SISTEMAS COMPLEXOS

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e

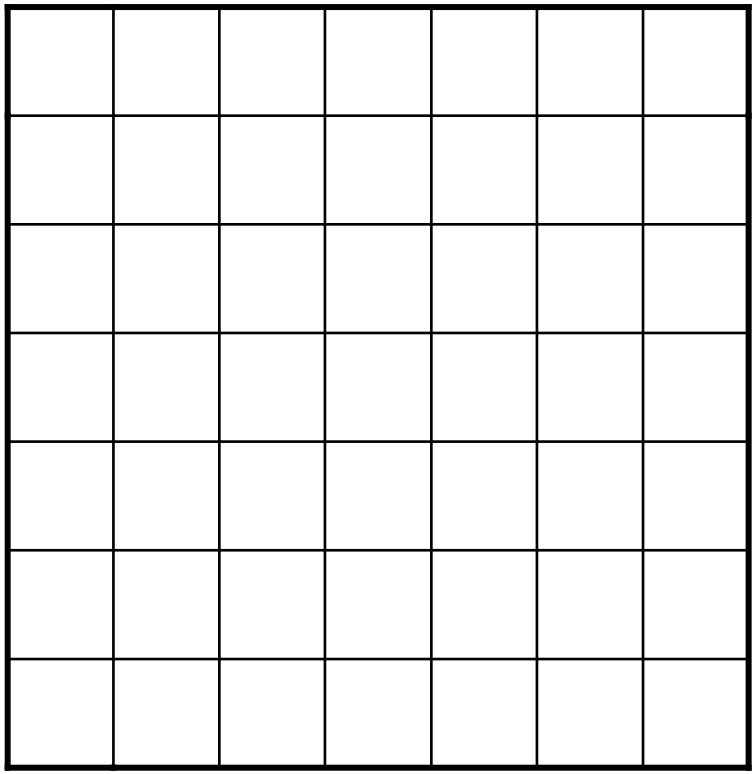
Santa Fe Institute, New Mexico - USA

Petrópolis, Abril 2011

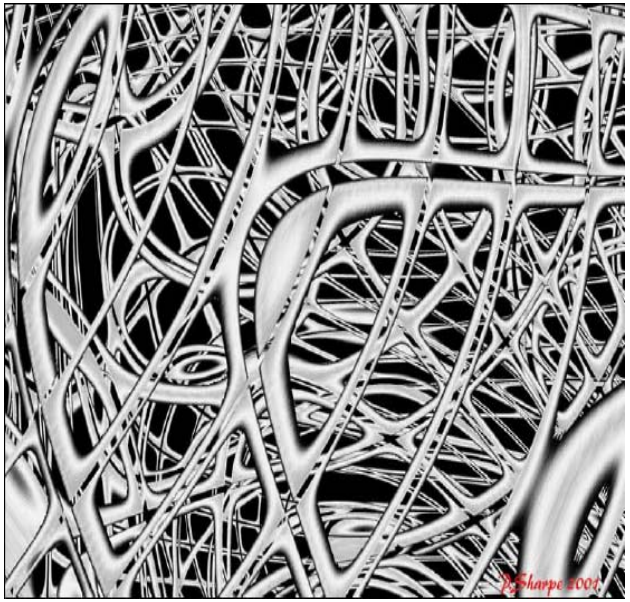
I think the next century will be the century of complexity

Stephen Hawking

[San Jose Mercury News (January 23, 2000)]

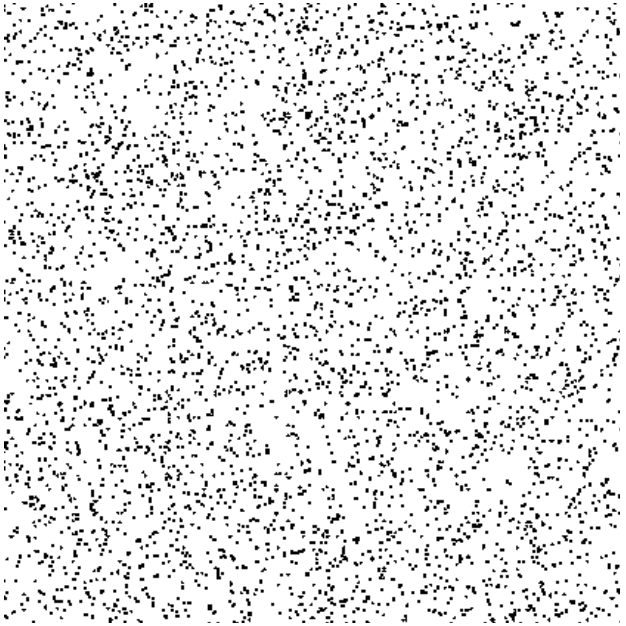


SIMPLES



COMPLEXO

SIMPLES

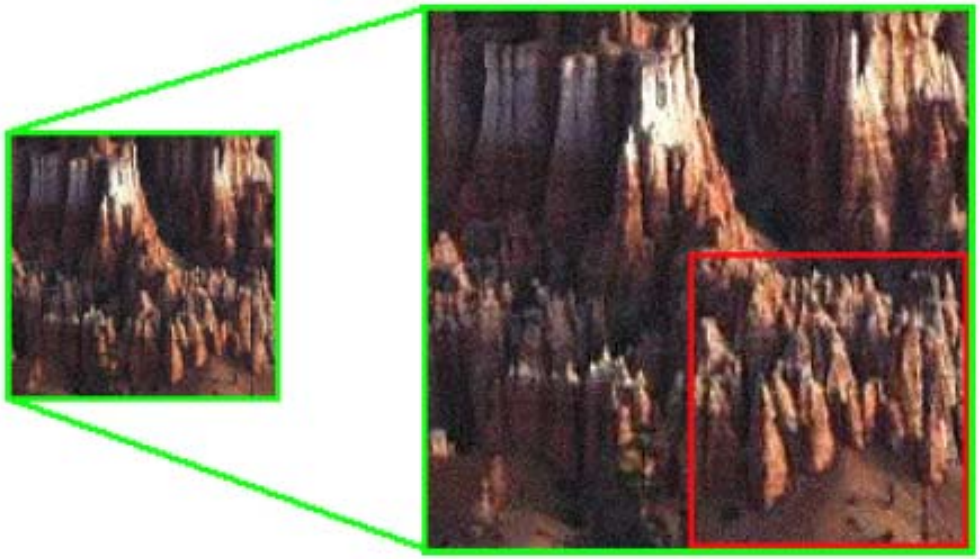


SIMETRIAS

TRANSLACAO

REFLEXAO

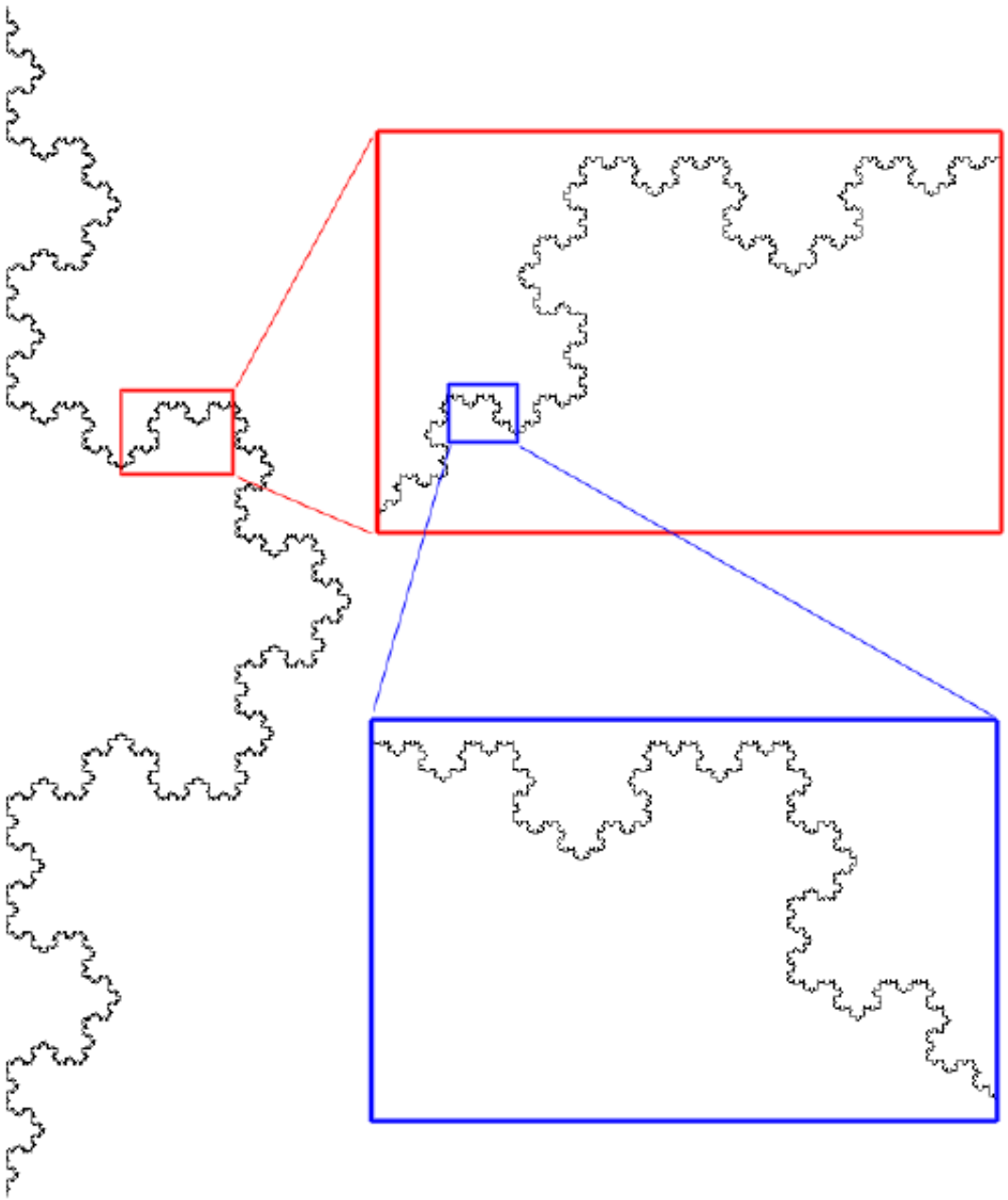
ROTACAO



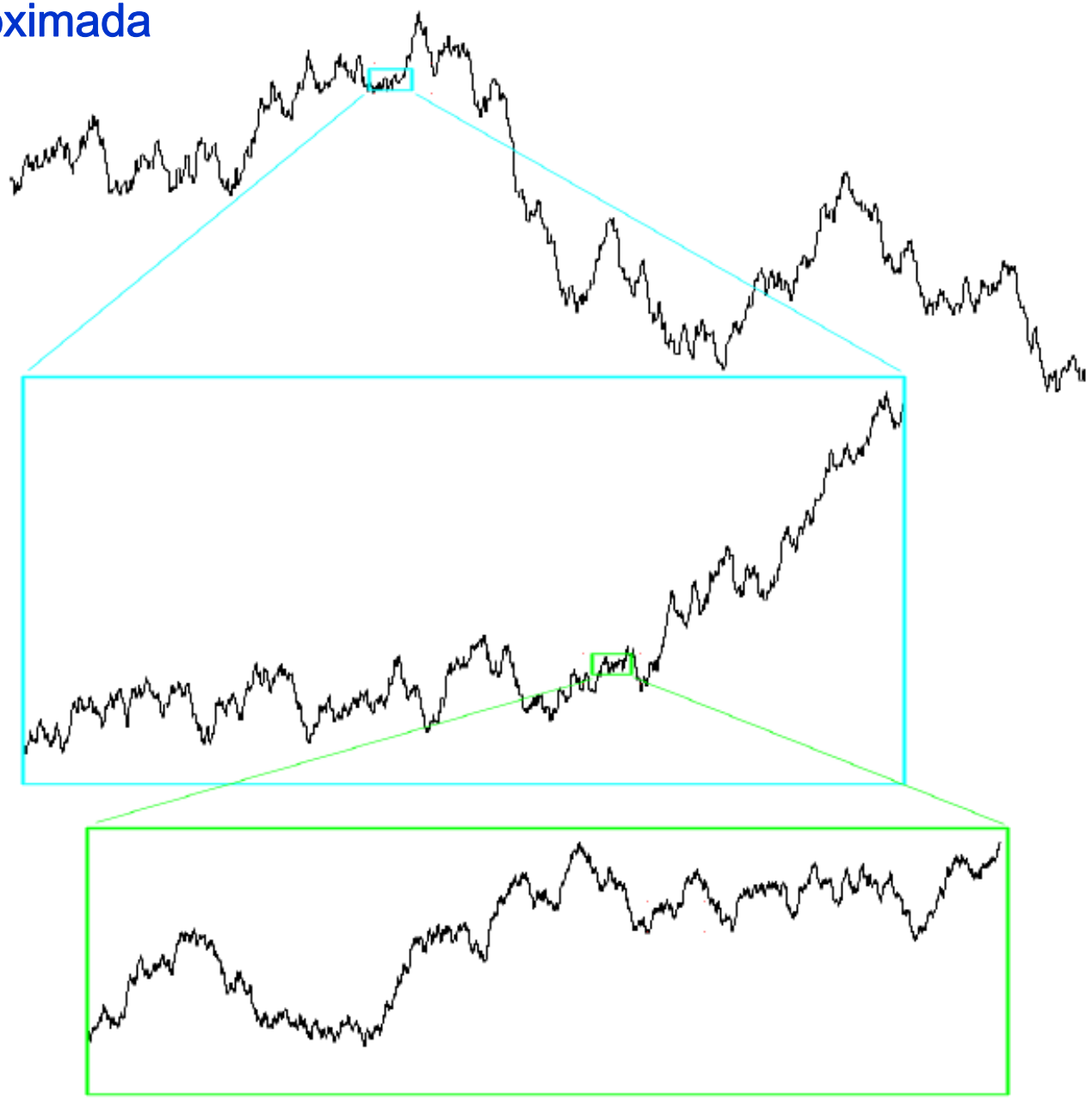
ESCALA

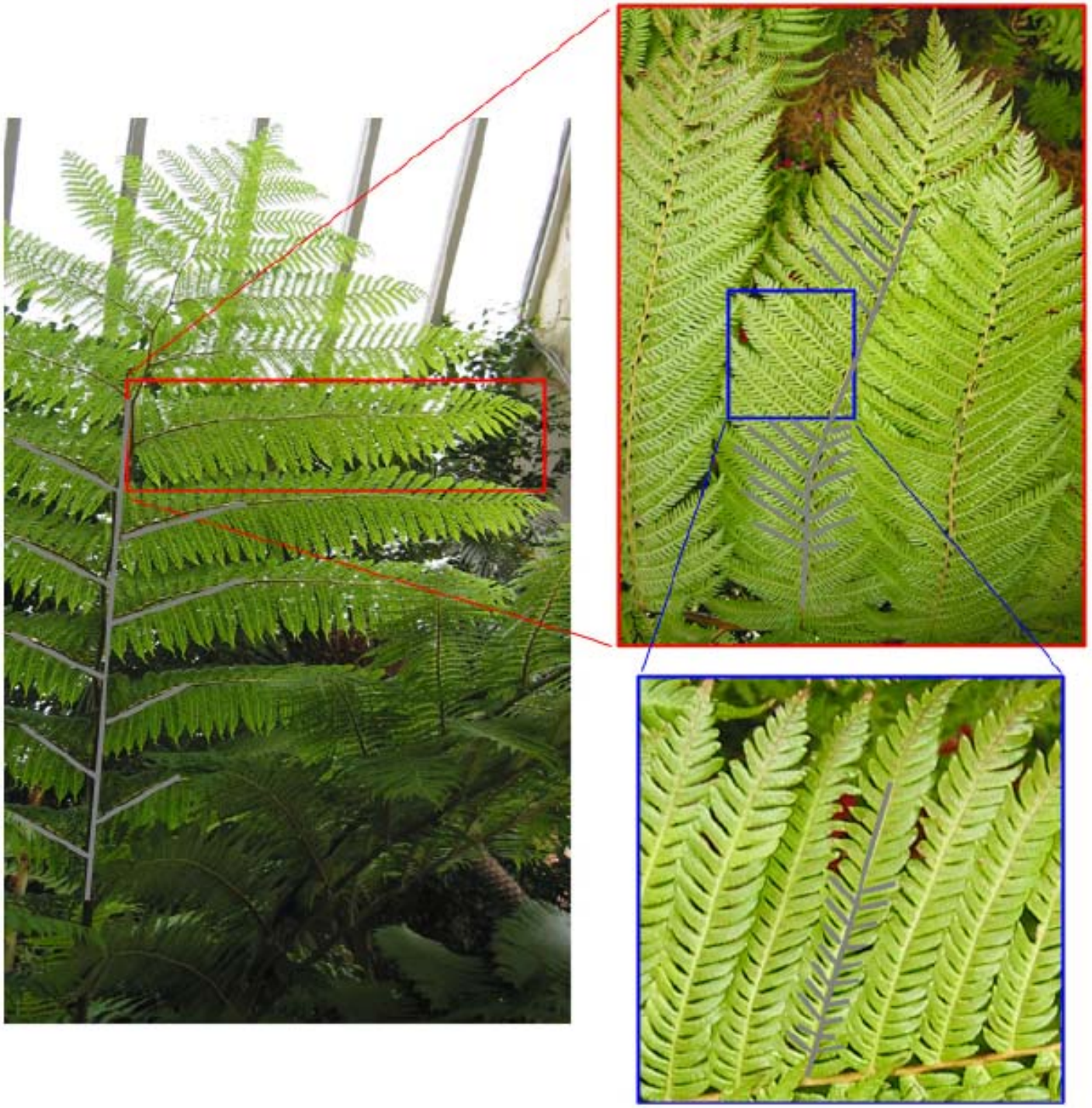
A. Robledo (2007)

Auto-semelhanca exata



Auto-semelhanca aproximada



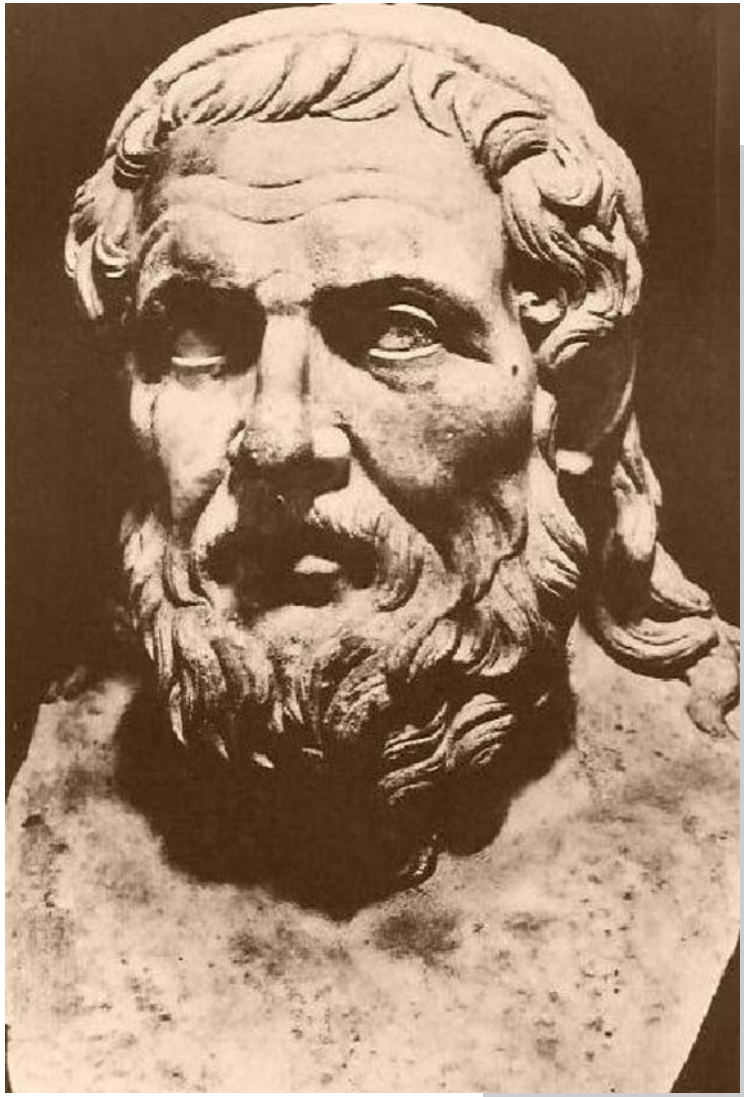


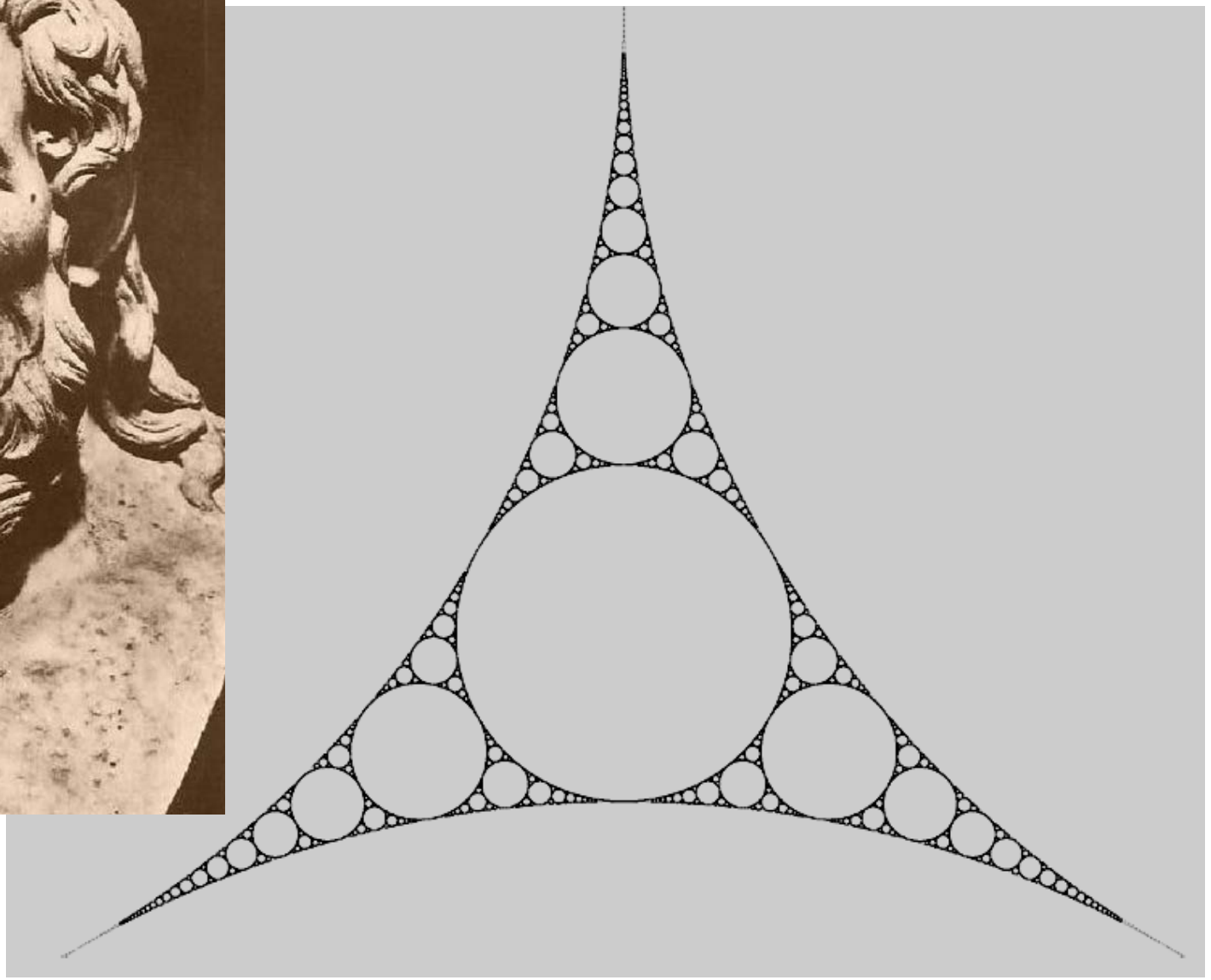
Samambaia

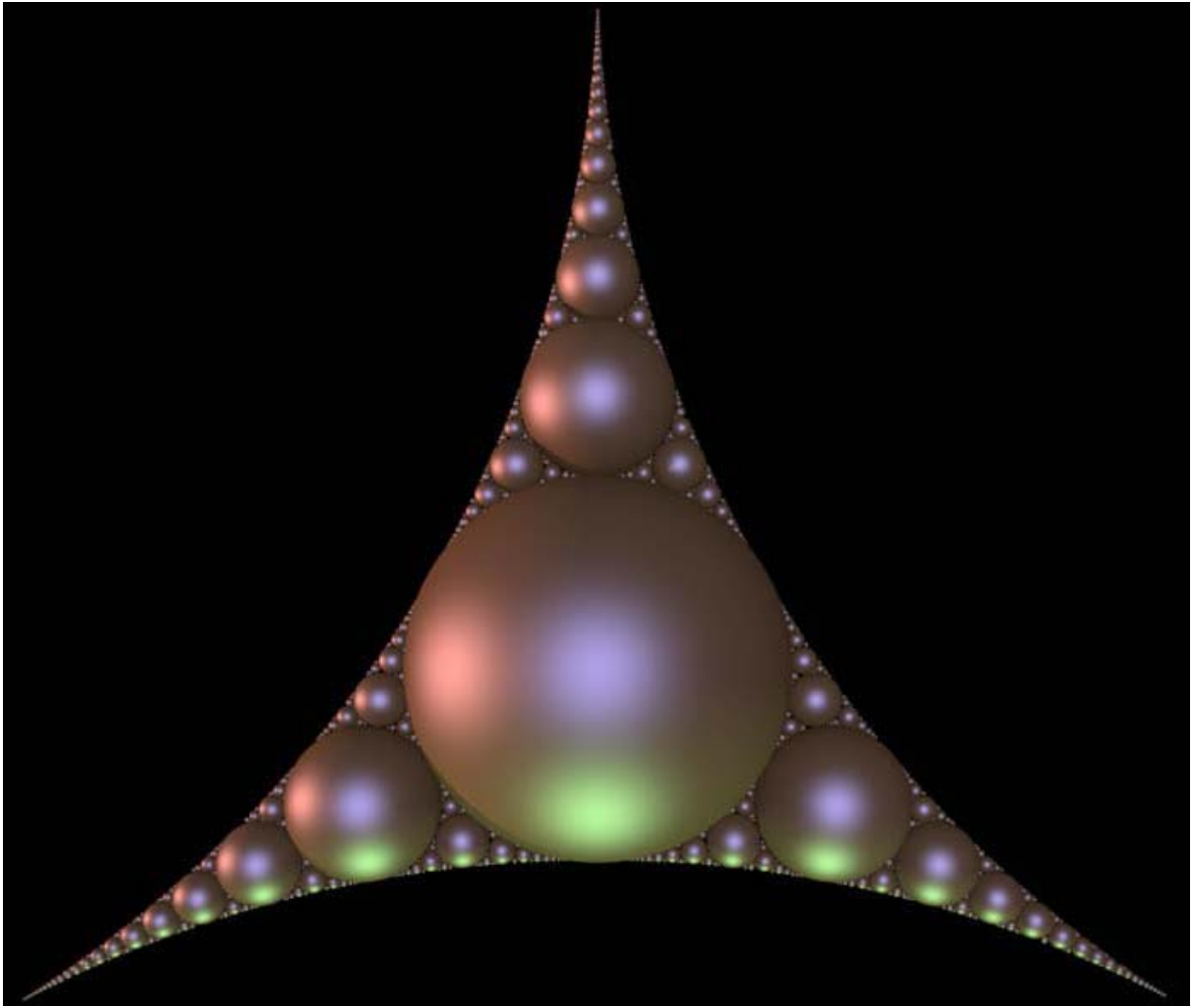
“Samambaia” computacional


Scale 3
Scale 2
Scale 1

Apolonio de Perga (262 – 190 AC)



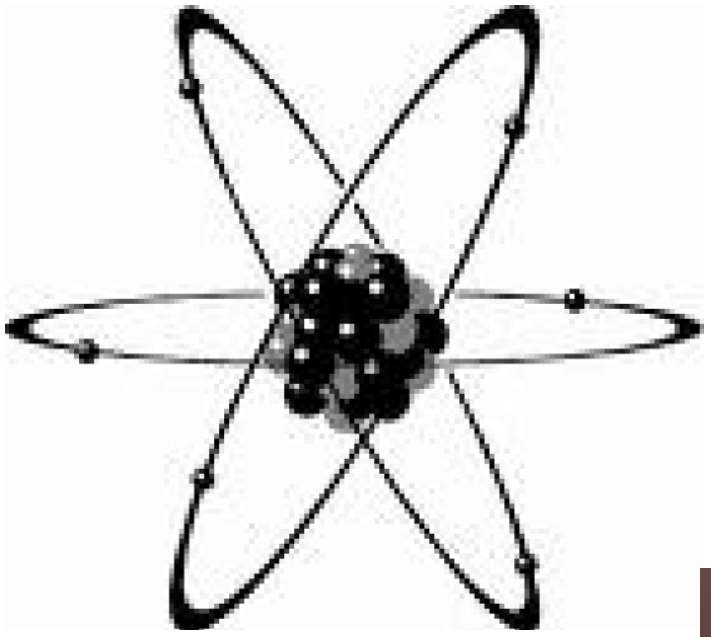




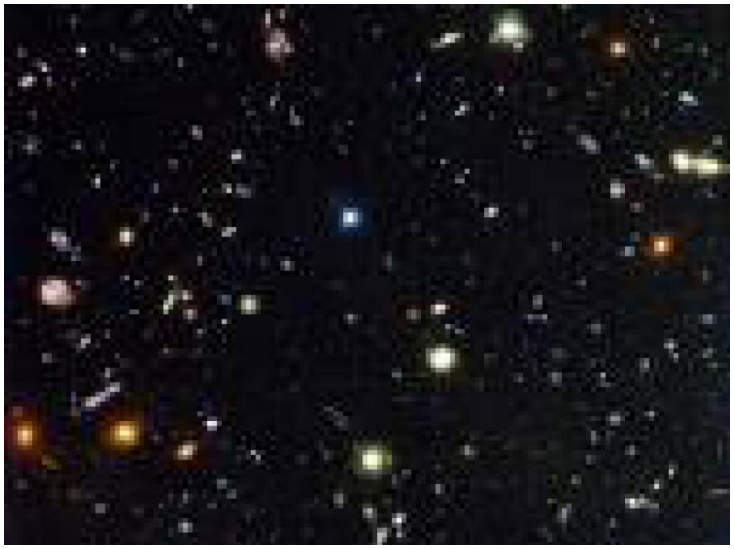
More Is Different

Philip Warren Anderson

[*Science* 177 (1972) 393-396]



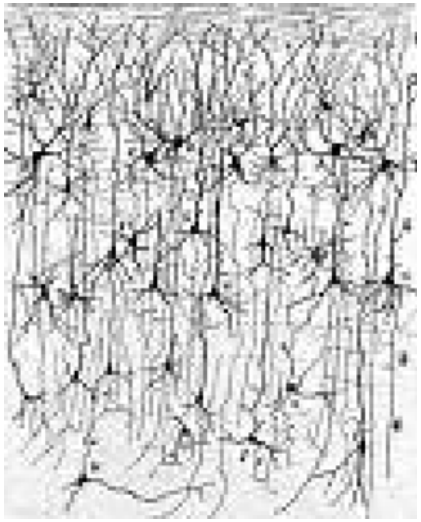
Isaac Newton
(1642 - 1727)

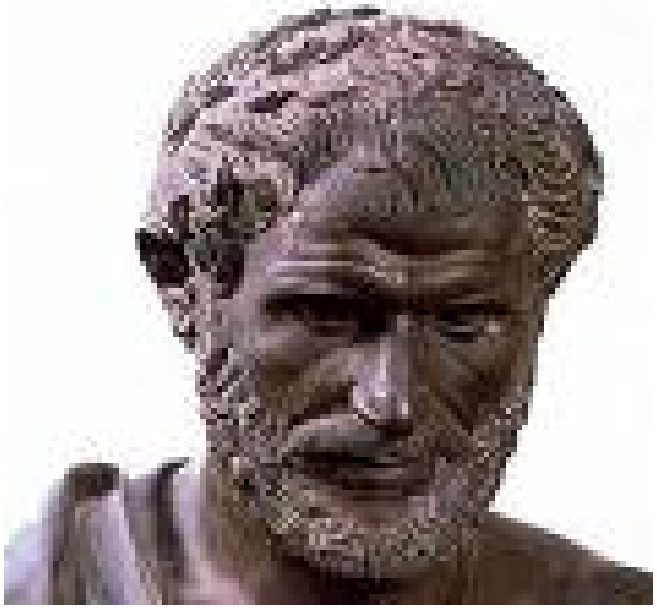


$$F = G \frac{m_1 \, m_2}{r^2}$$

Santiago Ramon y Cajal

(1852 – 1934)





(c. 460 BCE – c. 370 BCE)

By convention there is color,
By convention, sweetness,
By convention, bitterness,
But in reality there are atoms and space.

Democritus [fragment 145]

Rien ne se perd,
rien ne se crée,
tout se transforme.

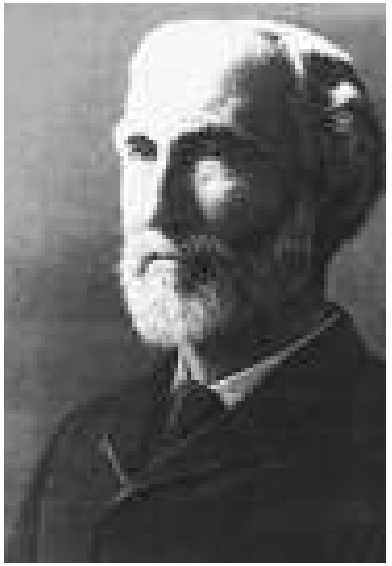
Antoine-Laurent Lavoisier (1743-1794):

I do not expect my ideas to be adopted all at once. [...] *It is the passage of time, therefore, which must confirm or destroy the opinions I have presented. Meanwhile, I observe with great satisfaction that the young people are beginning to study the science without prejudice ...*
[*Reflexions sur le Phlogistique* (1783)]

John Dalton (1766 - 1844)

Demócrito estava certo: os átomos existem!

Ludwig **Boltzmann** (1844-1906)



Josiah Willard **Gibbs** (1839-1903)

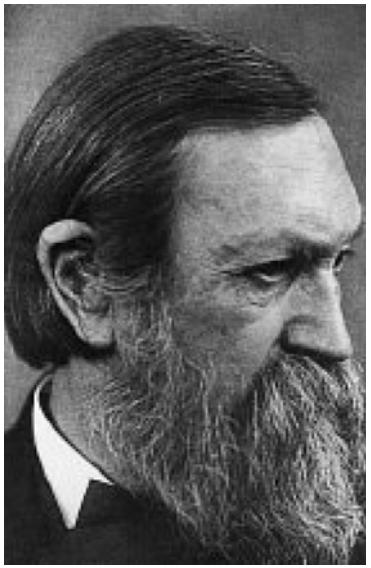
$$S_{BG} = k \ \ln \ W$$

ESTA ENTROPIA É ADITIVA,

É A BASE DA MECÂNICA ESTATÍSTICA DE BOLTZMANN-GIBBS,

E SERVE PARA OS SISTEMAS DITOS “SIMPLES”

Boltzmann versus Ostwald (Lubeck, 1895):



Wilhelm **Ostwald** (1853-1932)

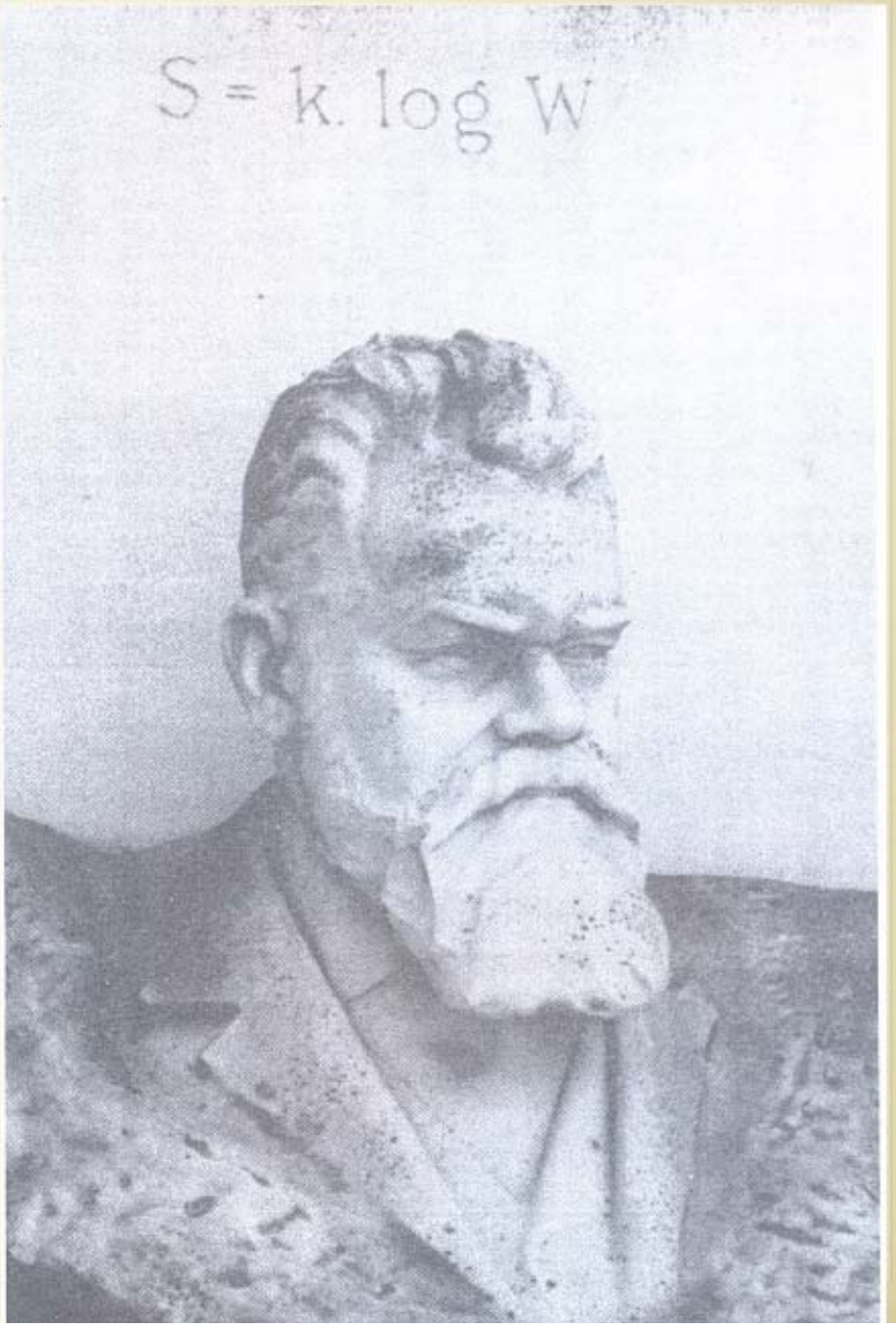
Ludwig **Boltzmann** (1844-1906)

Arnold Sommerfeld described Boltzmann's entry into the dramatic discussion on energism at the conference of German naturalists at Lubeck in 1895: "Helm (Dresden) was the main speaker on behalf of energism; backing him was Wilhelm Ostwald, and backing both of them was the natural philosophy of the absent Ernst Mach. The opponent was Boltzmann, seconded by Felix Klein. The battle between Boltzmann and Ostwald was both outwardly and inwardly like a bull fighting against the flexible fencer. But this time the bull conquered in spite of all the torero's fighting skill. Boltzmann's arguments triumphed. All of us younger mathematicians were on Boltzmann's side …"

I don't believe that atoms exist!

Ernst Mach (January 1897, Vienna)

- Ludwig Boltzmann
- Pai da Mecânica Estatística
- Século XIX



LAS 10 FORMULAS MATEMATICAS QUE CAMBIARON LA FAZ DE LA TIERRA (*Nicaragua, 1971*)

$1 + 1 = 2$

$f = \frac{G m_1 m_2}{r^2}$

Newton

$E = mc^2$

Einstein

$V = V_e \ln \frac{m_0}{m_1}$

Tsiolkovski

$\nabla^2 E = \frac{K\mu}{c^2} \frac{\partial^2 E}{\partial t^2}$

Maxwell

$e^{\ln N} = N$

Napier

$A^2 + B^2 = C^2$

Pythagoras

$S = k \log W$

Boltzmann

$\lambda = h / m v$

de Broglie

$F_1 x_1 = F_2 x_2$

Archimedes

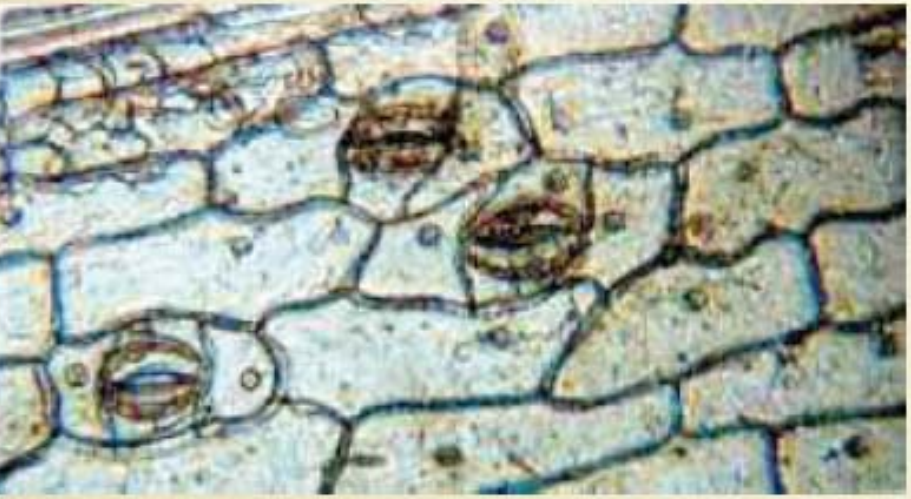
Ludwig Boltzmann
1844-1906

Las ecuaciones de Boltzmann reveló como el comportamiento de gases dependía del movimiento constante de átomos y moléculas. Su gran importancia reside en su aplicación donde los gases juegan un papel importante: en todas las máquinas impulsadas por vapor ó combustión interno; en las incontables reacciones entre gases usados por químicos para hacer drogas modernas, plásticos ú otras sustancias; en comprender el tiempo; y aún en explicar los procesos violentos del sol, estrellas y galaxias distantes.

$$S = k \log W \qquad \text{(Boltzmann)}$$

Movimento Browniano

- Robert Brown (botânico) - 1827

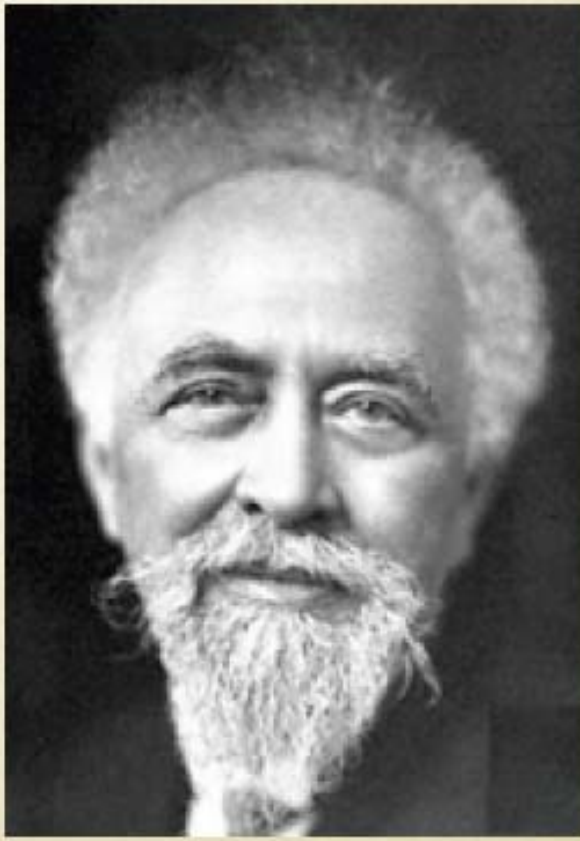


"This areola, or nucleus of the cell as perhaps it might b
termed, is not confined to the epidermis, being also found...i
many cases in the parenchyma or internal cells of the tissue." H

Movimento Browniano - 1905

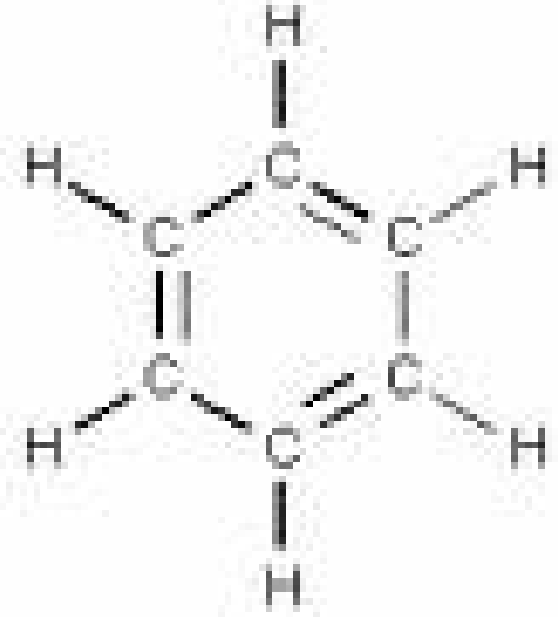
Jean Perrin

- 1908 J. Perrin, C. R. Acad. Sci. 146, 967
- "Les atomes" (Félix Alcan, Paris, 1913)



“Any really new idea in science always emerges through a metaphor.”
Chemistry Nobel laureate Roald Hoffmann,
[May 1995, in a Italian restaurant in Ithaca, New York]

Uroboros



benzene

Friedrich August Kekulé von Stradonitz

(1829 – 1896)

[384-322 BC]

[Αριστοτέλη, Περί Ποιητικής, 1459^{α}]

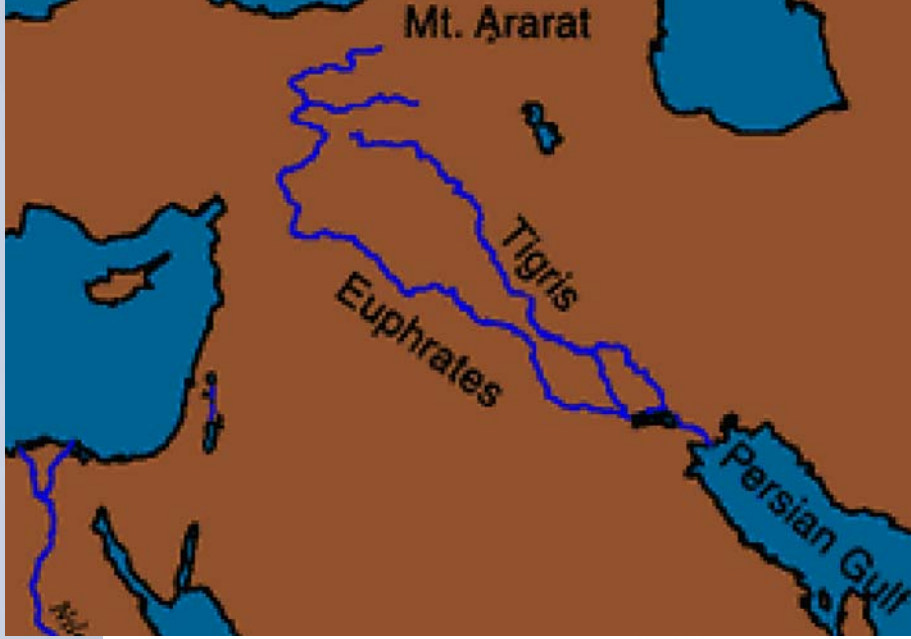
Ἔστιν δὲ μέγα μὲν τὸ ἑκάστωι τῶν εἰρημένων πρεπόντως χρῆσθαι, καὶ διπλοῖς ὀνόμασι καὶ γλώτταις, πολὺ δὲ μέγιστον τὸ μεταφορικὸν εἶναι. Μόνον γὰρ τοῦτο οὔτε παρ᾽ ἄλλου ἔστι λαβεῖν εὐφυίας τε σημεῖόν ἐστι· τὸ γὰρ εὖ μεταφέρειν τὸ τὸ ὅμοιον θεωρεῖν ἐστιν.

Το πιο σημαντικό από όλα τα παραπάνω είναι η δεξιοτεχνική χρήση της μεταφοράς. Διότι μόνο αυτό δεν μπορεί να διδαχθεί, ενώ είναι δείγμα ευφυΐας καθώς μια σωστή μεταφορά υποδηλώνει την ικανότητα να διακρίνει κανείς ομοιότητες ανάμεσα σε ανόμοια πράγματα.

[Aristotle, Ars Poetica, 322 BC]

"By far the greatest thing is to be a master of metaphor. It is the one thing that cannot be learned from others. It is a sign of genius, for a good metaphor implies an intuitive perception of similarity among dissimilars."

SYSTEMS	ENTROPY S_{BG} (additive)	ENTROPY S_q ($q<1$) (nonadditive)
Short-range interactions, weakly entangled blocks, etc	**EXTENSIVE**	**NONEXTENSIVE**
Long-range interactions (QSS), strongly entangled blocks, etc	**NONEXTENSIVE**	**EXTENSIVE**



King Thutmosis III
18th Dynasty
c. 1460 B. C.

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Physica A 356 (2005) 375–384
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Triangle for the entropic index q of non-extensive statistical mechanics observed by Voyager 1 in the distant heliosphere

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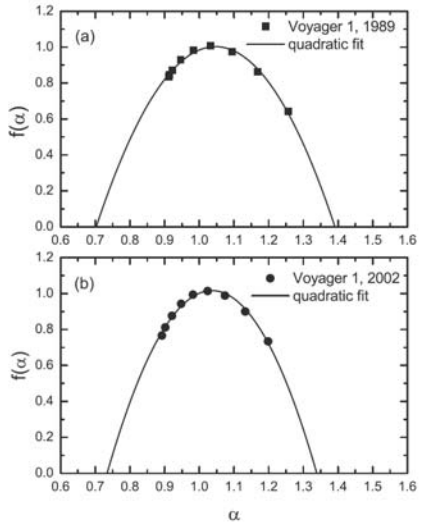
Available online 11 July 2005

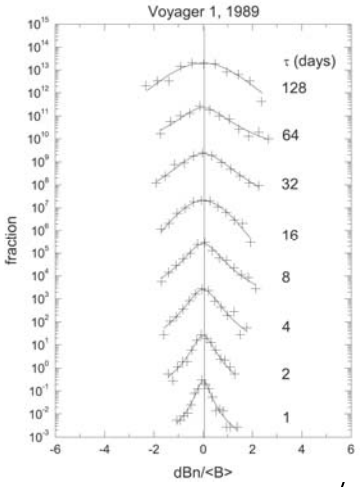
SOLAR WIND: Magnetic Field Strength

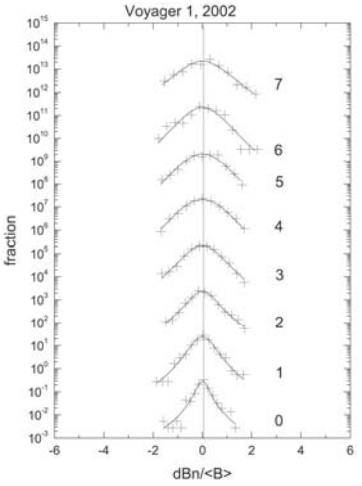
L.F. Burlaga and A. F.-Vinas (2005) / NASA Goddard Space Flight Center; Physica A **356**, 375 (2005)

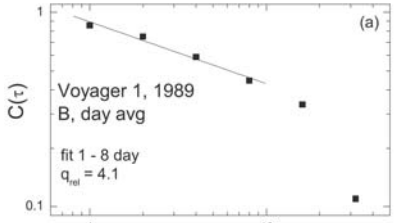
[Data: Voyager 1 spacecraft (1989 and 2002); 40 and 85 AU; daily averages]

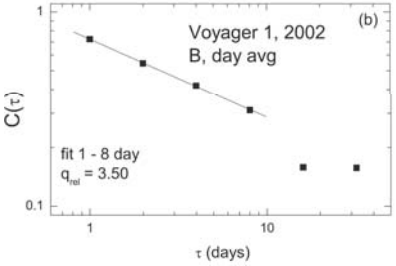


$q_{sen} = -0.6 \pm 0.2$







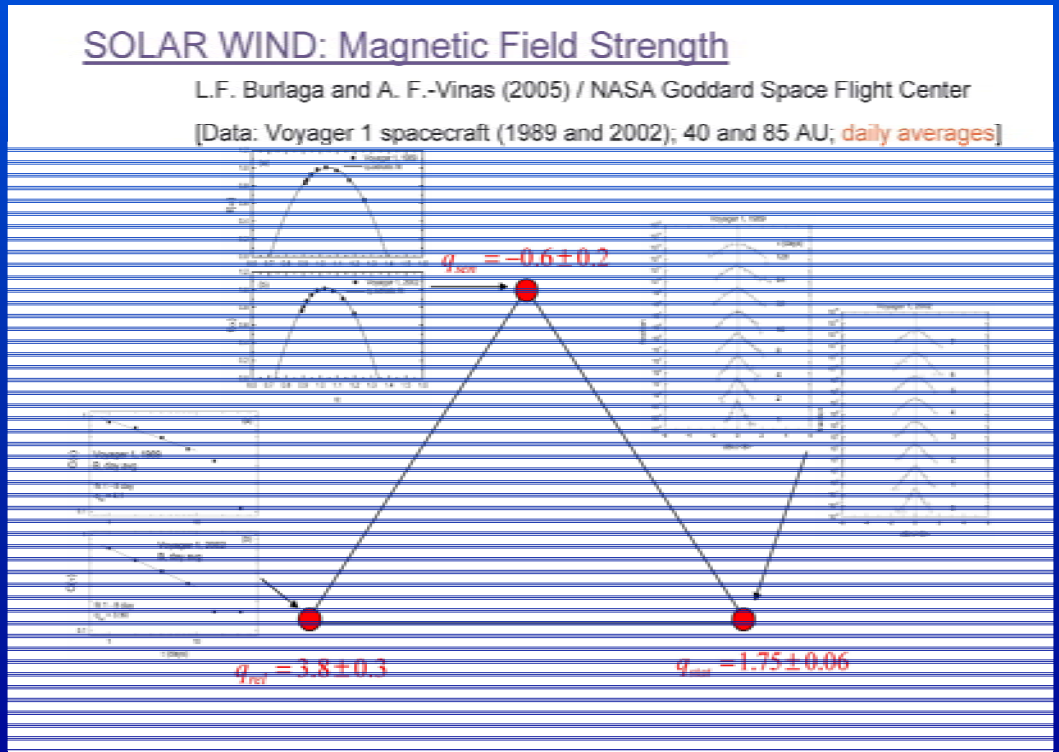


$q_{rel} = 3.8 \pm 0.3$

$q_{stat} = 1.75 \pm 0.06$

IHY 2007: VOYAGER 1: Fundamental Physics

The atmosphere of the Sun beyond a few solar radii, known as HELIOSPHERE, is fully ionized plasma expanding at supersonic speeds, carrying solar magnetic fields with it. This solar wind is a driven non-linear non-equilibrium system. The Sun injects matter, momentum, energy, and magnetic fields into the heliosphere in a highly variable way. Voyager 1 observed magnetic field strength variations in the solar wind near 40 AU during 1989 and near 85 AU during 2002. Tsallis' non-extensive statistical mechanics, a generalization of Boltzmann-Gibbs statistical mechanics, allows a physical explanation of these magnetic field strength variations in terms of departure from thermodynamic equilibrium in an unique way:



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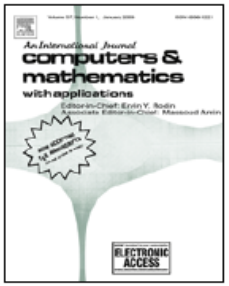

A novel automatic microcalcification detection technique using Tsallis entropy & a type II fuzzy index

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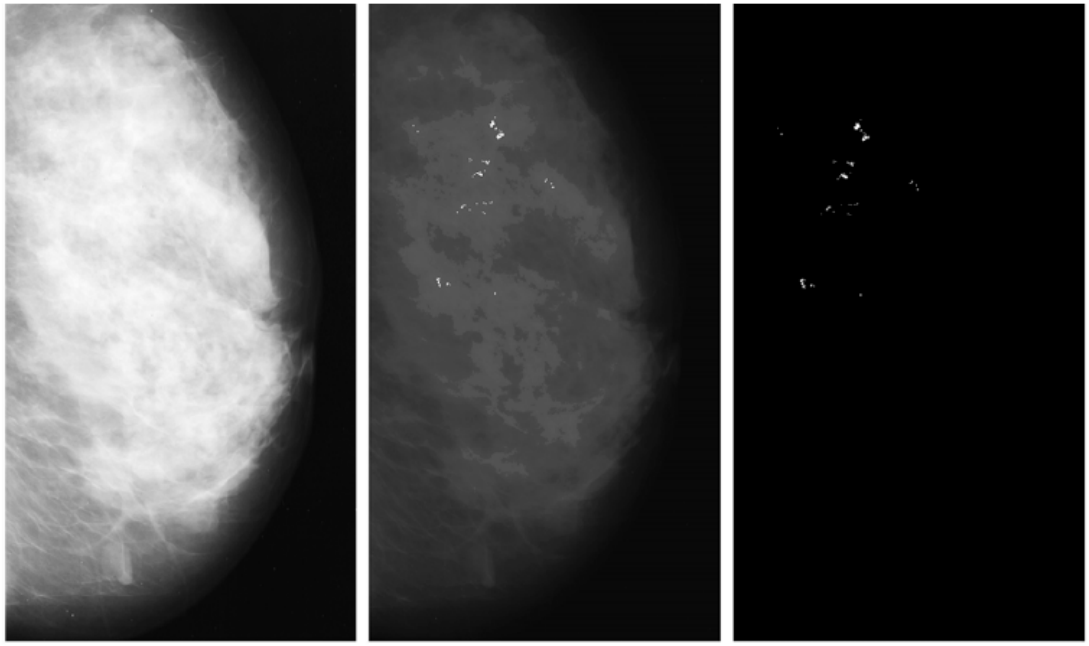
ABSTRACT

This article investigates a novel automatic microcalcification detection method using a type II fuzzy index. The thresholding is performed using the Tsallis entropy characterized by another parameter 'q', which depends on the non-extensiveness of a mammogram. In previous studies, 'q' was calculated using the histogram distribution, which can lead to erroneous results when pectoral muscles are included. In this study, we have used a type II fuzzy index to find the optimal value of 'q'. The proposed approach has been tested on several mammograms. The results suggest that the proposed Tsallis entropy approach outperforms the two-dimensional non-fuzzy approach and the conventional Shannon entropy partition approach. Moreover, our thresholding technique is completely automatic, unlike the methods of previous related works. Without Tsallis entropy enhancement, detection of microcalcifications is meager: 80.21% Tps (true positives) with 8.1 Fps (false positives), whereas upon introduction of the Tsallis entropy, the results surge to 96.55% Tps with 0.4 Fps.



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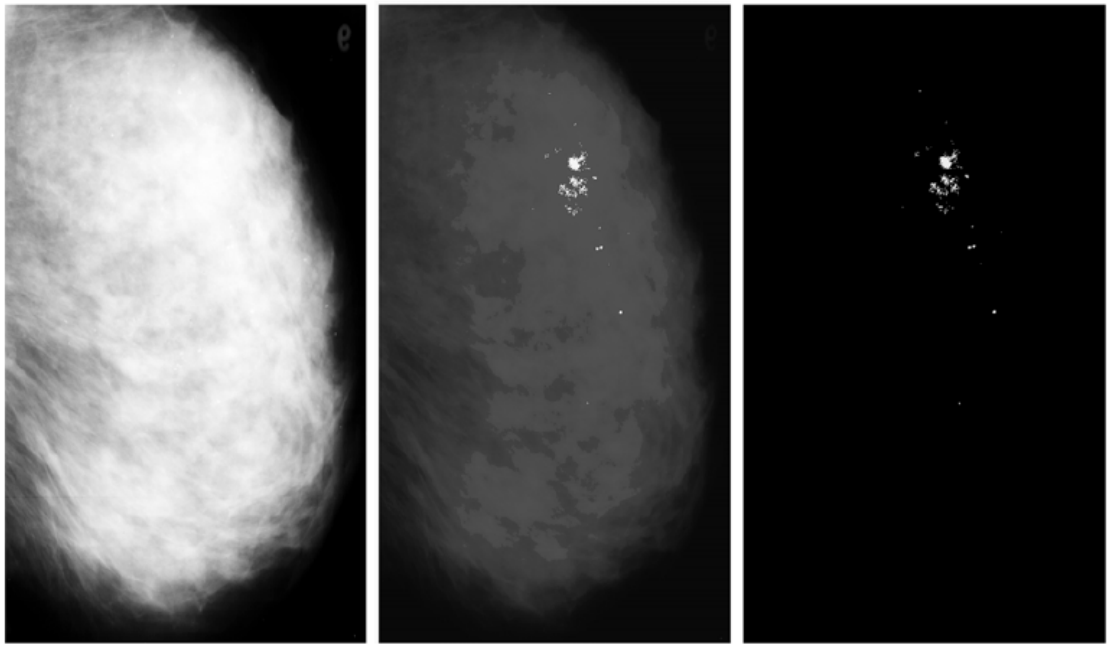

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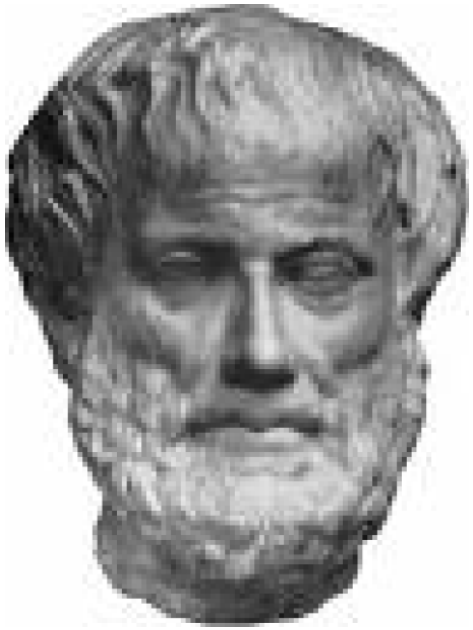

[384-322 BC]

ARISTOTLE

Poetry is more elevated and more philosophical than history; for poetry expresses the universal, and history only the particular. History tells us the events as they happened, whereas poetry tells them as they could or should have happened.

Je ne suis pas d'accord avec ce que vous dites, mais je me battrai jusqu'à la mort pour que vous ayez le droit de le dire.

Voltaire (François-Marie Arouet, 1694-1778)

If you have an apple and I have an apple,
and we exchange apples,
we both still only have one apple.
But if you have an idea and I have an idea,
and we exchange ideas,
we each now have two ideas.

George Bernard Shaw (1856-1950)

Si l’action n’a quelque splendeur de liberté, elle n’a point de grâce ni d’honneur.

Montaigne,
“Essais”, L.III, Chap. 9

Sofia e la scoperta delle fragole (Marco Bersanelli)

A Gutenberg, tra le verdissime colline austriache, una mattina saliamo per il sentiero che attraversa il bosco scuro e profumato alle spalle del paese. Dopo mezz'ora di cammino troviamo sulla destra una sorgente presso una radura e ci fermiamo a bere. Con una grande espressione di felicità ad un tratto Sofia, la piccola di tre anni, esclama: «Mamma, mamma!! una fragola!!». Gli altri due accorrono e, constatato che la sorellina ha prontamente raccolto e inghiottito il frutto della sua scoperta, si mettono a cercare, presto seguiti dai genitori. «Un'altra!» e dopo un po': «Guarda qui, ce ne sono altre tre, quattro...». La caccia è aperta. Cercando in quel prato abbiamo presto riempito un bicchiere di fragole di bosco. Poi al ritorno, con mia sincera sorpresa, ripercorrendo lo stesso sentiero dalla sorgente in giù ne abbiamo trovate altrettante! Zero fragole all'andata, forse un centinaio al ritorno: un effetto statisticamente schiacciante. Cos'era cambiato?

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Eravamo cambiati noi.