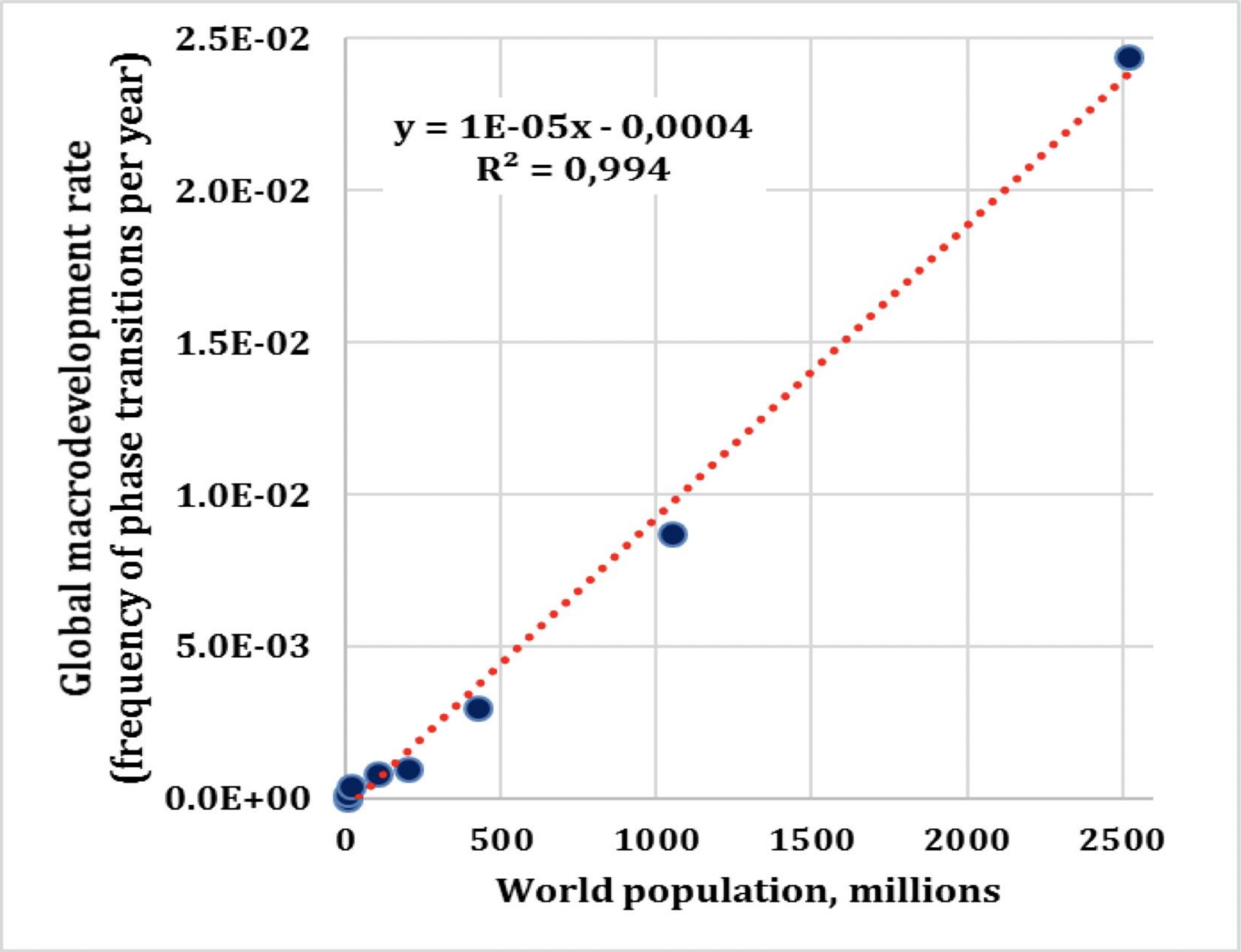


Fig. 2.21 Correlation between the world population and the global macrodevelopment rate in the Panov series, scatterplot with a fitted regression line, **natural scales** (*source of data on the historical world population estimates*: Kremer 1993: 683)

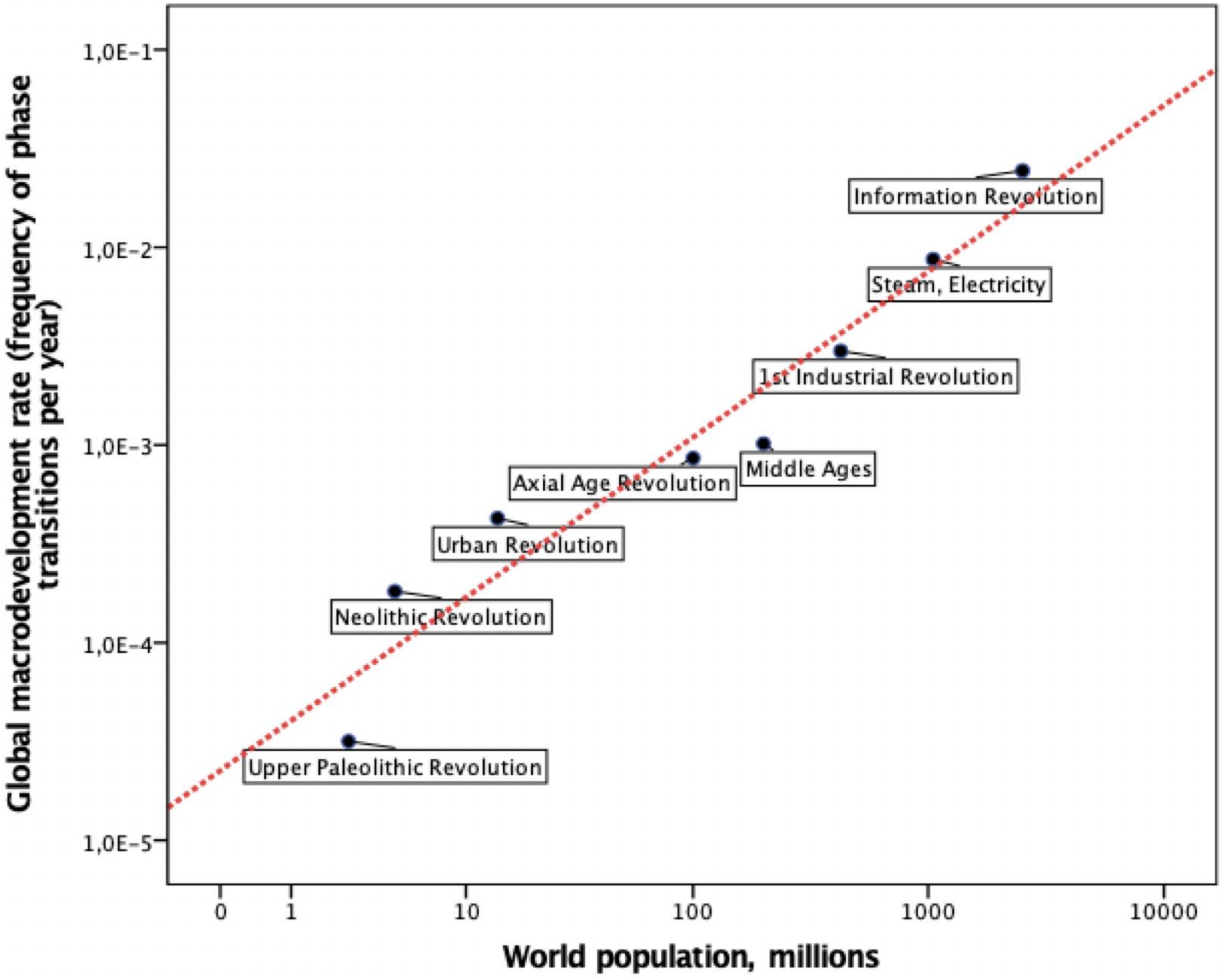


Fig. 2.22 Correlation between the world population and the global macrodevelopment rate in the Panov series, scatterplot with a fitted regression line, **double logarithmic scale** (*source of data on the historical world population estimates*: Kremer 1993: 683)

- Note that we still obtain rather similar results when we use estimates developed more directly to measure the global technological growth rate. Grinin et al. (2020) attempt to estimate specifically the dynamics of the global technological growth rate by identifying the main phase transitions in the specifically technological macrodevelopment (see also Grinin 2006). This series of specific estimates of the global technological growth rates demonstrates a comparably high correlation with the world population size ($r = 0.992$, $p < 0.001$), especially for the period since the start of more reliable estimates of both the world population and global technological growth rates and till the beginning of the systematic decline of the world population growth rates

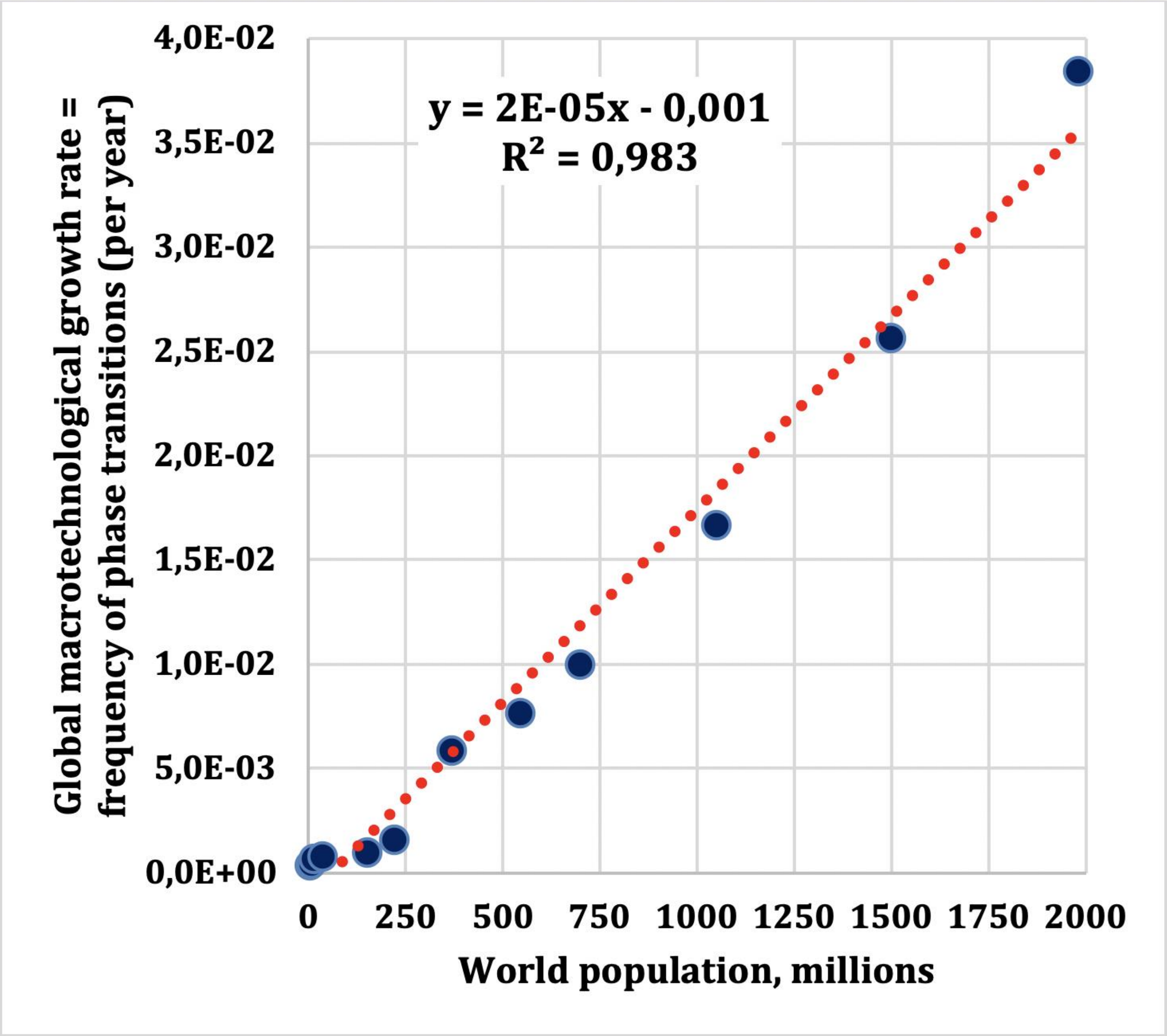
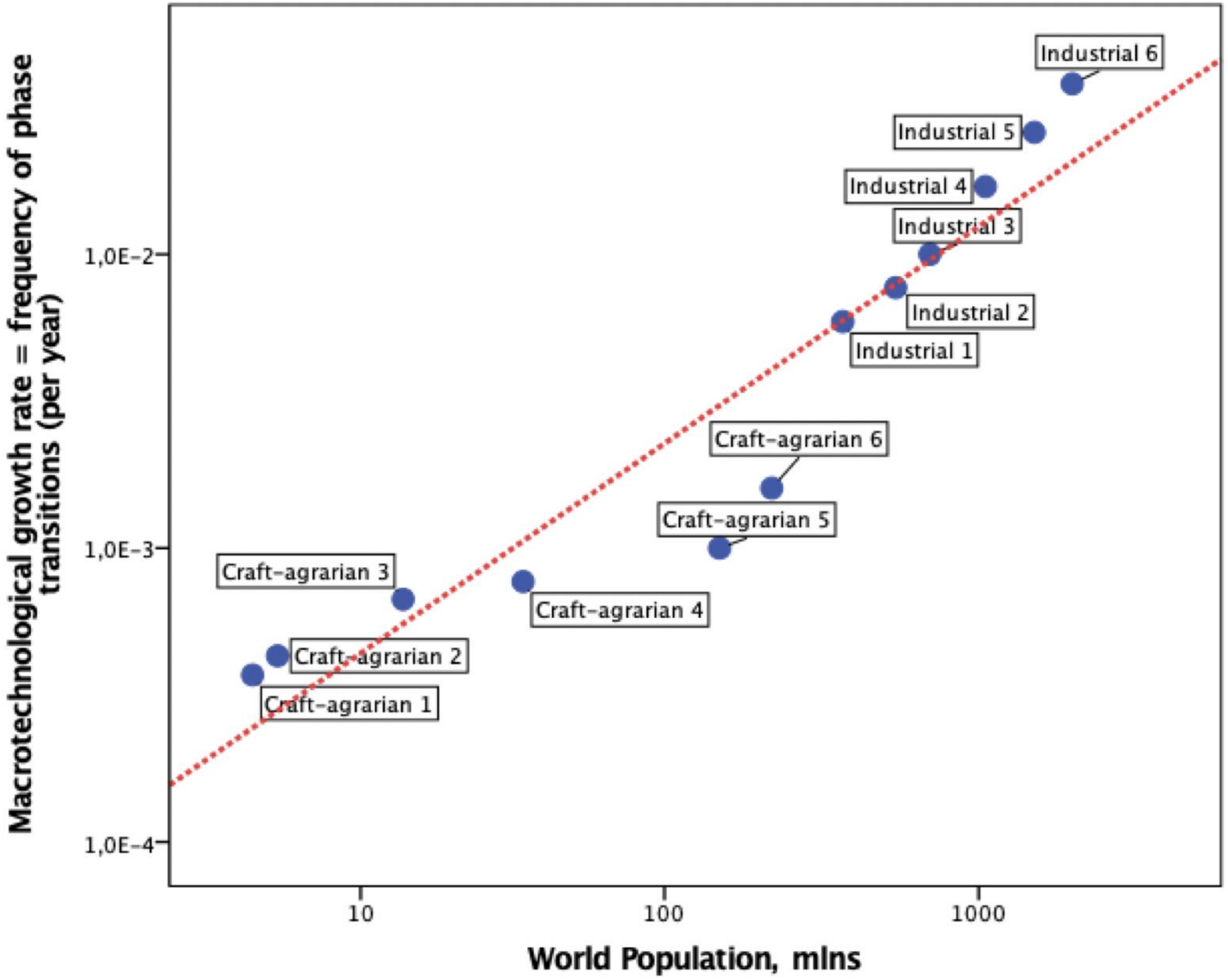


Fig. 2.23 Correlation between the world population and the global macrotechnological growth rate, 8,000 BCE – 1950 CE, scatterplot with a fitted regression line, **natural scales** (*source of data on the historical world population estimates*: Kremer 1993: 683; *source of data on the historical estimates of the global macrotechnological growth rate*: Grinin 2006; Grinin et al. 2020)



Correlation between the world population and the global macrotechnological growth rate, 8,000 BCE – 1950 CE, scatterplot with a fitted regression line, **double logarithmic scale** (*source of data on the historical world population estimates*: Kremer 1993: 683; *source of data on the historical estimates of the global macrotechnological growth rate*: Grinin 2006; Grinin et al. 2020)

- So, our calculations suggest that the fact that the RATES of growth of global complexity in the Panov series (*dn/dt*) and the population of the Earth (*N*) until the beginning of the 1970s grew according to the same law ($x_t = C / 2027\text{-}t$) is by no means an accident, but a manifestation of a fairly deep pattern.
- Thus, at the social phase of the universal and global history, the hyperbolic growth in the rate of increase in global complexity, the hyperbolic increase in the global rate of technological development and the hyperbolic growth of the population of the Earth turn out to be closely related aspects of a single process.
- This, by the way, makes one expect that the global demographic transition and the cessation of the hyperbolic growth of the Earth's population will be accompanied by a radical change in the patterns of the growth of global complexity and technological development, which naturally move more and more from the hyperbolic to a fundamentally different model, which is still waiting to be investigated.

World-Systems Evolution and Global Futures

Andrey V. Korotayev
David J. LePoire *Editors*

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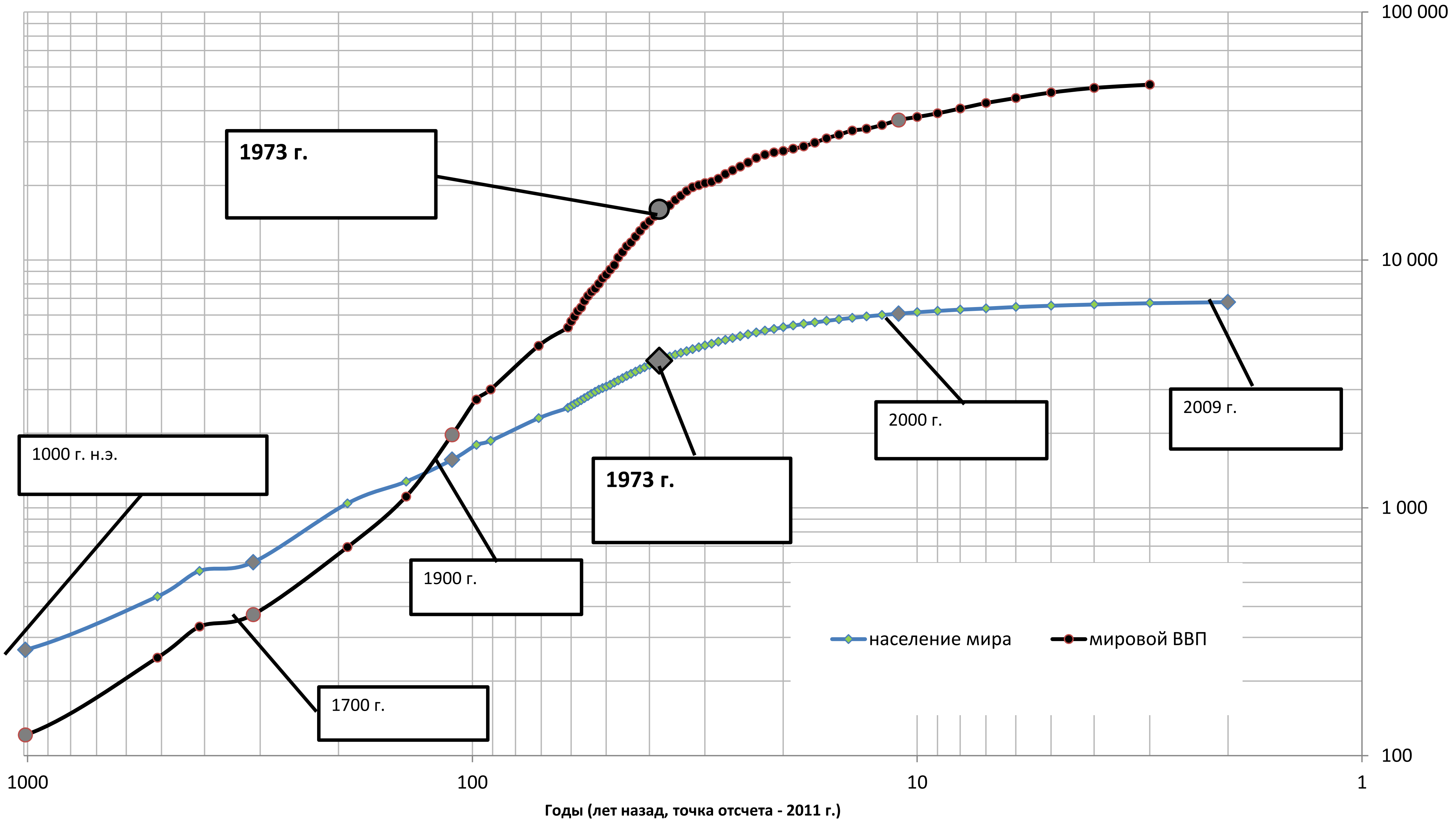
A Big History Perspective

Springer


Эволюция
ЭВОЛЮЦИОННЫЕ
ГРАНИ СИНГУЛЯРНОСТИ
Под редакцией
Л. Е. Гринина,
А. В. Коротаева



1973 г.
1973 г.
1000 г. н.э.
1900 г.
1700 г.
2000 г.
2009 г.
население мира
мировой ВВП
100 000
10 000
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100
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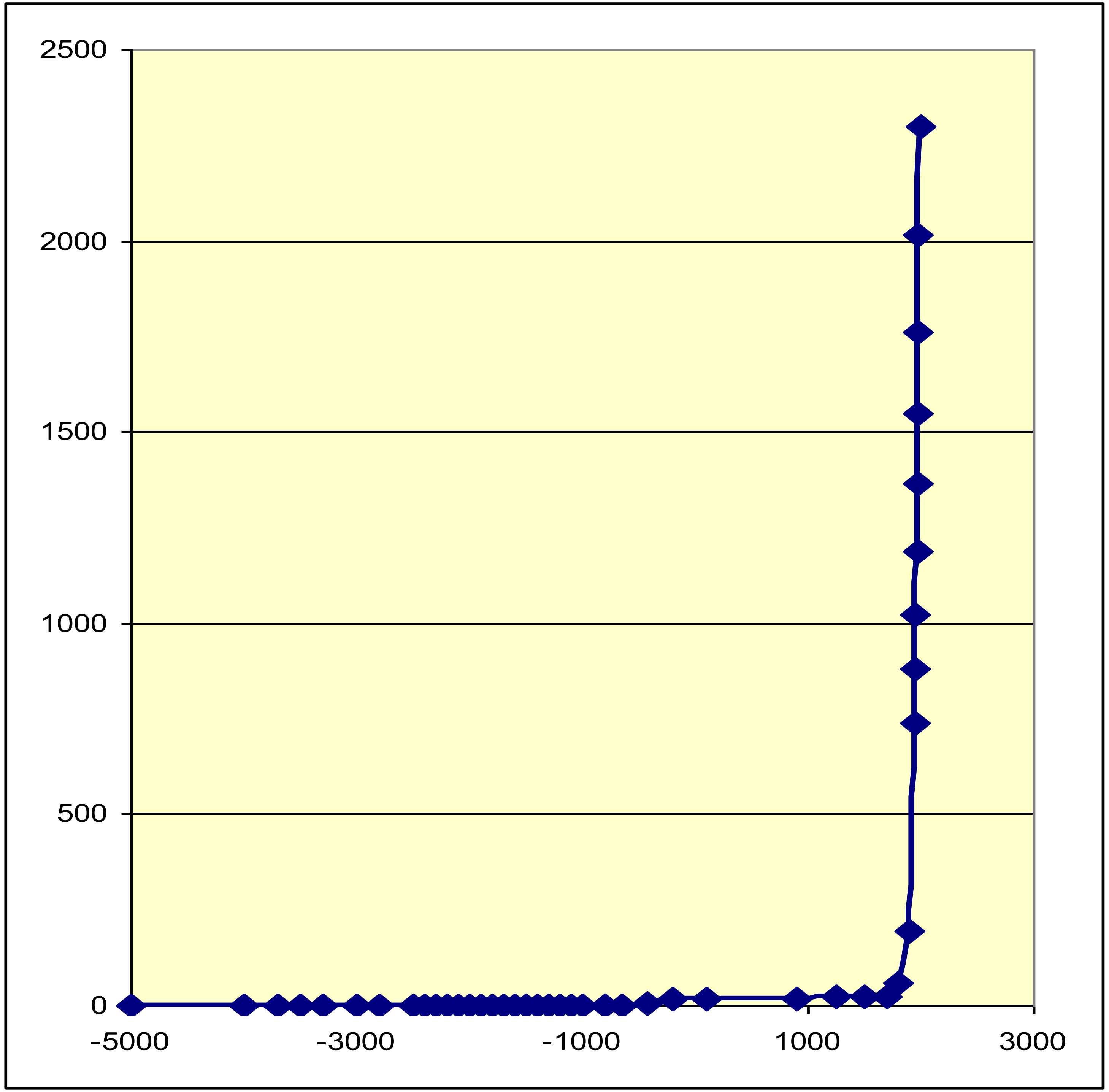
1
Годы (лет назад, точка отсчета - 2011 г.)



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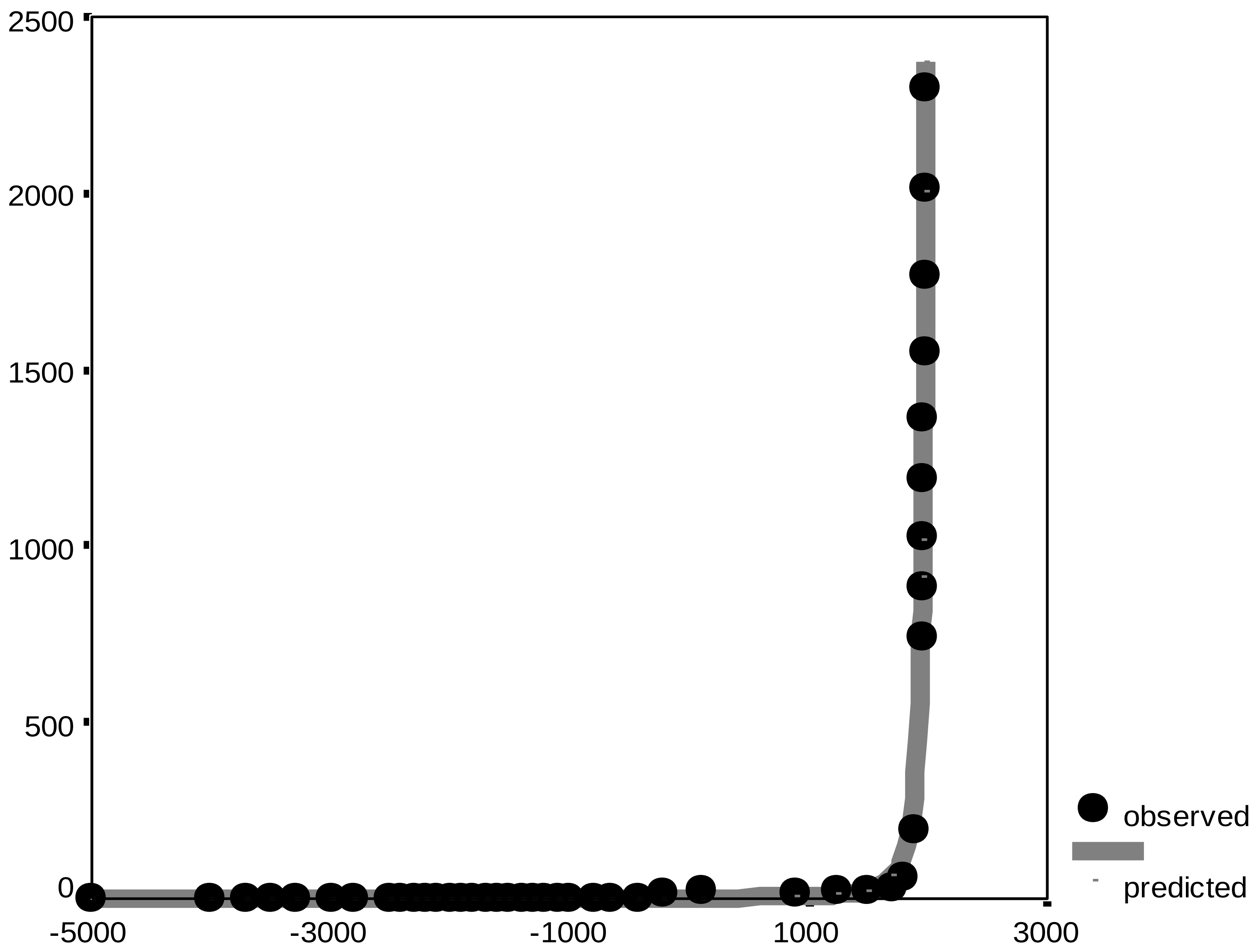
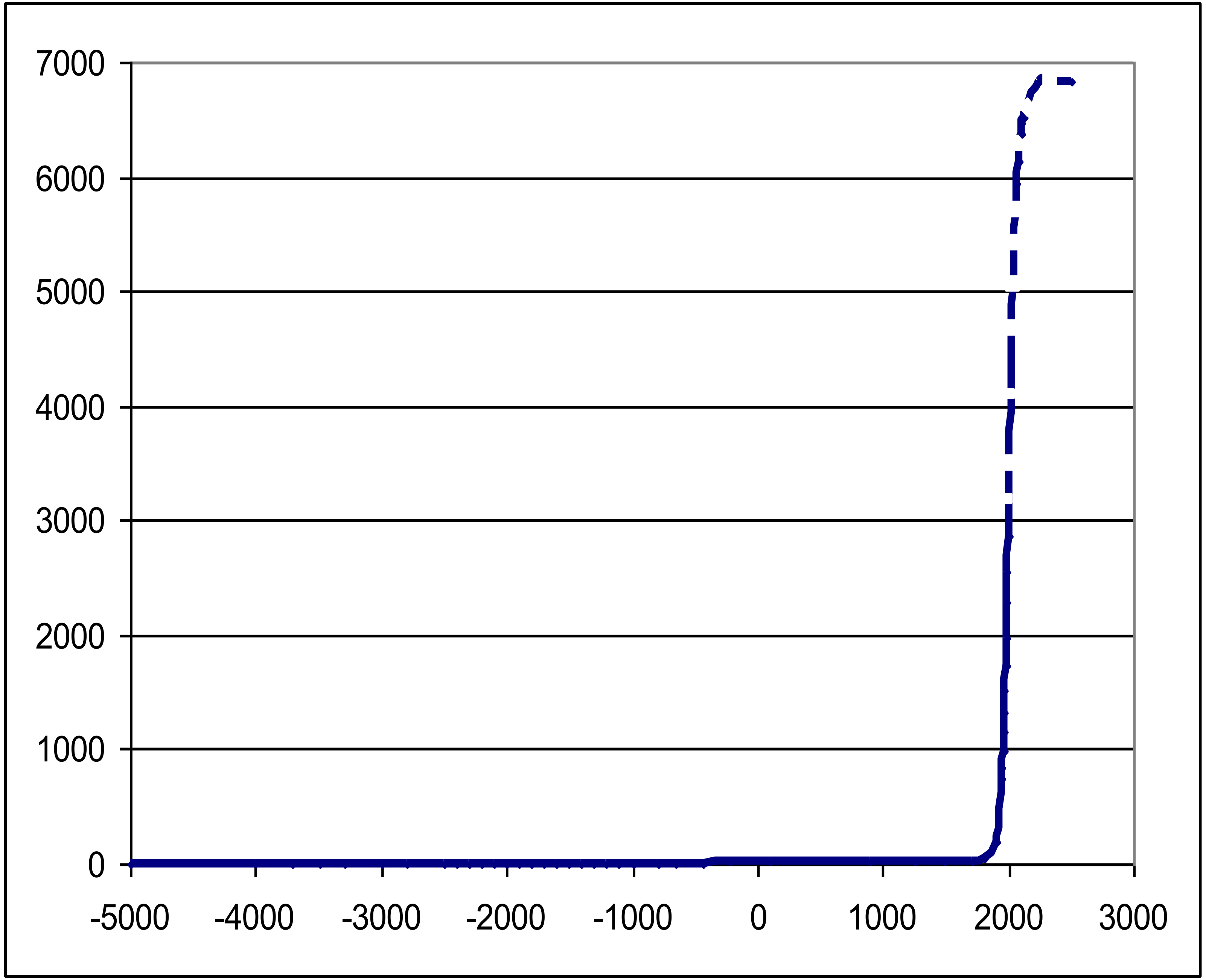


$$U_t = \frac{7705000}{(2047 - t)^2}$$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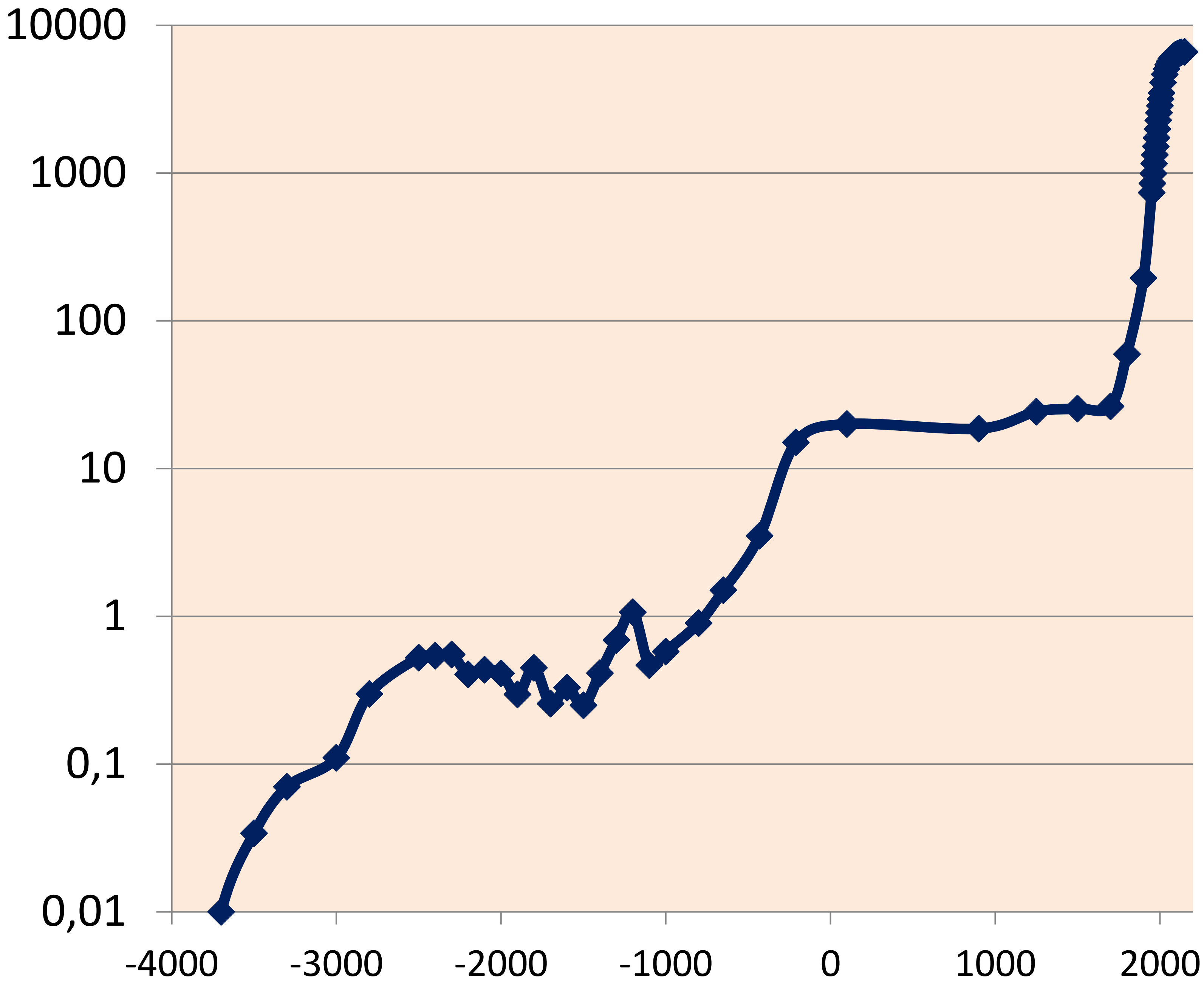

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-3000
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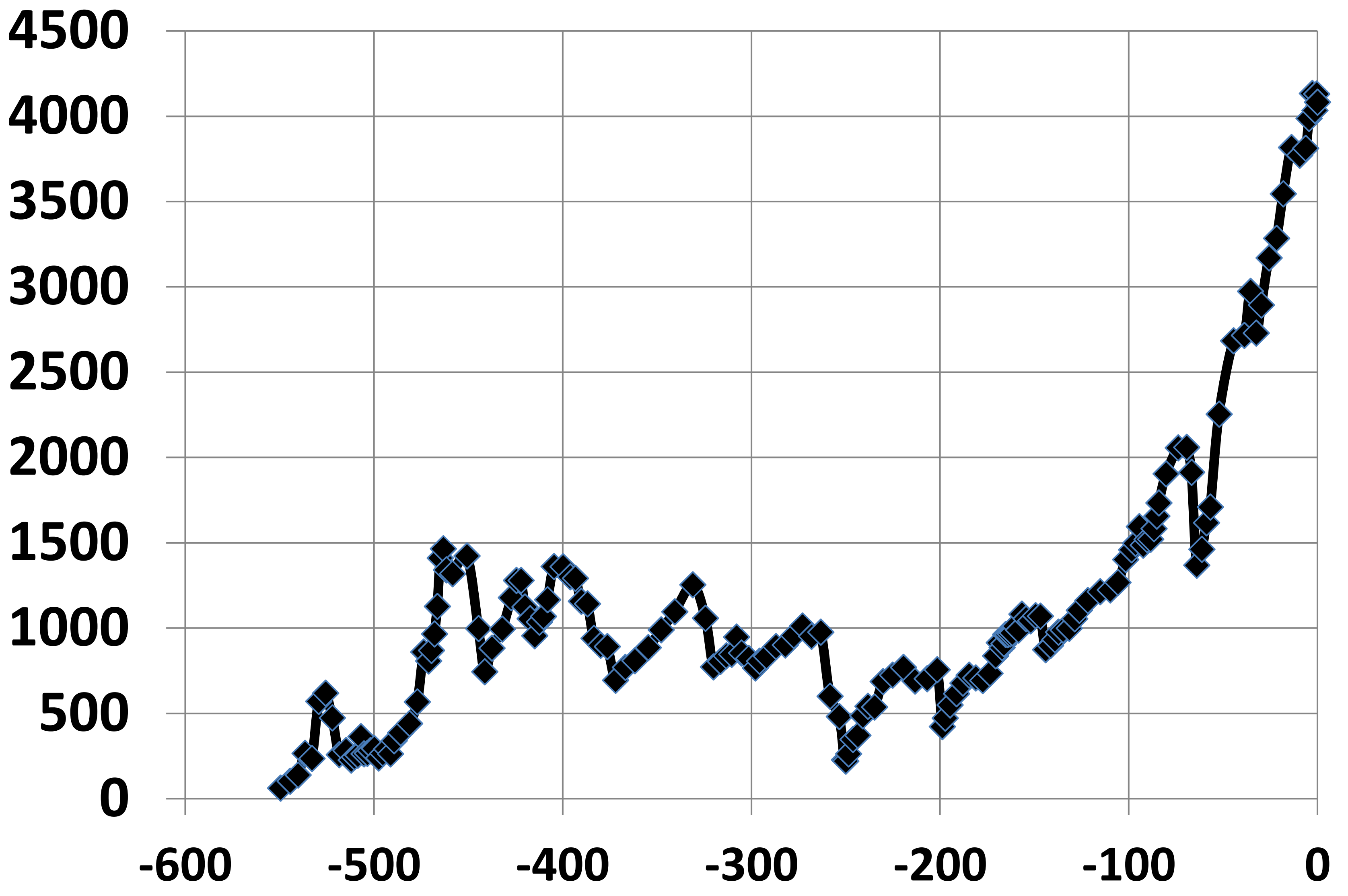
-1000
0
1000
2000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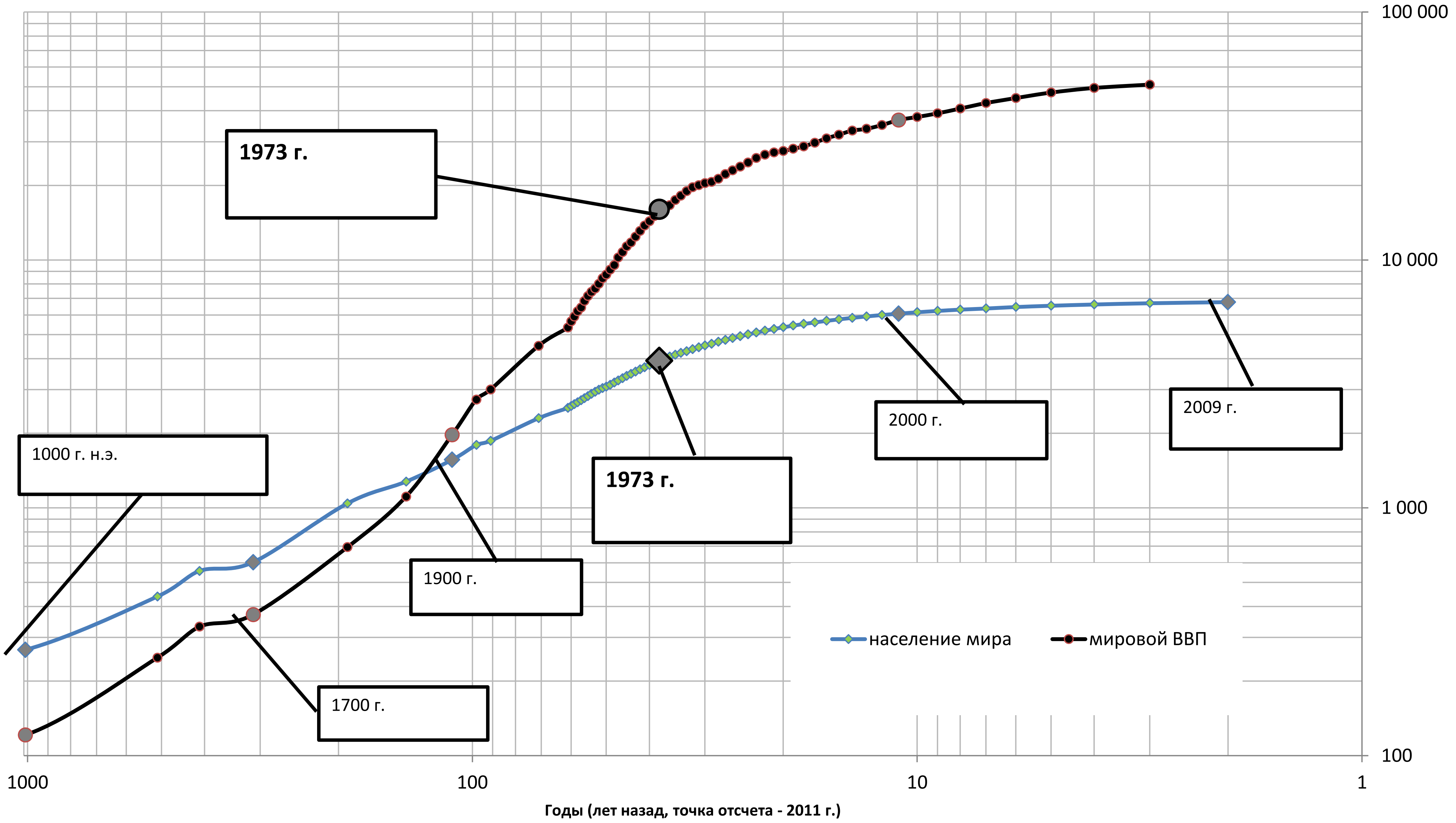
4000
3500
3000
2500
2000
1500
1000
500
0
-600
-500
-400
-300
-200
-100
0


1973 г.
1000 г. н.э.
1973 г.
2000 г.
2009 г.
1900 г.
1700 г.
население мира
мировой ВВП
100 000
10 000
1 000
100
1000
100
10
1
Годы (лет назад, точка отсчета - 2011 г.)

$$t_n = t^* - T/\alpha^n$$

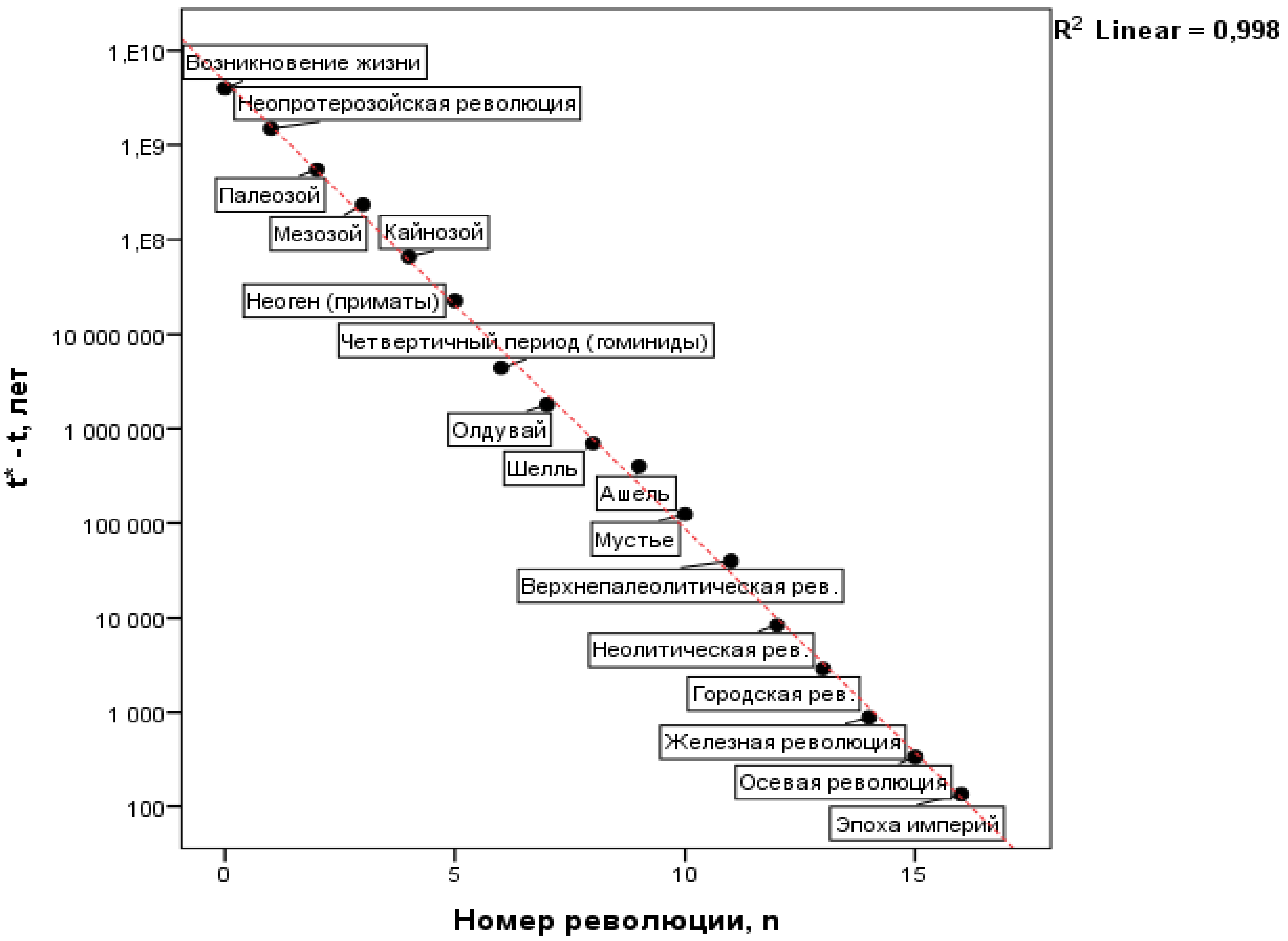
$$\lg(t^* - t_n) = \lg T - n \lg \alpha$$

Сингулярность Панова – Дьяконова

alpha = 2,67

t* = 2004 г. н.э.

Рис. 2. Автомодельность распределения планетарных революций во времени. Тре



R² Linear = 0,998
1,E10
1,E9
1,E8
10 000 000
1 000 000
100 000
10 000
1 000
100
t* - t, лет
Возникновение жизни
Неопротерозойская революция
Палеозой
Мезозой
Кайнозой
Неоген (приматы)
Четвертичный период (гоминиды)
Олдувай
Шелль
Ашель
Мустье
Верхнепалеолитическая рев.
Неолитическая рев.
Городская рев.
Железная революция
Осевая революция
Эпоха империй
0
5
10
15
Номер революции, n

Спасибо
за внимание!

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