Molecular Clock and

Evo – SETI

Theory of Evolution

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Presentation at «LIFE IN A COSMIC CONTEXT» Conference
Trieste, Italy, September 15-17, 2015.

Motoo Kimura (1924-1994)

Discoverer of the **NEUTRAL THEORY** OF EVOLUTION at molecular level (1968).

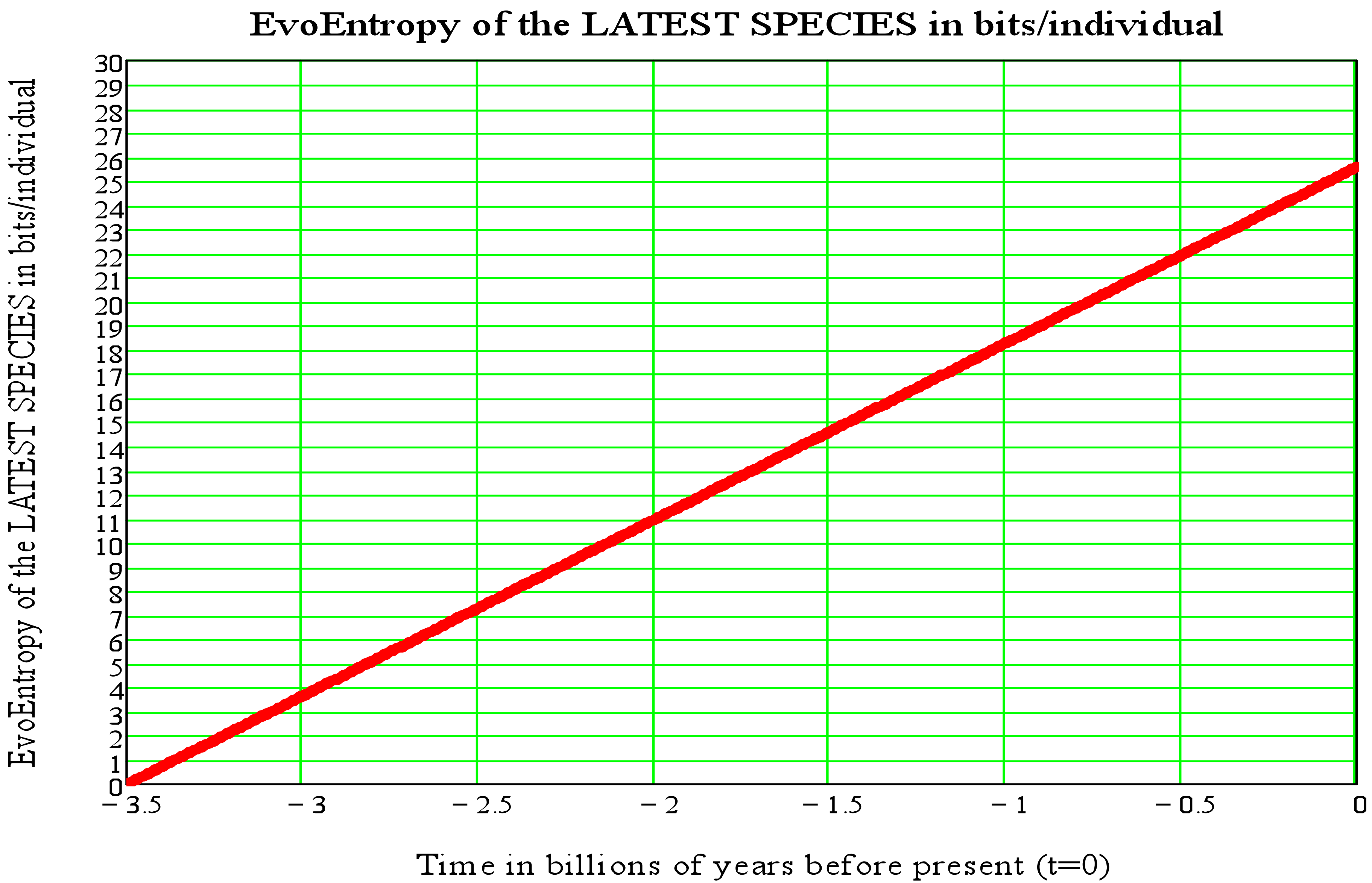
Thus confirming the **MOLECULAR CLOCK.**

To him this presentation is dedicated.

We intend to prove that :

MOLECULAR CLOCK = ENTROPY of b-lognormals

Evo-ENTROPY = MOLECULAR CLOCK



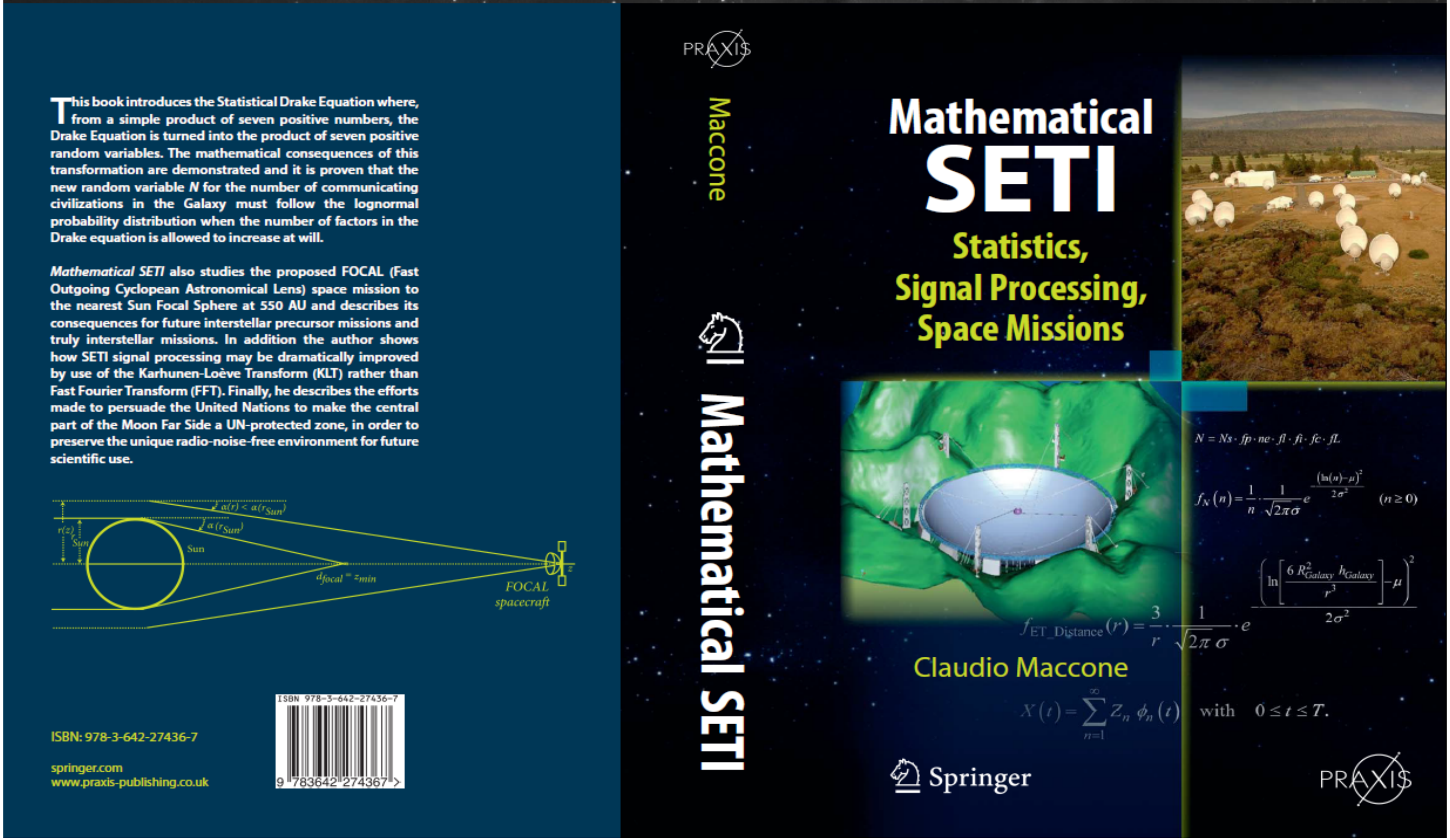
ABSTRACT

The number of newly discovered exoplanets keeps increasing constantly, especially for smaller planets, possibly similar to Earth.

The time is thus ripe to strengthen SETI, the Search for ExtraTerrestrial Intelligence.

In 2012 the author published a book entitled
"Mathematical SETI",
that is a textbook for University courses on SETI.

700-pages BOOK about "Mathematical SETI"



TALK's SCHEME

Part 1: The STATISTICAL DRAKE EQUATION

Part 2: LIFE in time as a b-LOGNORMAL

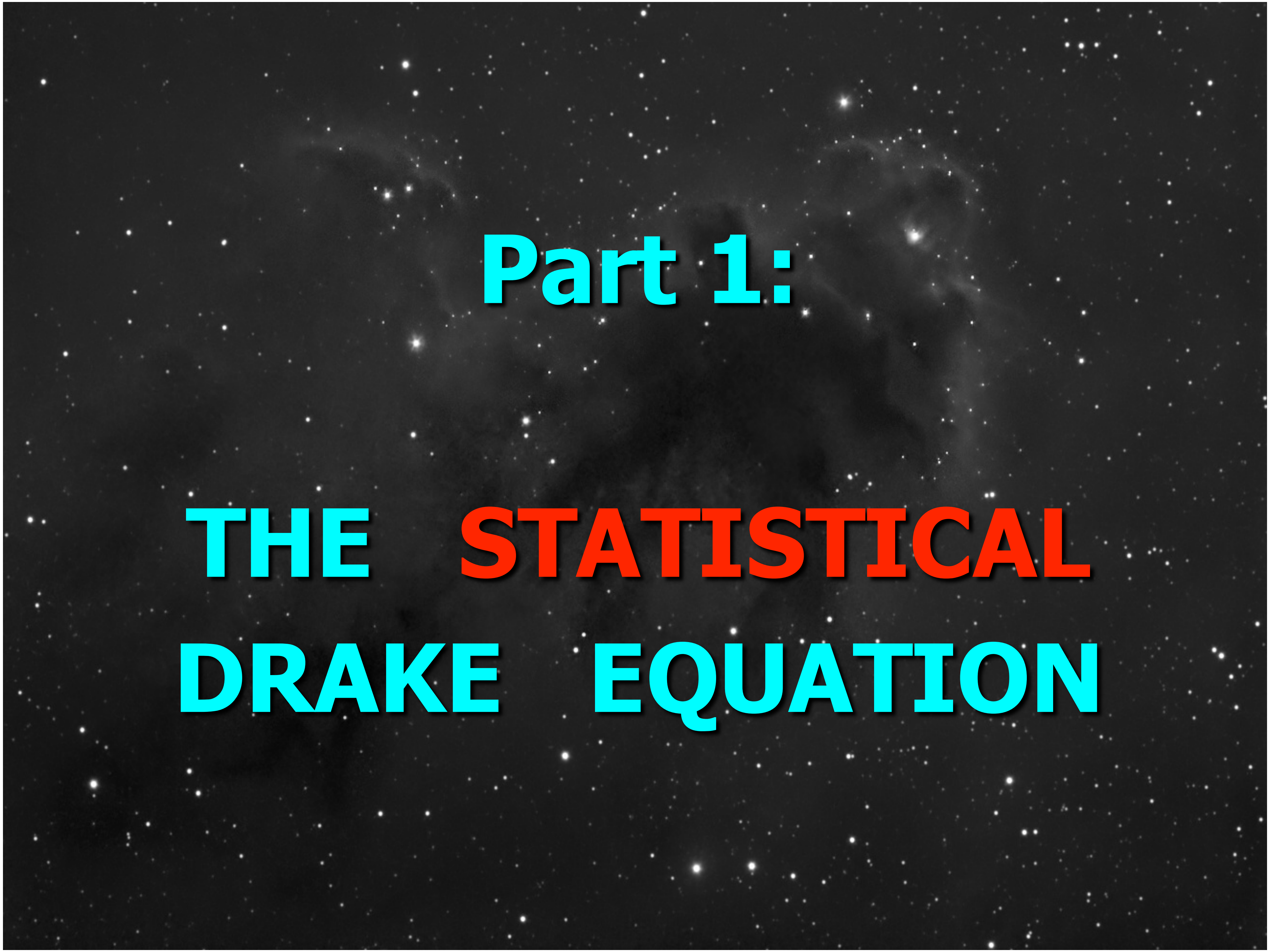
Part 3: EXPONENTIAL Peak-Locus Theorem

Part 4: Geometric Brownian Motion (GBM)

Part 5: CLADISTICS: Species = b-LOGNORMALS

Part 6: ENTROPY as EVOLUTION MEASURE

Part 7: Mass Extinctions


Part 1:
THE STATISTICAL
DRAKE EQUATION

The Classical Drake Equation /1

- In 1961 Frank Drake introduced his famous "Drake equation" described at the web site http://en.wikipedia.org/wiki/Drake_equation. It yields the number *N* of communicating civilizations in the Galaxy:

$$N = Ns \cdot fp \cdot ne \cdot fl \cdot fi \cdot fc \cdot fL$$

- Frank Donald Drake (b. 1930)

The Classical Drake Equation /2

- The meaning of the seven factors in the Drake equation is well-known.
- The middle factor fl is Darwinian Evolution.
- In the classical Drake equation the seven factors are just POSITIVE NUMBERS. And the equation simply is the PRODUCT of these seven positive numbers.
- It is claimed here that Drake's approach is too "simple-minded", since it does NOT yield the ERROR BAR associated to each factor!

The STATISTICAL Drake Equation /1

- If we want to associate an ERROR BAR to each factor of the Drake equation then…
- … we must regard each factor in the Drake equation as a RANDOM VARIABLE.
- Then the number *N* of communicating civilizations also becomes a random variable.
- This we call the STATISTICAL DRAKE EQUATION and studied in our mentioned reference paper of 2010 (Acta Astronautica, Vol. 67 (2010), pages 1366-1383)

The STATISTICAL Drake Equation /2

- Denoting each random variable by capitals, the STATISTICAL DRAKE EQUATION reads

$$N = \prod_{i=1}^{7} D_i$$

- Where the D sub i ("D from Drake") are the 7 random variables, and *N* is a random variable too ("to be determined").

Generalizing the STATISTICAL Drake Equation to ANY NUMBER OF FACTORS /1

- Consider the statistical equation

$$N = \prod_{i=1}^{any\_number} D_i$$

- This is the generalization of our Statistical Drake Equation to the product of ANY finite NUMBER of positive random variables.
- Is it possible to determine the statistics of *N* ?
- Rather surprisingly, the answer is "yes" !

Generalizing the STATISTICAL Drake Equation to ANY NUMBER OF FACTORS /2

- First, you obviously take the natural log of both sides to change the finite product into a finite sum

$$\ln(N) = \sum_{i=1}^{any\_number} \ln(D_i)$$

- Second, to this finite sum one can apply the CENTRAL LIMIT THEOREM OF STATISTICS. It states that, in the limit for an infinite sum, the distribution of the left-hand-side is NORMAL.

- This is true WHATEVER the distributions of the random variables in the sum MAY BE.

Generalizing the STATISTICAL Drake Equation to ANY NUMBER OF FACTORS /3

- So, the random variable on the left is NORMAL, i.e.

$$\ln(N)$$

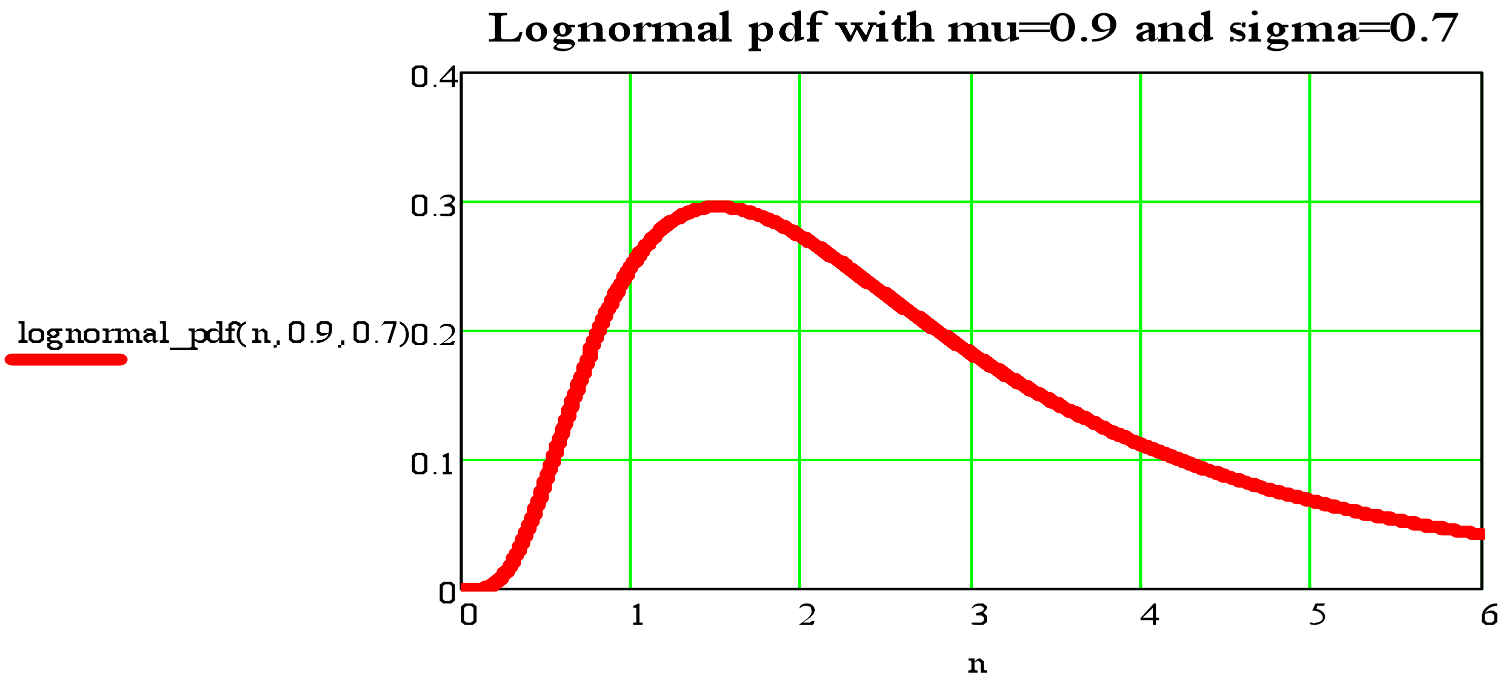
- Thus, the random variable *N* under the log must be LOG-NORMAL and its distribution is determined!

- One must, however, determine the mean value and variance of this log-normal distribution in terms of the mean values and variances of the factor random variables. This is DIFFICULT. But it can be done, for example, by a suitable numeric code that this author wrote in MathCad language.

LOGNORMAL pdf

$$\text{lognormal\_pdf}(n,\mu,\sigma) = \frac{1}{\sqrt{2\pi}\,\sigma\, n}\, e^{-\frac{(\log(n)-\mu)^2}{2\sigma^2}}$$

This pdf starts at 0, that is: $n \geq 0$.



Conclusion

The number of Signaling Civilizations is LOGNORMALLY distributed

- Our Statistical Drake Equation, now Generalized to any number of factors, embodies as a special case the Statistical Drake Equation with just 7 factors.

- The conclusion is that the random variable *N* (the number of communicating ET Civilizations in the Galaxy) is LOG-NORMALLY distributed.

- The classical "old pure-number Drake value" of *N* is now replaced by the MEAN VALUE of such a log-normal distribution.

- But we now also have an ERROR BAR around it !

REFERENCE PAPER :

- The Statistical Drake Equation
- Acta Astronautica, Vol. 67 (2010) p. 1366-1383.

Acta Astronautica 67 (2010) 1366–1383

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Acta Astronautica

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The Statistical Drake Equation

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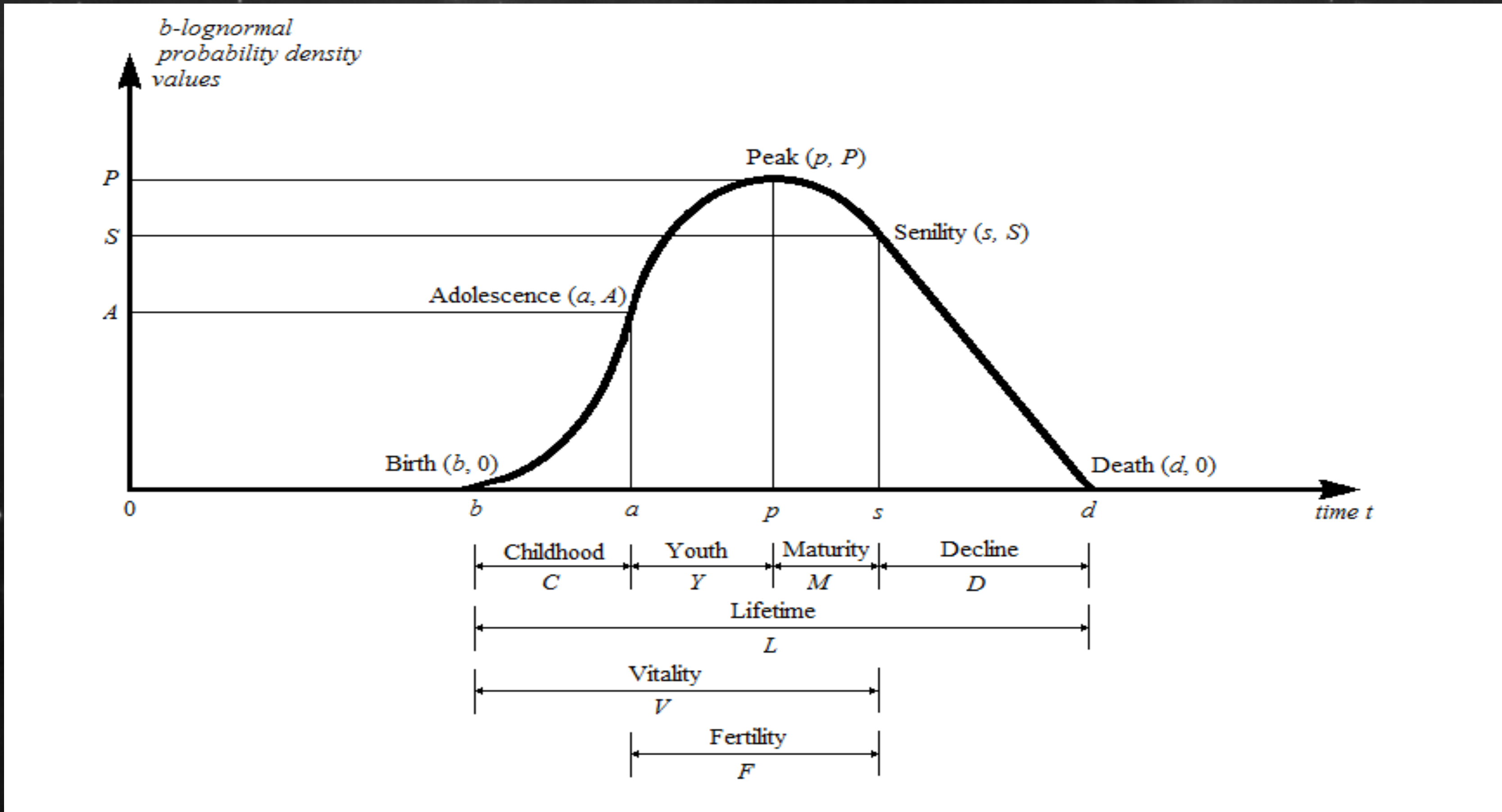
Part 2:
b-LOGNORMALS in time as the LIFE of a cell, of an animal, of a human, a civilization (f sub i) even ET (f sub L)

LIFE as a FINITE b-LOGNORMAL

- The lifetime of a cell, an animal, a human, a civilization can be modeled as a b-lognormal with tail REPLACED at senility by the descending TANGENT. The interception at time axis is DEATH=d.



LIFE as a FINITE b-LOGNORMAL

- The equation of a INFINITE b-lognormal is :

$$\text{b-lognormal\_pdf}(t;\mu,\sigma,b) = \frac{1}{\sqrt{2\pi}\,\sigma\,(t-b)}\, e^{-\frac{(\ln(t-b)-\mu)^2}{2\sigma^2}}$$

This pdf only starts at time $t = b$, that is: $b < t$

- The lifetime of a cell, an animal, a human, a civilization can be modeled as a FINITE b-lognormal: namely an infinite b-lognormal whose TAIL has been REPLACED at senility by the descending TANGENT STRAIGHT LINE. The interception of this straight line at time axis is DEATH=d.

LIFE as a FINITE b-LOGNORMAL

b = birthtimeissupposedtobeknown.

adolescence ϑ=abe 22 ασb 22+43 22 — I

b-lognormal$_{peak}$ ϑ=pbeebe I σ2σ 22

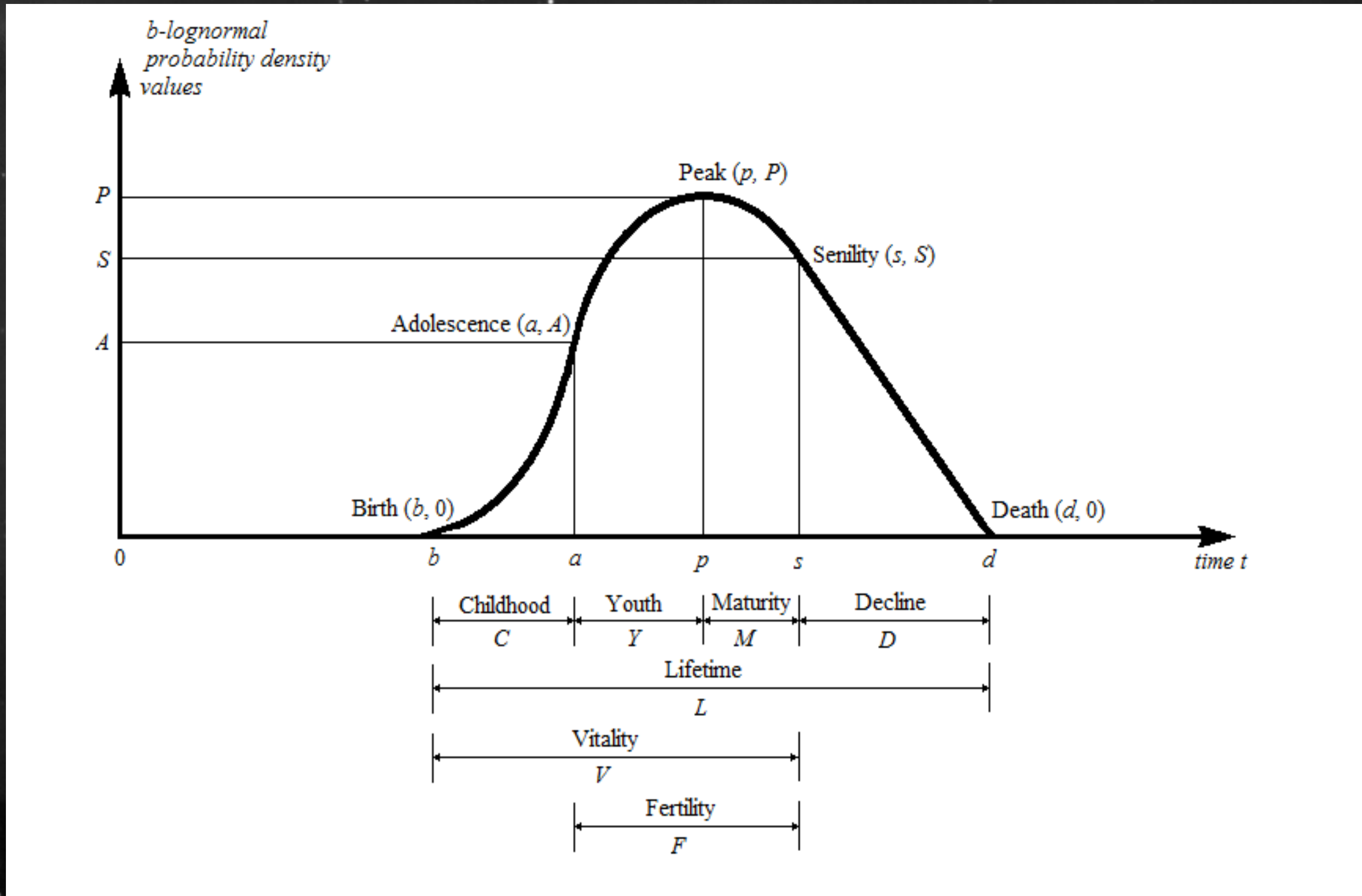
senility ϑ=sbe ασb 22+43 2+ 22 I

db=+ (√σ3+4)² e ασb 22+43 2+ 22 I / 4.

Childhood ϑ=Cabe 22 ασb 22+43 22 — I

Youth ϑ=Ypaee I σ 2 22 ασb 22+43 22 — I

Maturity ϑ=M2pee ασb 22+43 2+ 22 I I σ 2



Decline ϑ=D2eex (√σσσσ4+)² e ασb 22+43 2+ 22 I / 42 σσσσσ4343 2+2+ 2222 I I √ — (√)

Lifetime.==D2db (√σ3+4)² e ασb 22+43 2+ 22 I / 4

Fertility 2ϑ=F2eex ασσσσ3433 2+2+2+ 22222 I I I √ — — φ σ √ 2 + 4 τ÷ τ÷ 2 φε

Vitality ϑ=V2be ασb 22+43 2+ 22 I

LIFE as FINITE b-LOGNORMAL

- Let a = increasing inflexion, s = decreasing inflexion.
- Then any b-lognormal has birth time (b), adolescence time (a), peak time (p) and senility time (s).
- HISTORY FORMULAE : GIVEN (b, s, d) it is always possible to compute the corresponding b-lognormal by virtue of the HISTORY FORMULAE :

$$O = \frac{ds2}{\sqrt{db22b}\,\sqrt{}}$$

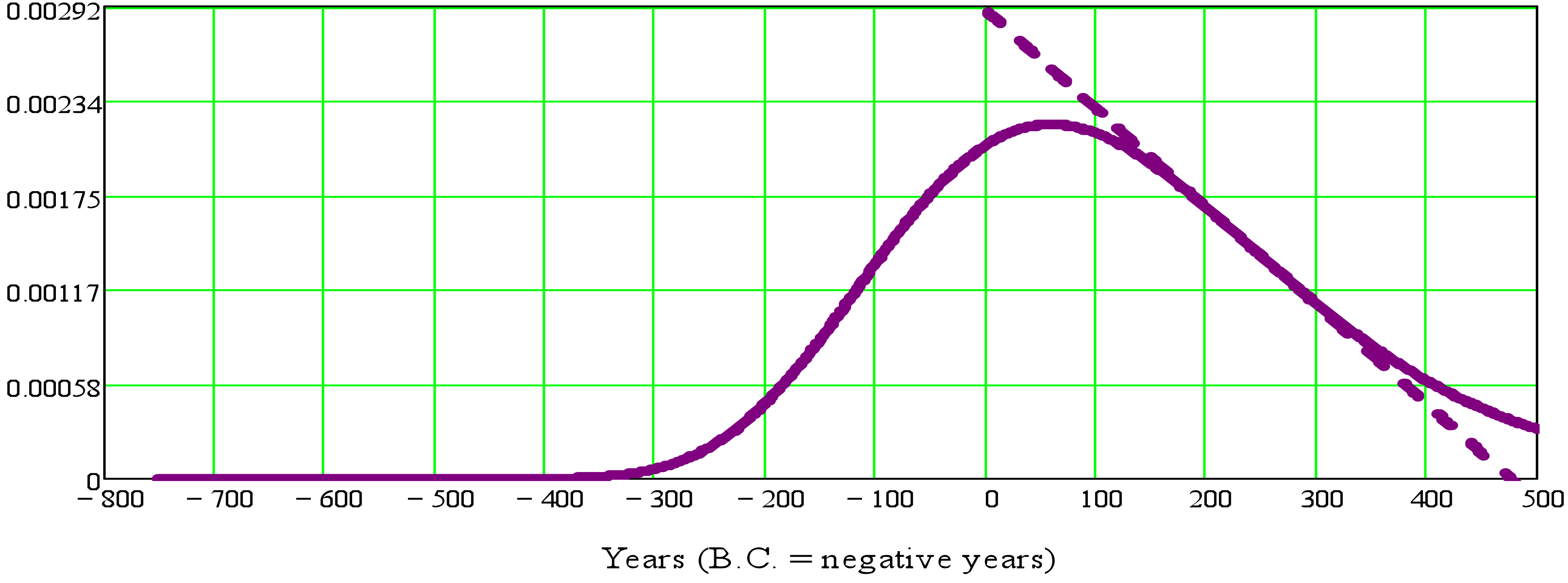
$$\omega$$

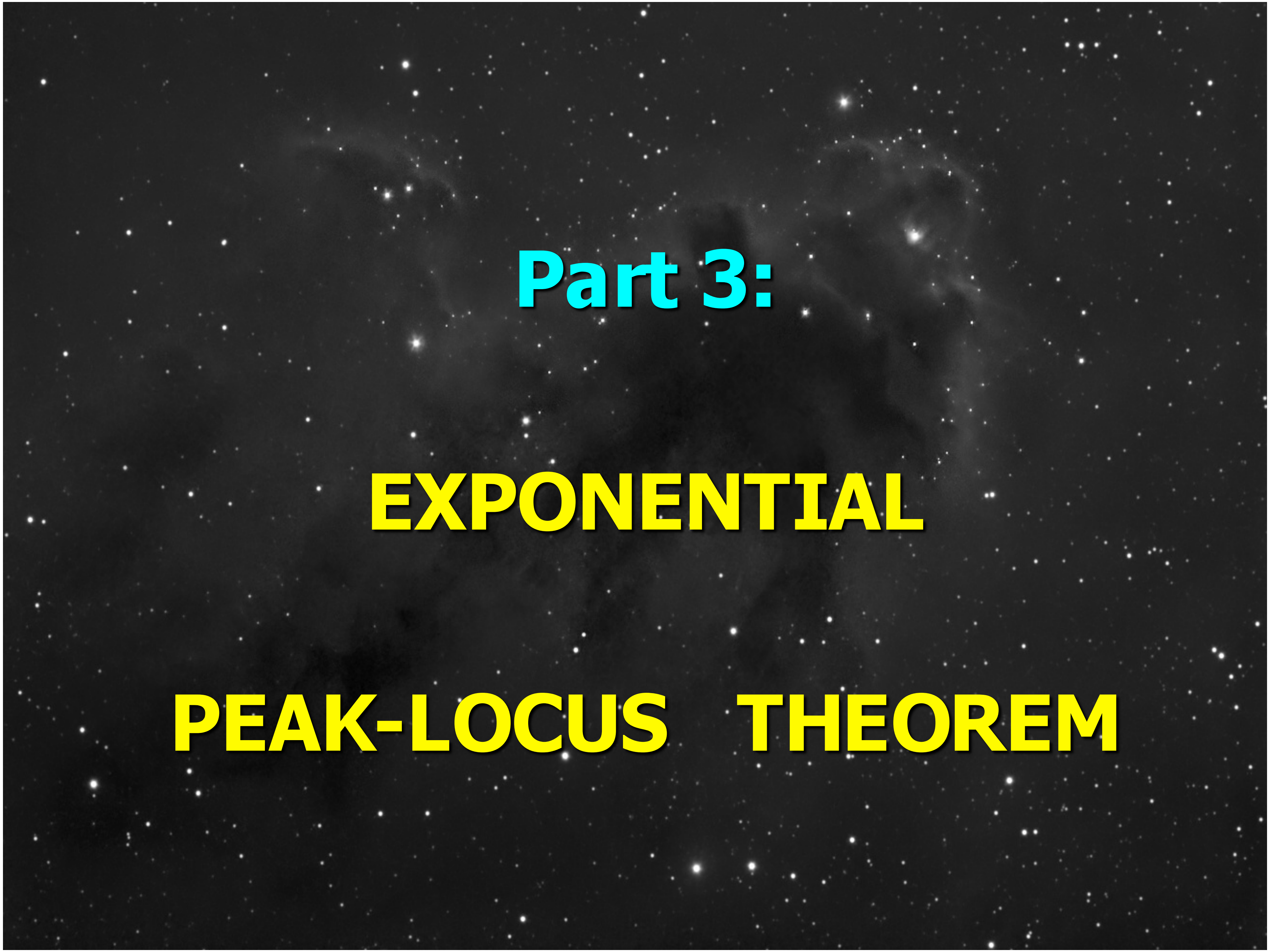
$$I = 2\ln(sb\quad)\quad \frac{23sdb2sd b d\;(\quad)}{(db2s2db)^{2}}$$

LIFE as FINITE b-LOGNORMAL

- Let a = increasing inflexion, s = decreasing inflexion.
- Then any b-lognormal has birth time (b), adolescence time (a), peak time (p) and senility time (s).
- Rome's civilization: b=-753, a=-146, p=59, s=235.

FINITE b-lognormal of the CIVILIZATION OF ROME (753 B.C. - 476 A.D).




Part 3:
EXPONENTIAL
PEAK-LOCUS THEOREM

REFERENCE PAPER :

- A Mathematical Model for Evolution and SETI
- Origins of Life and Evolution of Biospheres (OLEB), Vol. 41 (2011), pages 609-619.

Orig Life Evol Biosph (2011) 41:609–619
DOI 10.1007/s11084-011-9260-3

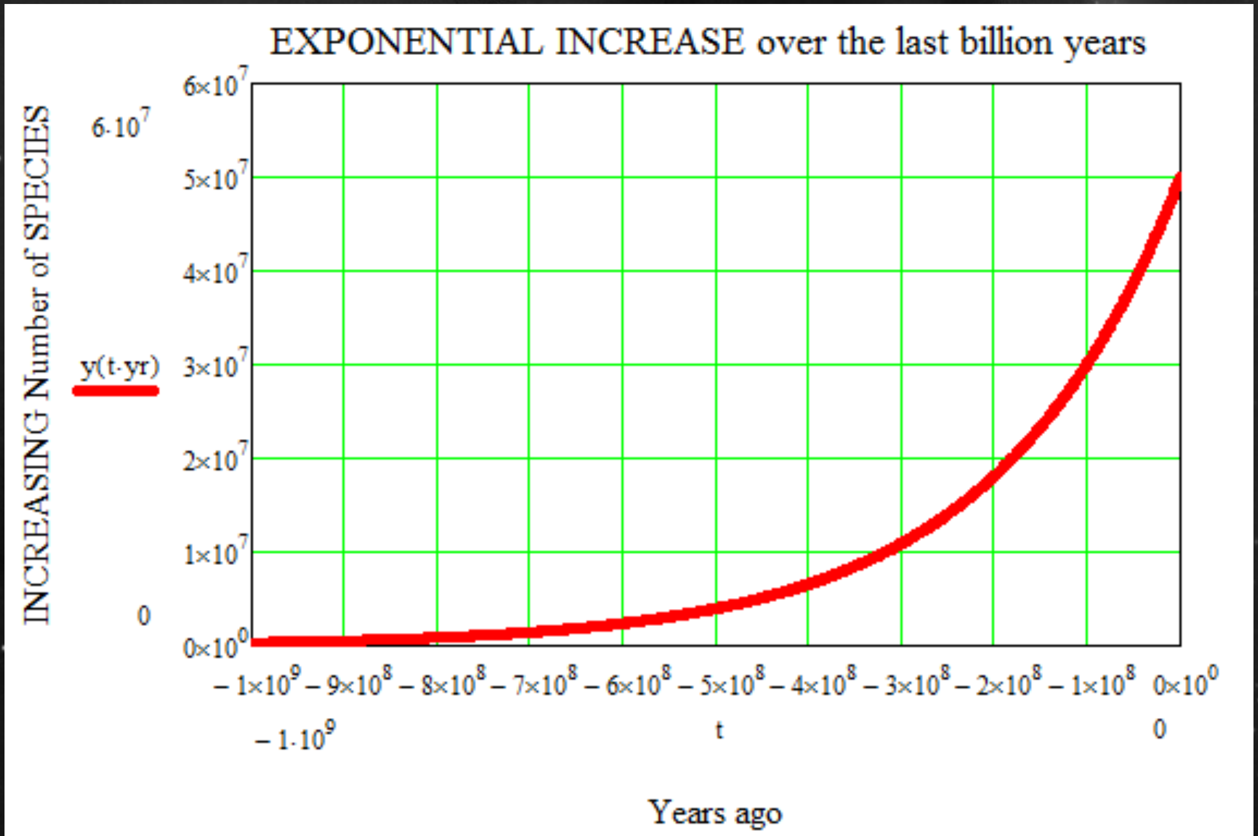
EVOLUTIONARY PERSPECTIVES

A Mathematical Model for Evolution and SETI

Claudio Maccone

Darwinian EXPONENTIAL GROWTH

- Life on Earth evolved since 3.5 billion years ago.
- The number of Species GROWS EXPONENTIALLY: assume that today 50 million species live on Earth
- Then:



Darwinian EXPONENTIAL GROWTH

- Life on Earth evolved since 3.5 billion years ago.
- The number of Species GROWS EXPONENTIALLY: assume that today 50 million species live on Earth
- Then:

$$\text{exponential curve in time :} \quad E(t) = A e^{Bt}$$

- with:

$$A = 50 \text{ million species} = 5 \times 10^{7} \text{ species}$$

$$B = \frac{\ln\left(E(t_2)\right)}{t_1} = \frac{\ln\left(5\times10^{7}\right)}{3.5\times10^{9}\,\text{year}} = \frac{1.605\times10^{-16}}{\text{sec}}.$$

Invoking b-LOGNORMALS i.e. LOGNORMALS starting at *b* =birth

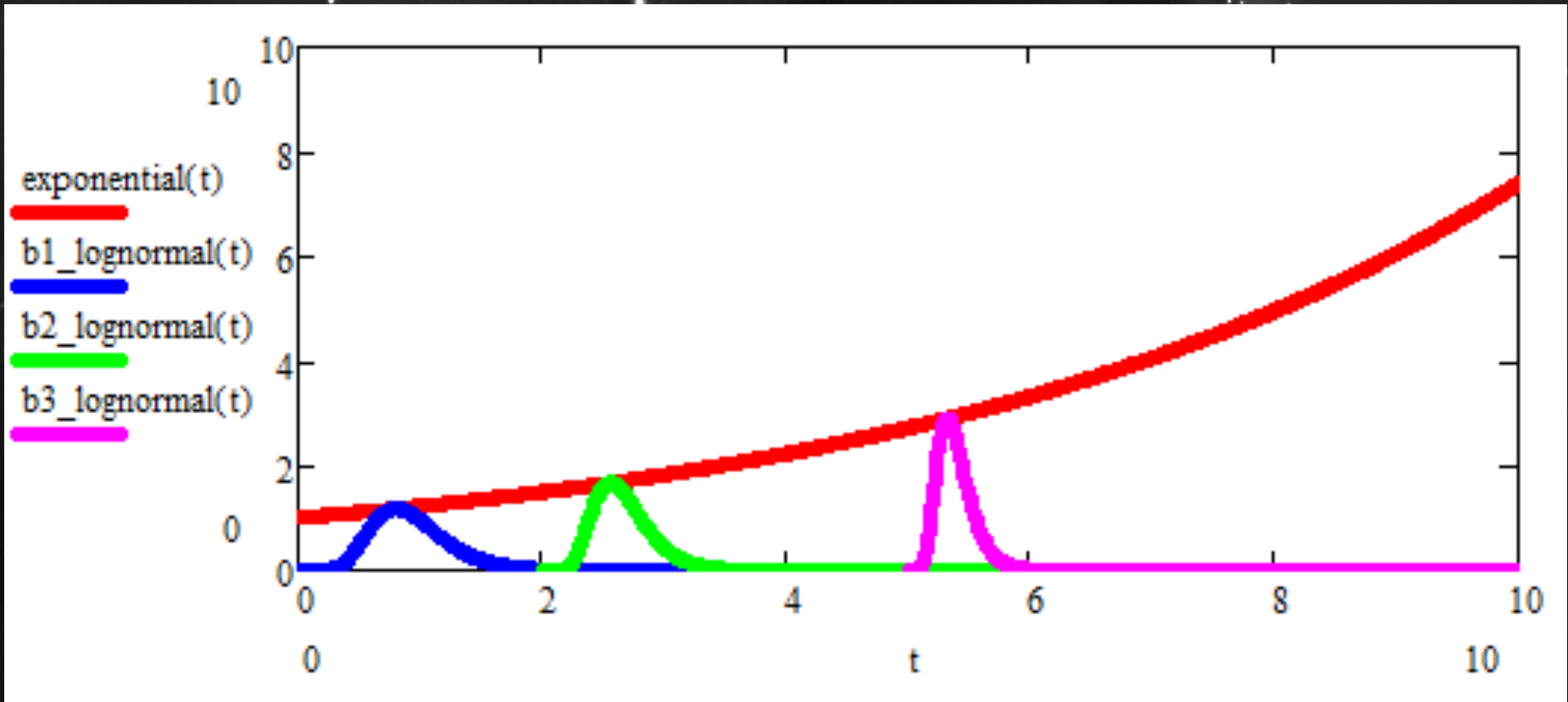
$$\text{b-lognormal}(t;\mu,\sigma,b) = \frac{1}{\sqrt{2\pi}\,\sigma\times(t-b)}\, e^{-\frac{(\ln(t-b)-\mu)^2}{2\sigma^2}}$$

This pdf only starts at time, that is: $b \le t$

- b-lognormals are just lognormals starting at any finite positive instant $b > 0$, that is supposed to be known.
- b-lognormals are thus a family of probability density functions with three parameters: μ, σ, and b.
- μ and b are REAL variables, but σ must be POSITIVE.

EXPONENTIAL as "ENVELOPE" of b-LOGNORMALS

- Each b-lognormal has its peak on the exponential.
- PRACTICALLY an "Envelope".



b-LOGNORMAL PEAK /1

b-lognormalpeakabscissa $\vartheta = p\, b e^{I\,2\,O^{2}}$

ω

b-lognormalpeakordinate. $\vartheta = P \dfrac{e^{\frac{O^2}{2} 2I}}{\sqrt{2M}O}$

- QUESTION: Is it POSSIBLE to match the second equation (peak ordinate) with the EXPONENTIAL curve of the increasing number of Species ?
- YES, by setting:

b-LOGNORMAL PEAK /2

· exponential ordinate at t = p: $E(p) = A e^{Bp}$

b-lognormal peak ordinate at : $t = p$: $P = \dfrac{e^{\frac{O^2}{2} - 2I}}{\sqrt{2M}O}$

- We noticed that it is POSSIBLE to MATCH these two equations EXACTLY just upon setting:

$$A = \frac{1}{\sqrt{2M}O}$$

$$Bp = 2\frac{O^2}{2} - I$$

b-LOGNORMAL PEAK /3

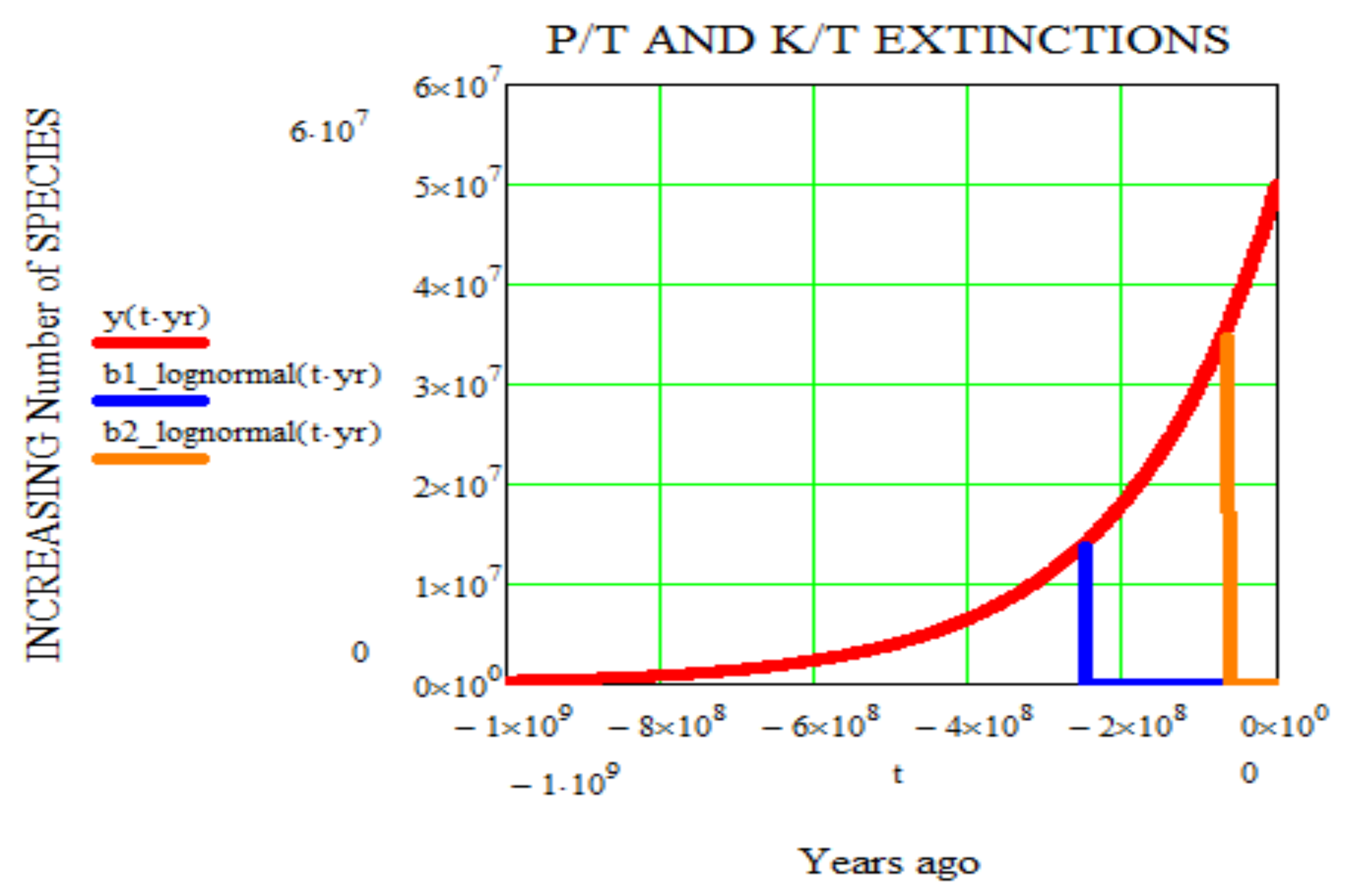
- Moreover, the last two equations can be INVERTED, i.e. solved for μ and σ EXACTLY, thus yielding:

$$O = \frac{1}{\sqrt{2MA}}$$

$$I = 2 = 2\frac{O^2}{24} \quad BpBp\frac{1}{MA^2}$$

- These two equations prove that, knowing the exponential (i.e. A and B) and peak time p, the b-lognormal HAVING ITS PEAK EXACTLY ON THE EXPONENTIAL is perfectly determined (i.e. its μ and σ are perfectly determined given A, B and p. This is the BASIC RESULT to make further progress.

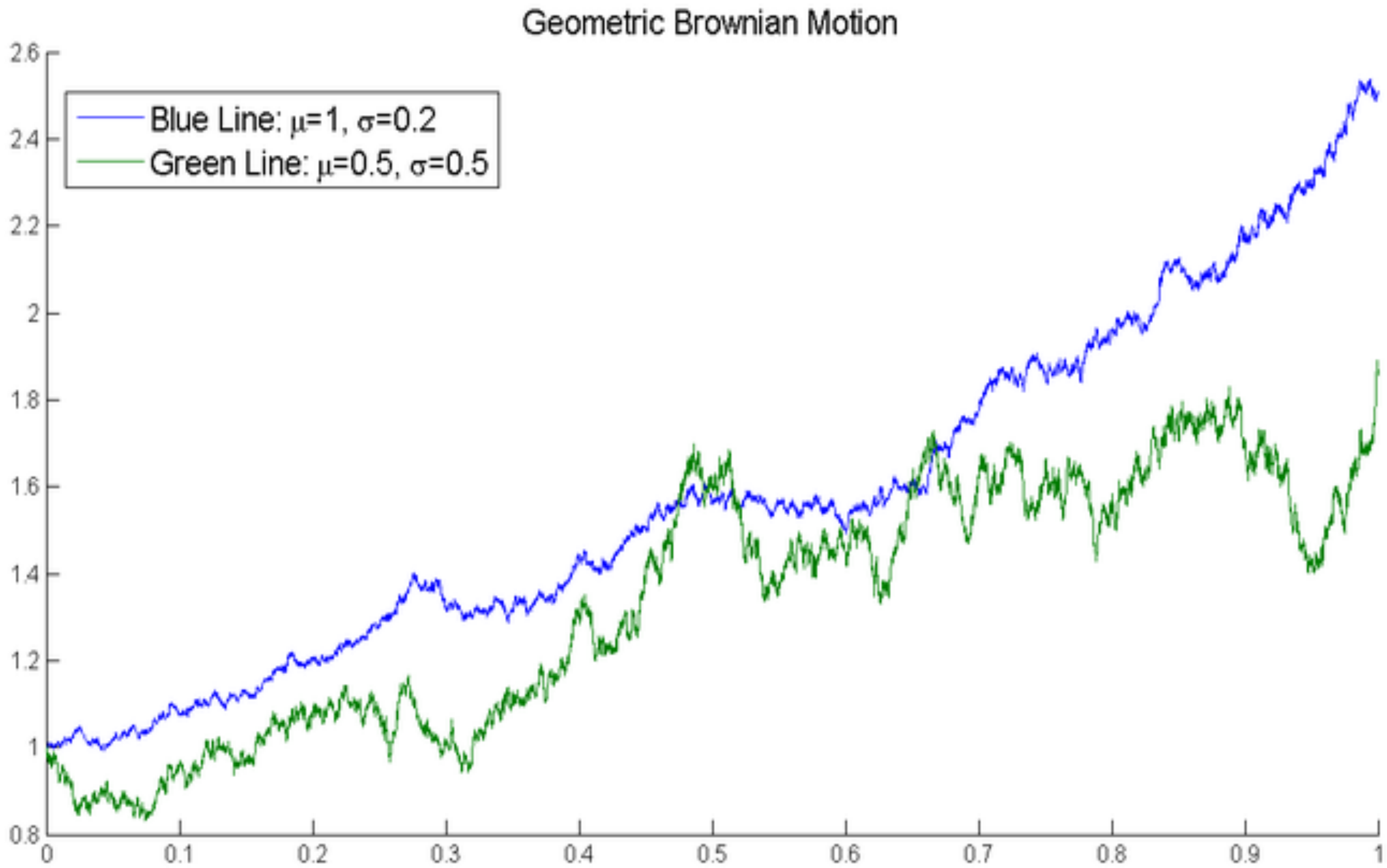
b-LOGNORMALS for P-T and K-Pg Mass Extinctions



Part 4:

GEOMETRIC BROWNIAN MOTION (GBM)

GEOMETRIC BROWNIAN MOTION (GBM): *exponential mean value*



GEOMETRIC BROWNIAN MOTION (GBM): exponential mean value :

$$\langle N(t)\rangle = N_0\, e^{\mu t}.$$

GEOMETRIC BROWNIAN MOTION lognormal probability density :

$$N(t)\_\mathrm{lnpdf}(n; N_0, \mu, \sigma, t) = \frac{e^{-\frac{\left[\ln(n) - \ln(N_0) - \left(\mu - \frac{\sigma^2 t}{2}\right)\right]^2}{2\sigma^2 t}}}{\sqrt{2\pi}\,\sigma\,\sqrt{t}\,n}$$

WARNING !!!

GEOMETRIC BROWNIAN MOTION
is a WRONG NAME :

This process in NOT a Brownian Motion at all since its probability density function is a LOGNORMAL, and *NOT A GAUSSIAN !!!*

So, the pdf ranges between ZERO and INFINITY, and NOT between minus infinity and infinity!!!

GBMs are the «Black-Sholes» Models in FINANCE.

GEOMETRIC BROWNIAN MOTION is the extension in time of the STATISTICAL DRAKE EQUATION:

- $t = 1$
- $\mu_{GBM} = \mu_{Drake}$
- $\sigma_{GBM} = \sigma_{Drake}$
- $N_0 e^{\frac{\sigma^2}{2}} =$

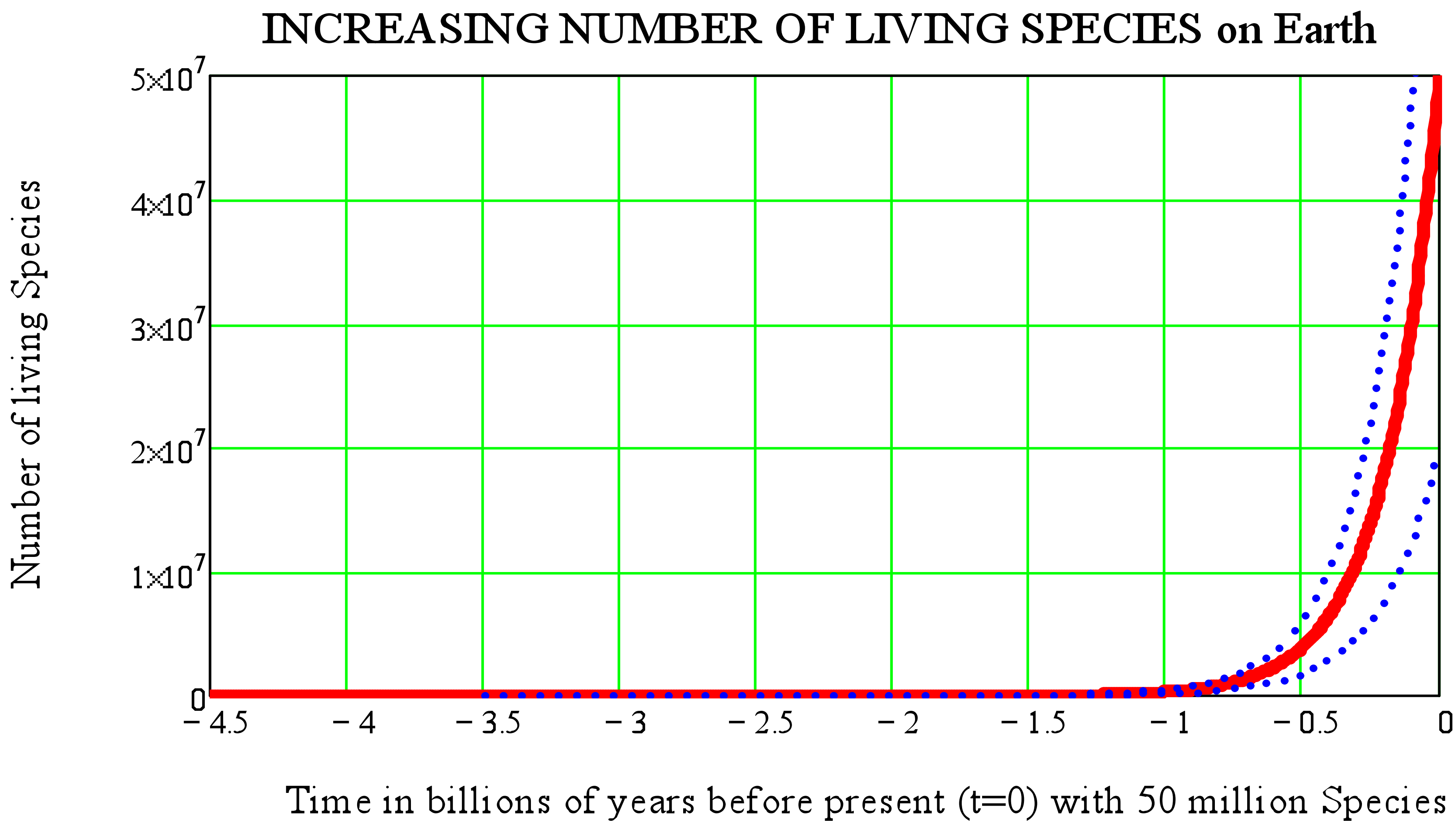
The two lognormals (of movie & picture) then COINCIDE.

In other words still:

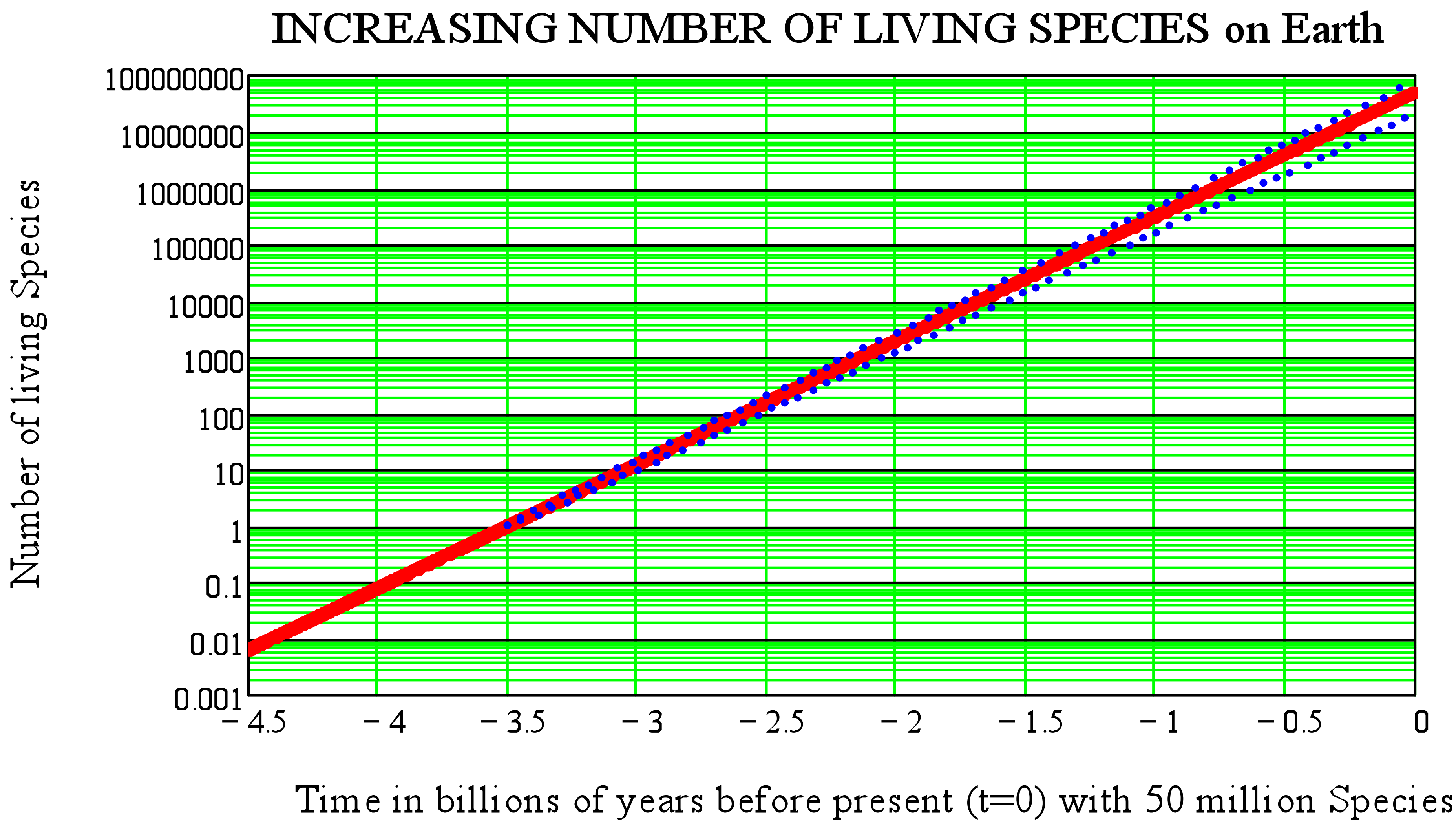
1) The CLASSICAL DRAKE EQ.
is STATIC, and is a SUBSET of the STATISTICAL DRAKE EQUATION.

2) But in turn, the STATISTICAL DRAKE EQUATION is the STATIC VERSION
(i.e. the STILL PICTURE) of the GEOMETRIC BROWNIAN MOTION (the MOVIE).

DARWINIAN EVOLUTION is a GBM in the increasing number of Species



DARWINIAN EVOLUTION is a GBM in the increasing number of Species



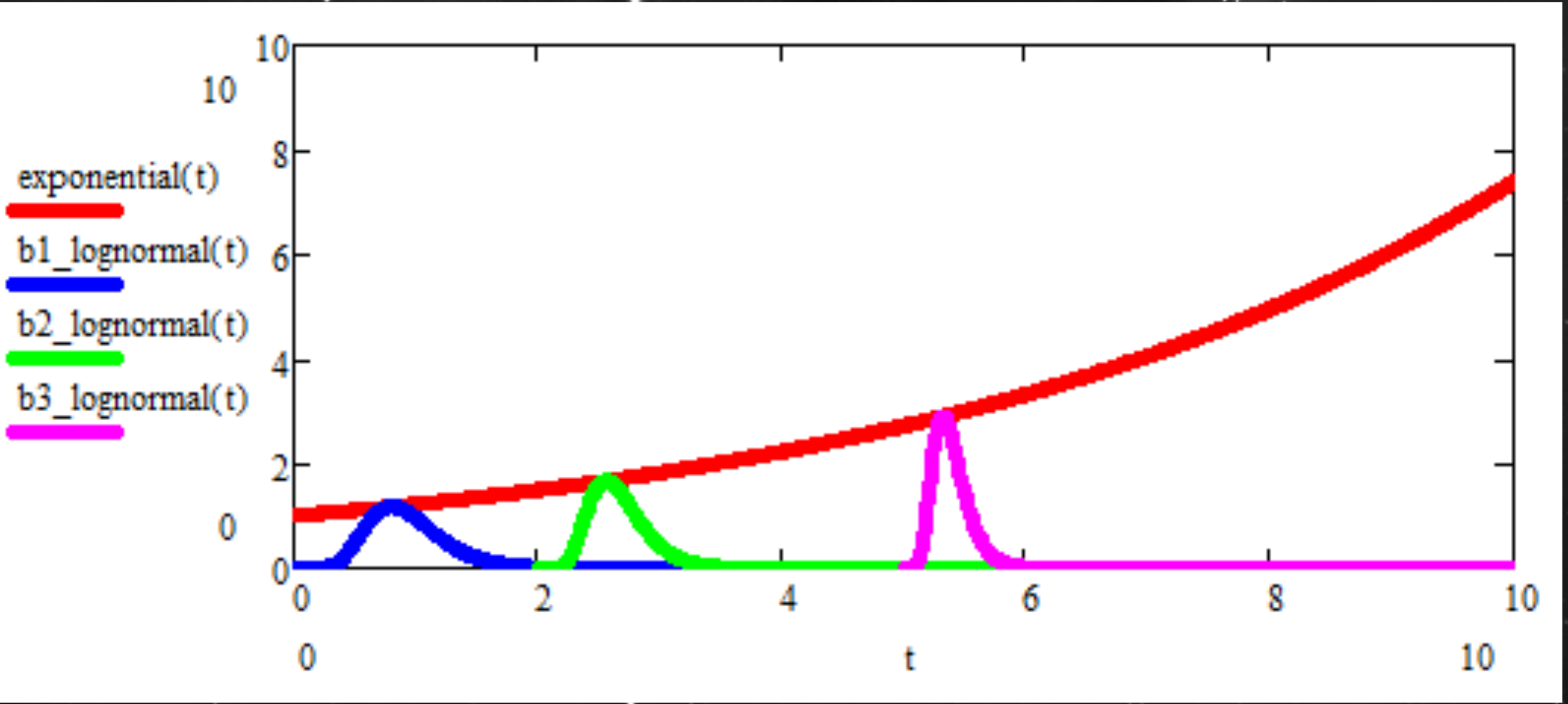
Part 5:

CLADISTICS :

Every new Species is a b-lognormal IN TIME

CLADISTICS : every new Species is just a new b-LOGNORMAL

- Each b-lognormal has its peak on the exponential.
- PRACTICALLY an "Envelope", though not so formally.



A REFERENCE PAPER

- **Evolution and History in a new "Mathematical SETI" model.**
- **ACTA ASTRONAUTICA, Vol. 93 (2014), pages 317-344. Online August 13, 2013.**

Acta Astronautica ■ (■■■) ■■■–■■■

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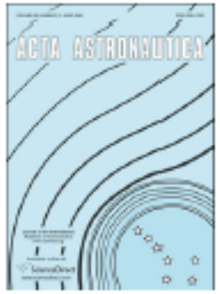

Academy Transactions Note

Evolution and History in a new "Mathematical SETI" model

Claudio Maccone*

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Part 6:

ENTROPY
as the
EVOLUTION MEASURE

b-LOGNORMAL ENTROPY

- Shannon ENTROPY for a probability density (in bits) :

$$Shannon\,Entropy = -\int_{-\infty}^{\infty} f_X(x)\,\log_2\left(f_X(x)\right)dx$$

$$\ldots in\,bits = -\frac{1}{\ln 2}\int_{-\infty}^{\infty} f_X(x)\,\ln\left(f_X(x)\right)dx$$

- ***Shannon's ENTROPY for b-lognormals (in bits)***

$$H_{\text{b\_lognormal\_in\_bits}}(I,\sigma) = \frac{1}{\ln 2}\left(\sqrt{}\;[illegible]\right) -$$

b-LOGNORMAL ENTROPY

- But μ ONLY is a function of the peak abscissa *p* :

$$\sigma = \frac{1}{\sqrt{2MA}}$$

$$\mu(p) = 2 B p + \frac{1}{4MA^2}$$

- ***Shannon ENTROPY for any b-lognormal in bits***

$$H_{\text{b\_lognormal\_in\_bits}}(p) = \frac{1}{\ln 2} \times \mu(p) + \text{part\_not\_depending\_on\_p} =$$

$$= 2 \times \frac{B}{\ln 2}\, p + \text{another\_part\_not\_depending\_on\_p.}$$

CIVILIZATION LEVEL DIFFERENCE

- The ENTROPY DIFFERENCE among any two Civilizations having their two peak abscissae at *p sub 1* and *p sub 2* is given by

$$EntropyDIFFERENCEpp=\infty=2\times 2\ H\_in\_bits21 \quad \frac{B}{\ln 2}\left(\qquad \right)$$

- ENTROPY IS THUS A MEASURE OF THE LEVEL OF PROGRESS REACHED BY EACH CIVILIZATION.
- ENTROPY DIFFERENCE measures the DIFFERENCE in civilization level among any two Civilizations.
- If it is known WHEN the two Civilizations reached their two peaks, the above formula yields their CIVILIZATION LEVEL DIFFERENCE.

EXAMPLES : CIVILIZATION DIFFERENCE

- The DIFFERENCE in Civilization Level between the **Spaniards and Aztecs** in 1519 was about **3.84 bits** per individual.
- The DIFFERENCE in Civilization Level between a **Victorian Briton and a Pericles Greek** was about **1.76 bits** per individual.
- The DIFFERENCE in Civilization Level between **Humanity and the first Alien Civilization** we will find in the Galaxy is UNKNOWN, of course, but…
- … but now we have a Mathematical Theory to ESTIMATE IT on the basis of the messages we get.

EXAMPLE
EVOLUTION DIFFERENCE

- The DIFFERENCE in Darwinian Evolution between two species on Earth is given by the same equation

$$\infty = 2\, ShannonEntropy\, p\, p_{\text{in\_bits}\,2\,1} \quad \frac{B}{\ln 2} \left(\qquad \right)$$

- The result is that the ***DIFFERENCE IN EVOLUTION*** LEVEL between the first living being 3.5 billion years ago – ***RNA - and Humans*** is about **25.57 bits** per individual.

- As for the DIFFERENCE in Civilization Level, except we must now use the different numerical value of *B* the enveloping Darwinian exponential, found earlier.

INTRODUCING **EVO-ENTROPY** as INCREASING ORGANIZATION

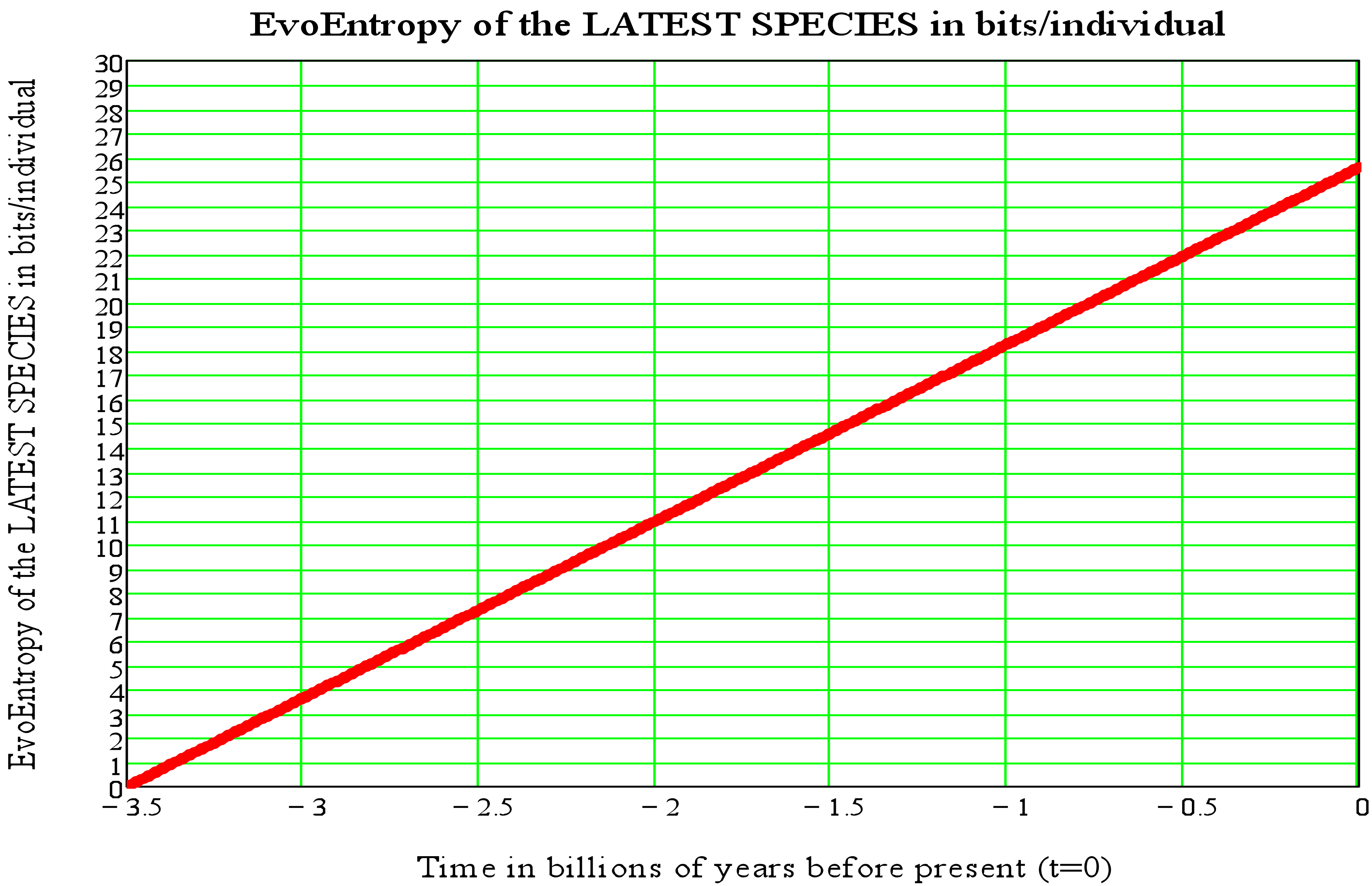
► We had to introduce **EVO-ENTROPY** as a measure of the ORGANIZATIONAL LEVEL of different SPECIES :

$$EvoEntropy_{in\_bits}(t) = H_{Shannon}(t) - H_{Shannon}(Life\_Origin)$$

► 1) We have dropped the MINUS SIGN in front of the Shannon Entropy in order to pass from a measure of disorganization (good for gases) to a measure of organiization of the living SPECIES.

► 2) We also wanted a straight line starting at zero at the time of the ORIGIN OF LIFE = -3.5 billion years.

Evo-ENTROPY = MOLECULAR CLOCK



TWO REFERENCE PAPERS

- SETI, Evolution and Human History Merged into a Mathematical Model.
- International Journal of ASTROBIOLOGY, Vol. 12, issue 3 (2013), pages 218-245.

International Journal of Astrobiology 12 (3): 218–245 (2013) doi:10.1017/S1473550413000086

SETI, Evolution and Human History Merged into a Mathematical Model

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- Evolution and History in a new "Mathematical SETI" model.
- ACTA ASTRONAUTICA, Vol. 93 (2014), pages 317-344. Online August 13, 2013.

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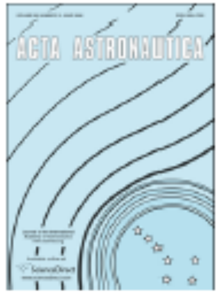

Academy Transactions Note

Evolution and History in a new "Mathematical SETI" model

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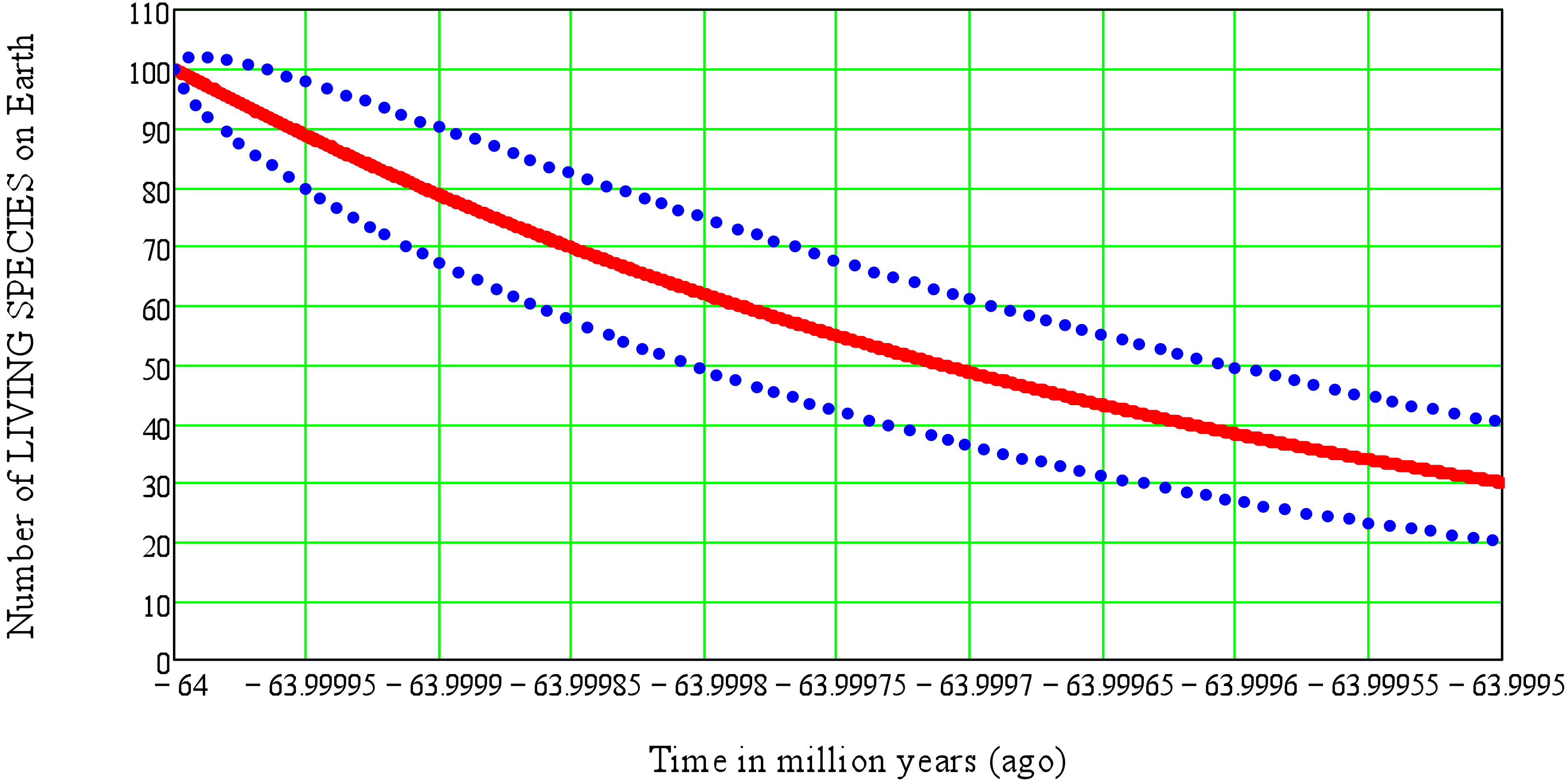
Part 7:

MASS EXTINCTIONS :

GBMs in the DECREASING NUMBER OF LIVING SPECIES

MASS EXTINCTION: a GBM in the decreasing number of living species

DECREASING number of species during the K-Pg MASS EXTINCTION



COMING PAPER

- Evolution and Mass Extinctions as Lognormal Stochastic Processes.
- International Journal of Astrobiology, in press.

International Journal of Astrobiology, Page 1 of 20 doi:10.1017/S147355041400010X

Evolution and mass extinctions as lognormal stochastic processes

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CONCLUSIONS about Evo-SETI

1) We developed here a new mathematical model embracing all of Big History, including Darwinian Evolution (RNA to Humans), and Human History. We call it "Evo-SETI" Theory.

3) Our mathematical model is based on LOGNORMAL probability distributions. It is compatible with the Statistical Drake Equations, the foundational equation of SETI.

5) Merging all these apparently different topics into the larger but single topic called is the achievement of Evo-SETI Theory.

6) When SETI scientists succeed in finding the first ET Civilization our statistical Evo-SETI theory should allow us to estimate how much more advanced than Humans those Aliens could be.


Thank you very much !