

# STATISTICAL MECHANICS FOR COMPLEXITY

## A CELEBRATION OF THE 80TH BIRTHDAY OF CONSTANTINO TSALLIS

### *On the genesis of non-extensive statistical mechanics: modes of inference and openings of the logic of surprise.*

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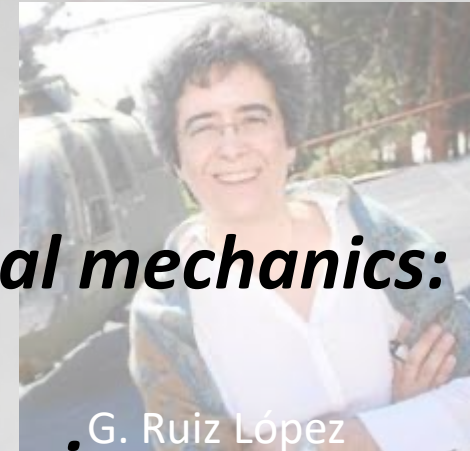
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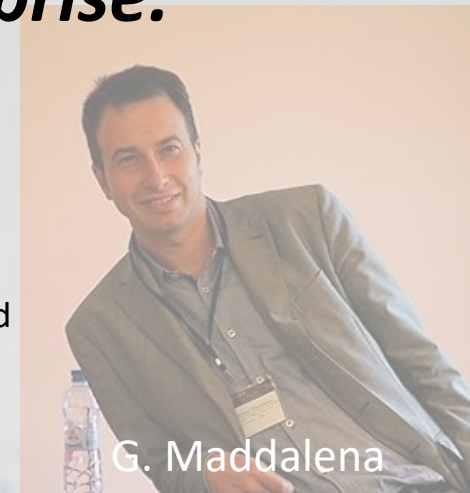
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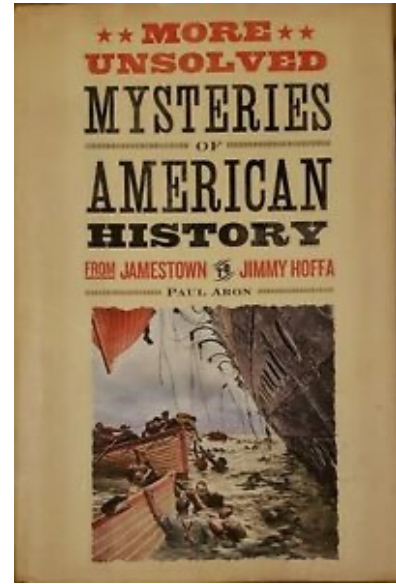
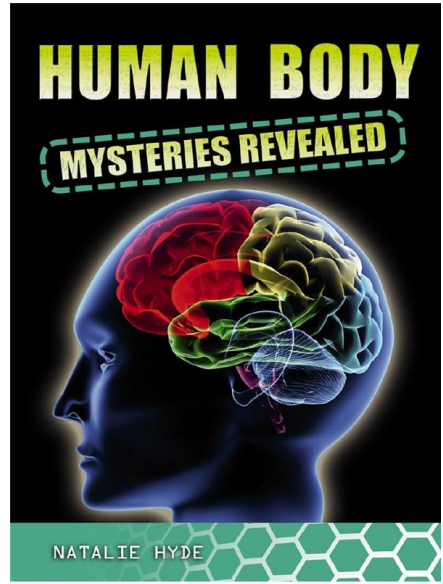
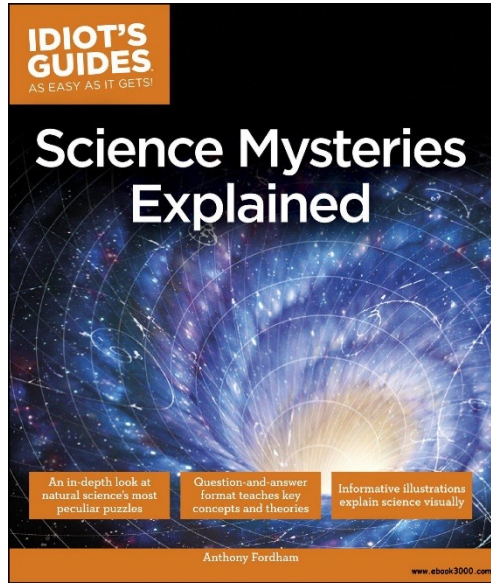


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# “Mystery”



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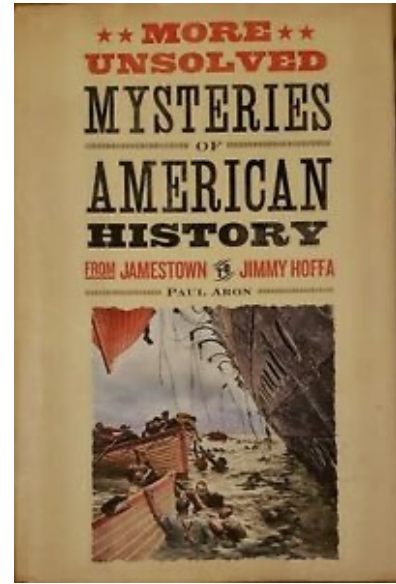
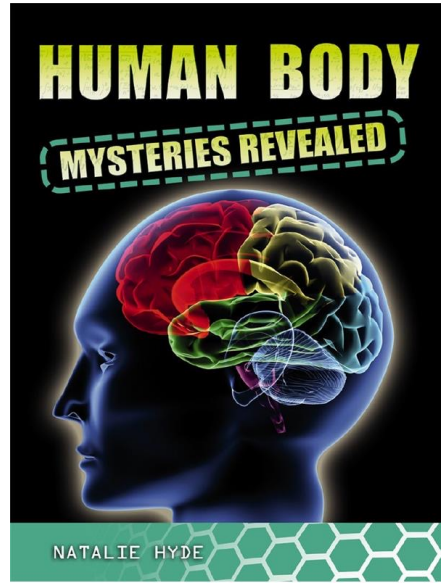
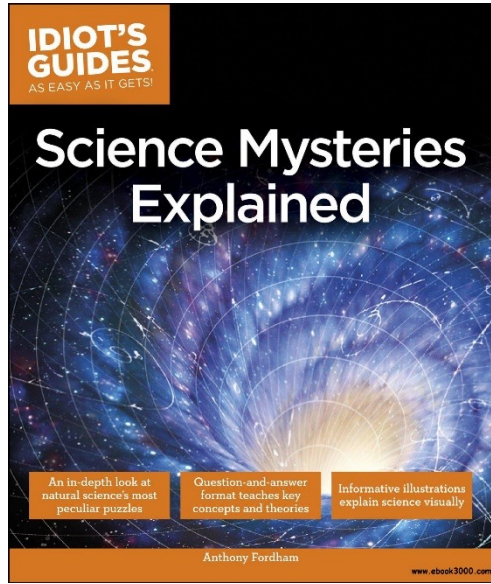


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## “Mystery”

mysterium (secret) – myo (close eyes and mouth)



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Above this starry vault, what is there? New starry skies. And beyond? The human spirit will never cease to ask itself, pushed by an invincible force: what lies beyond? Since the point at which it stops is but a finite magnitude - greater than those that have preceded it - as soon as it begins to perceive it, the question always returns, unable to silence the cry of its curiosity. It is useless to answer that beyond there are spaces, times, or magnitudes without limit. The notion of the infinite has this double character of imposing itself and of being incomprehensible.

Louis Pasteur, 1882



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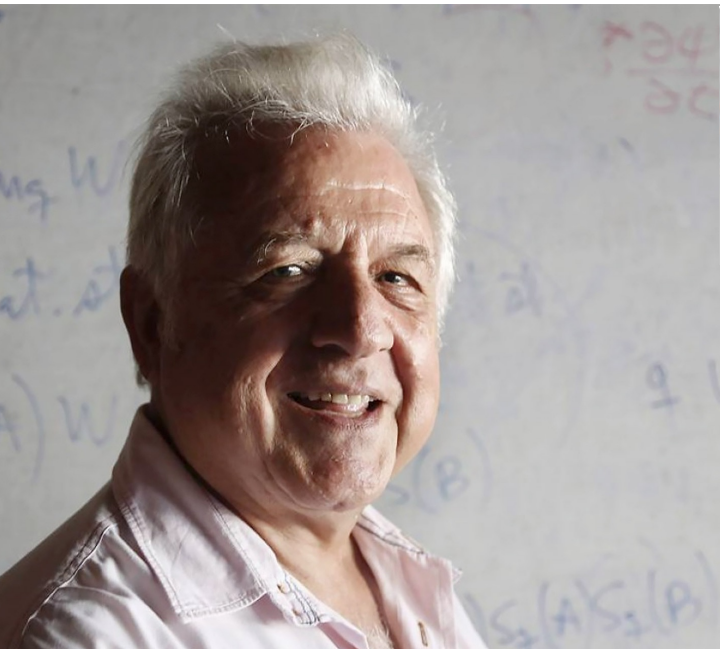


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$$S_q = -k \frac{1 - \sum_n p_n^q}{1 - q}$$

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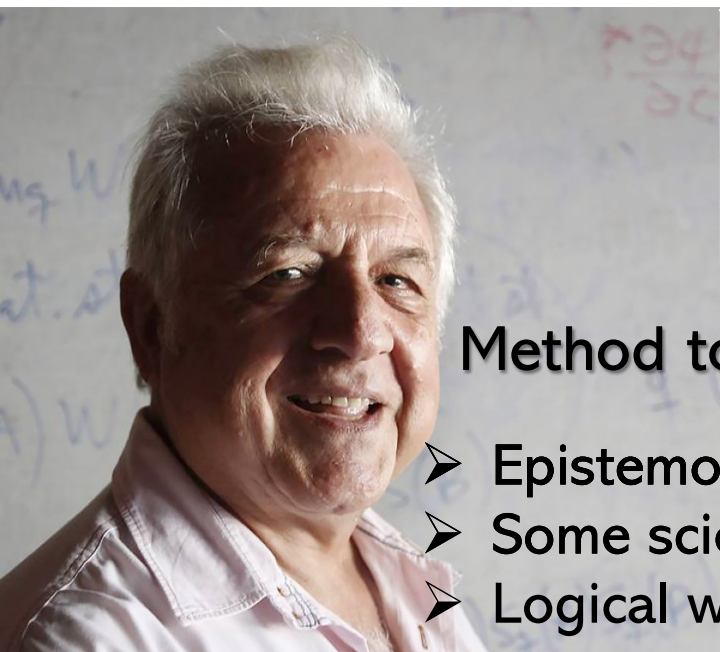
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Method to attain knowledge about something new?

- Epistemological vision of L. Giussani (1922-2005)
- Some scientific examples
- Logical work of C.S. Peirce (1839-1914)

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# STATISTICAL MECHANICS FOR COMPLEXITY

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## I - Recovering the affective dimension of scientific work

“knowledge is the fruit of the encounter between human energy and a presence. It is an event in which the energy of human consciousness assimilates the object”.

L. Giussani, *The Religious Sense*, McGill-Queen's University Press, Chicago 2023, p. 8.



***The hearth – reason and affectivity – leads to knowledge***

Affectivity/Adhesion to reality:

- *Allows all factors to be grasped and affirmed.*
- *It makes reasonable the fatigue of work and of breaking schemes*

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### *Amazement*

“For how, otherwise, should it happen that sometimes we “wonder” quite spontaneously about some experience? (...) A wonder of this kind I experienced as a child of four or five years when my father showed me a compass. That this needle behaved in such a determined way did not all fit into the kind of occurrences that could find a place in the unconscious world of concepts. I can still remember that this experience made a deep and lasting impression upon me. Something deeply hidden had to be behind things”.

A. Einstein, *Autobiographical notes*, Paul Arthur Schilpp

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## I - Recovering the affective dimension of scientific work

### *Awe*

“Why does one always want to know more if one knows that no one will ever know everything? I don't know how to answer, it's something mysterious. Love leads to the care of the loved one, for a reason that I don't understand, but I recognize that it is so. [...] It is the astonishment in the face of reality [...] that keeps me wondering. One is satisfied if one contributes to know the infinite unknown, at whatever point you are. Humans are made like that; I can't say why.”

C. Tsallis, *La aventura del descubrimiento*, Encuentro, Madrid 2009, p. 56.

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# STATISTICAL MECHANICS FOR COMPLEXITY

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## II - Presentiment of a mysterious "correspondence" with reality

“For understanding to take place, there must be correspondence [...] Truth is the correspondence between consciousness and reality [...] this is the nature of rational dynamism”.

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### Correspondence:



- Reality awakens what characterizes us most: **the question**
- The Universe **allows itself to be known.**

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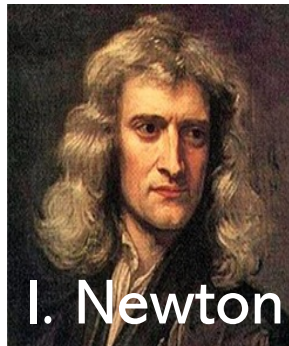
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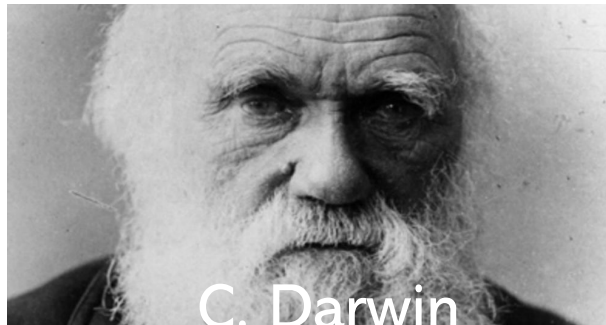
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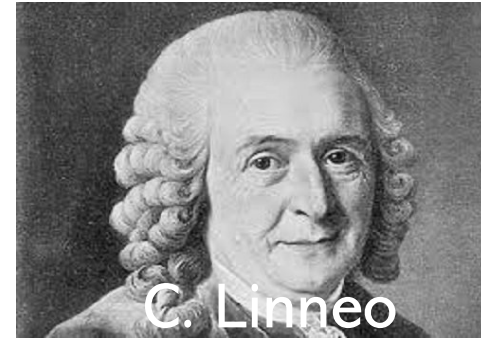
### *Witnesses*



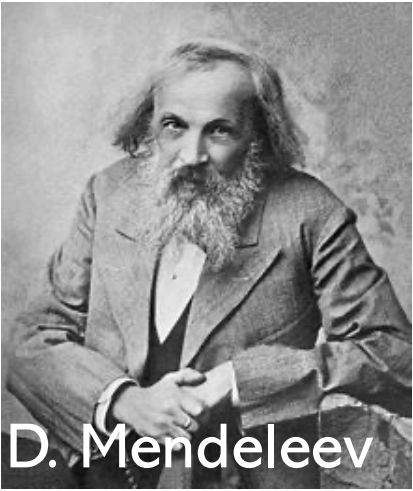
I. Newton



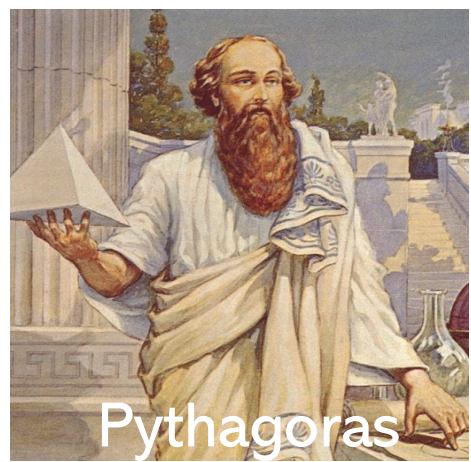
C. Darwin



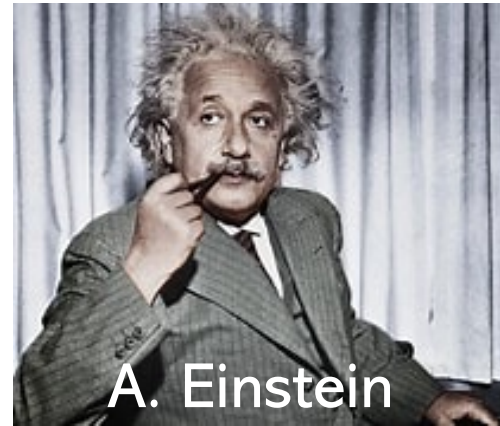
C. Linneo



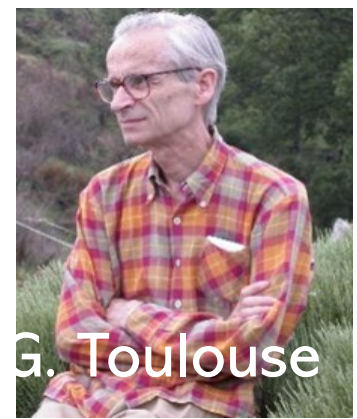
D. Mendeleev



Pythagoras



A. Einstein



G. Toulouse

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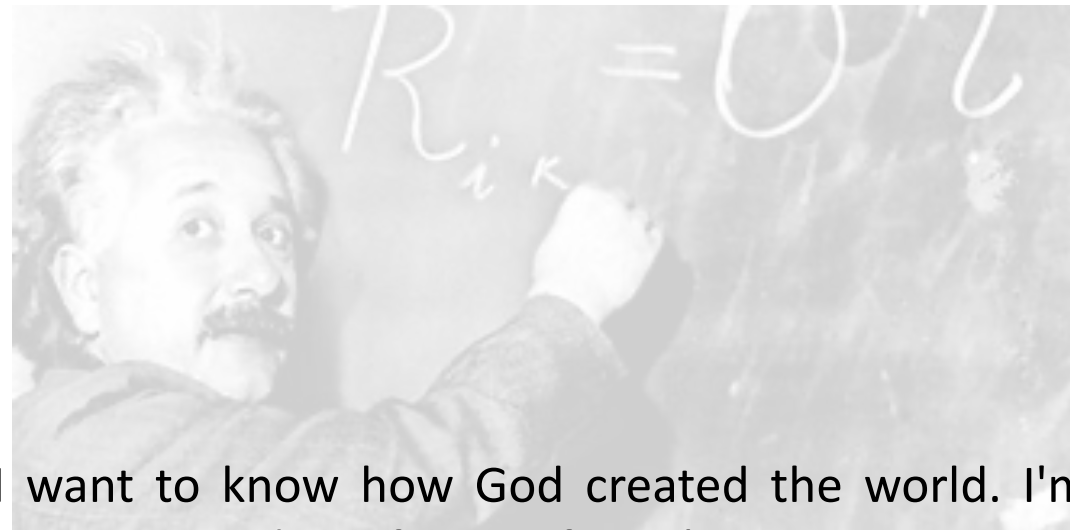
*Understanding*

*All-encompassing*



“The fantasy is the cradle of theory; the experimental observation is its tutor”.

L.W. Boltzmann



“I want to know how God created the world. I'm not interested in *this* or *that* phenomenon, or in the spectrum of a chemical element. I want to know his thought; the rest is a detail.”

A. Einstein [E. Salaman, "A Talk With Einstein," *The Listener* 54 (1955)]

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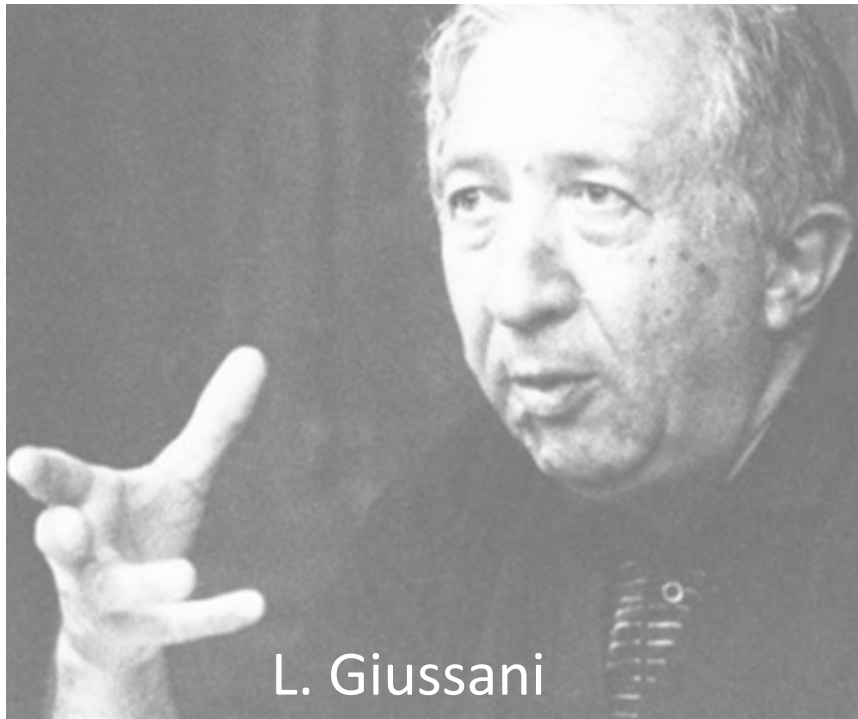
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## III – Diversity of methods. Logic and rationality



Constrained to measure against...



L. Giussani

**Elementary experience**



C. S. Peirce

**Rational Instinct**

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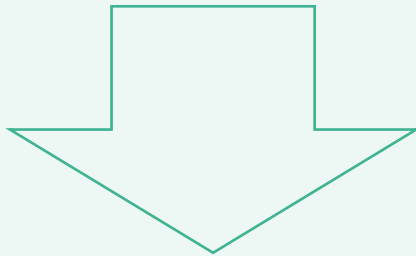
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### Modern Logic

*Formal mathematical logic:*

- Deduction
- Induction

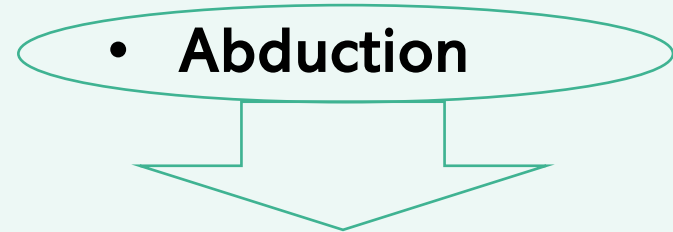


New ideas are the result of  
"creative intuitions".

### Giussani & Pierce

*Theory of reasoning:*

- Deduction
- Induction
- Abduction



Genesis of scientific theories

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**Deduction:** Consequences from a pre-existing scheme

**Example:**  $L=2\pi R$

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**Deduction:** Consequences from a pre-existing scheme

**Induction:** Generalization of cases where "something" is true

**Example:**  $F_1 = F_2 = G \frac{m_1 \times m_2}{r_2}$

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**Induction:** Generalization of cases where "something" is true

**Abduction** (**abductio**: open, spread apart)/“logic of surprise”(J.Nubiola)

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**Induction:** Generalization of cases where "something" is true

**Abduction** (*abductio*: open, spread apart)/“logic of surprise”(J.Nubiola)

1. A surprising fact “C” is observed;
2. if “X” were true, “C” would necessarily occur.
3. So, there is reason to believe that “X” is true.

### CHARACTERISTICS::

- To account for a surprising phenomenon.
- Something new has to be discovered.
- Solution cannot be a generalization.

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## IV– Elementary experience and normative value of aesthetics

### *How to formulate an abductive hypothesis?*

- *Reading of signs (rapid INFERENCE; NOT intuition)*
- *Same logic of the phenomenon of trust/moral certainty*

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### *How to formulate an abductive hypothesis?*

“as a method, the last one is akin to the flair of an artist or a genius, who, through signs, proceeds to the perception of what is true. When Newton saw the famous apple fall, it became a sign that immediately sparked his great hypothesis”

L. Giussani, *The Religious Sense*, McGill-Queen's University Press, Chicago 2023.

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*Aesthetic* reading of signs



Equiprobability head/tail  $\Rightarrow$  Boltzmann Statistical Mechanics

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**Beauty underpins a method**

$$e=2.7182818284590452353\dots = 1 + \frac{1}{2} + \frac{1}{2.3} + \frac{1}{2.3.4} + \dots$$

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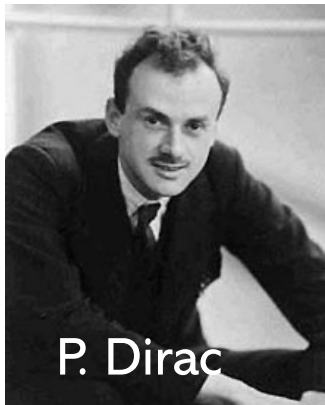
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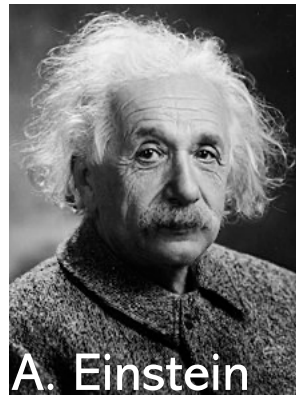


**Beauty underpins a method**

$$e=2.7182818284590452353\dots = 1 + \frac{1}{2} + \frac{1}{2.3} + \frac{1}{2.3.4} + \dots$$



P. Dirac



A. Einstein



J.H. Poincaré



C. Tsallis

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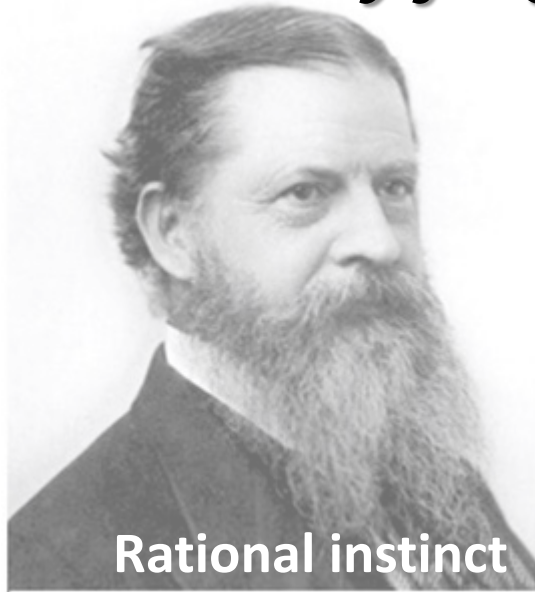
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## IV– Elementary experience and normative value of aesthetics

### *Plausibility judgement criteria*



Rational instinct

“Rational instinct is the aspect of our thinking that is in harmony with reality”

C.S.Pierce

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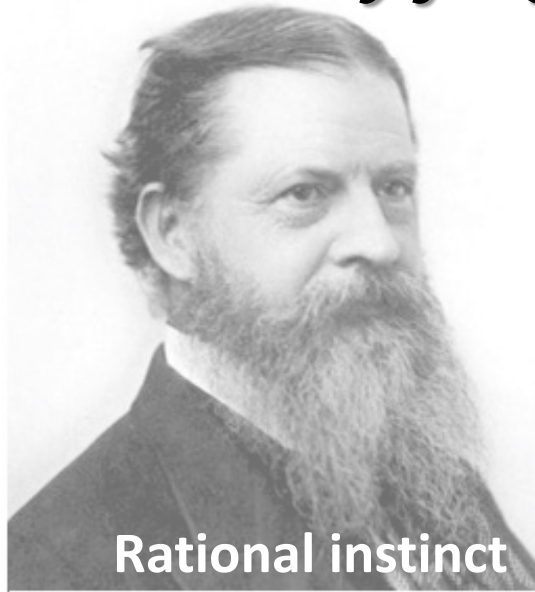
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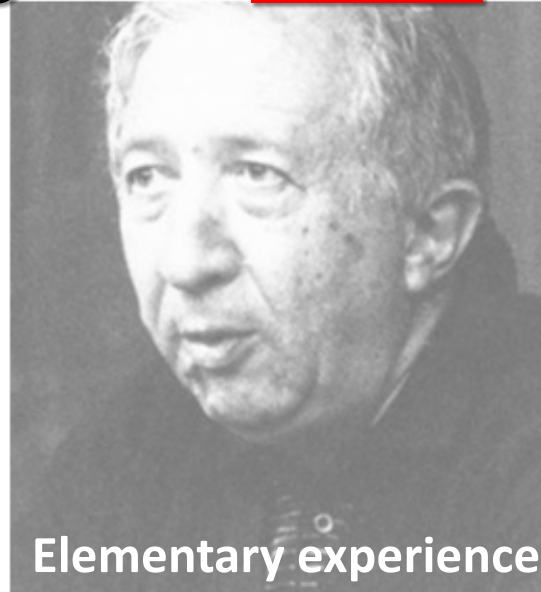
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Rational instinct



Elementary experience

“The need for totality, which is our reason [...] our essential capacity for knowledge, our openness to penetrate and embrace reality to an ever greater degree”

L. Giussani, *The Religious Sense*, McGill-Queen’s University Press, Chicago 2023, p. 59

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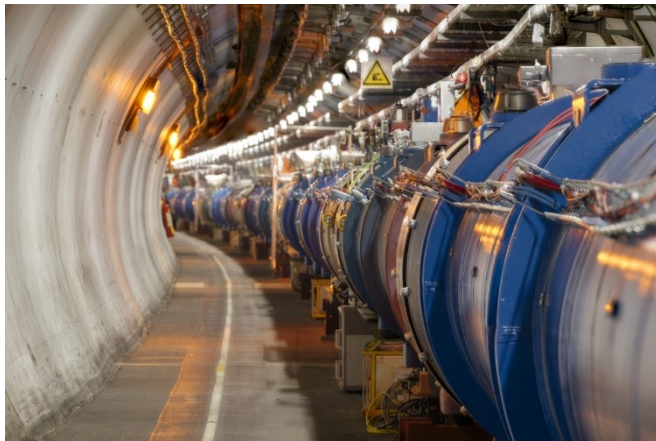
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# STATISTICAL MECHANICS FOR COMPLEXITY

A CELEBRATION OF THE 80TH BIRTHDAY OF CONSTANTINO TSALLIS

## V- Structural disproportion in the dynamics of reason

*“Shall we stop in time or space?”*



“I must admit that when we’ll have a final theory, we will not have a totally satisfactory picture of the world because there will always be the question *why?*”

S. Weinberg, *An Universe with no designer*,  
*Annals of the New York Academy of Science* 956. (Weinberg).

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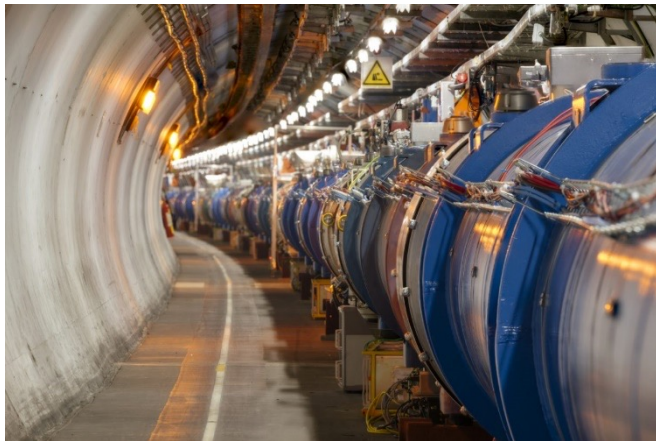
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## V- Structural disproportion in the dynamics of reason

### *Science and fallibilism*



“The best hypothesis, in the sense of the one most recommending itself to the inquirer, is the one which can be the most readily refuted if it is false [...] If a hypothesis can quickly and easily be cleared away so as to go toward leaving the field free for the main struggle, this is an immense advantage”

Peirce, The uncertainty of scientific results, CP 1.120.

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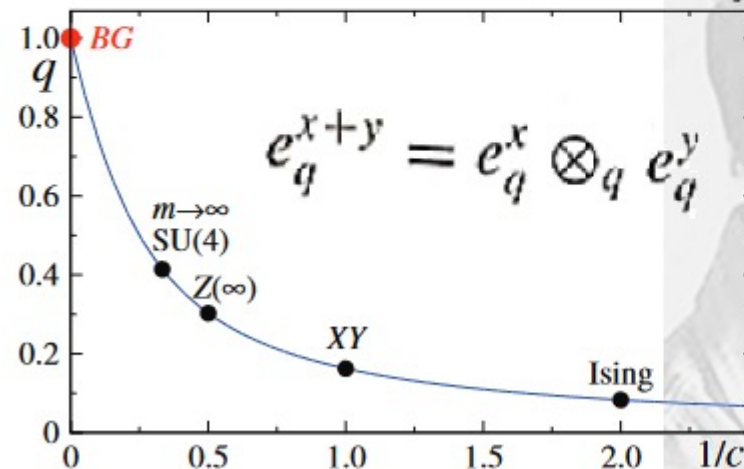
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## V- Structural disproportion in the dynamics of reason

$$S = k \log W$$

### Science and fallibilism

$$\frac{d \ln_q x}{dx} = \frac{1}{x^q} \quad (x > 0; \forall q)$$



$$S_q = k \ln_q W$$

C. Tsallis and H. J. Haubold 2015 *EPL* **110** 30005

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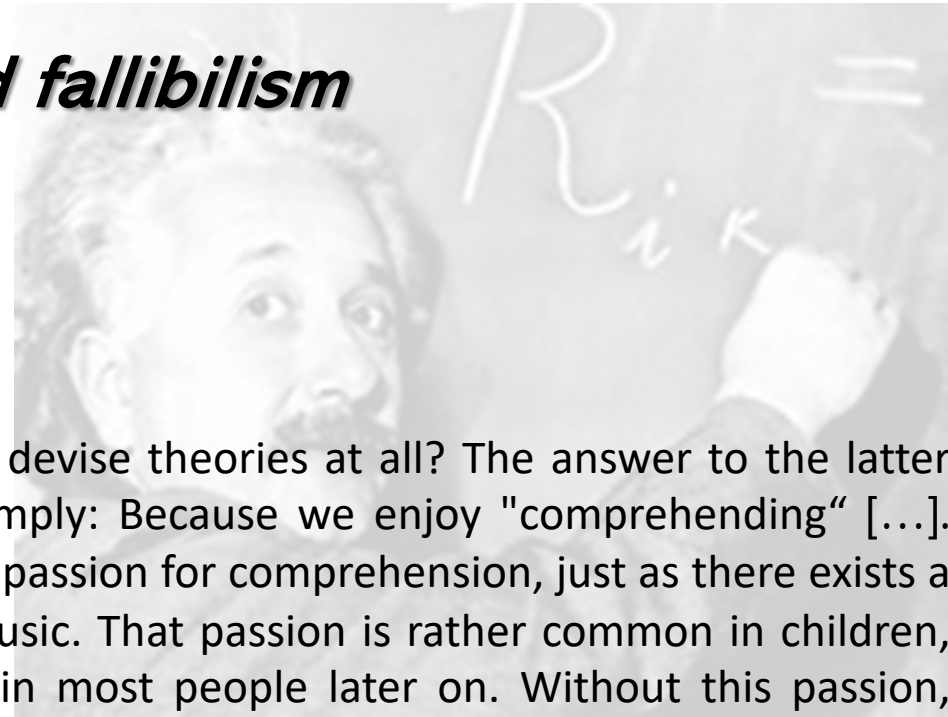
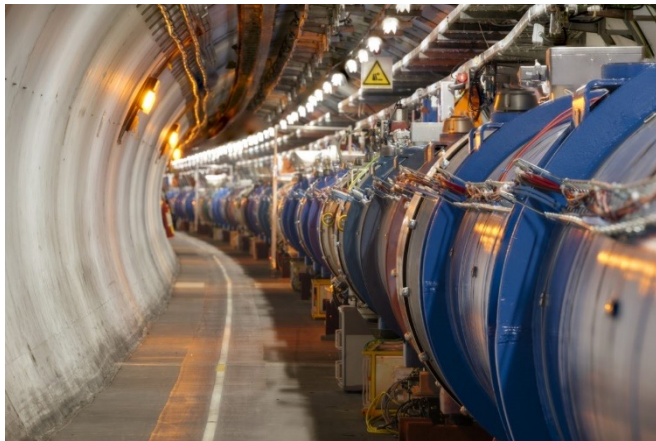
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### *Science and fallibilism*



Why do we devise theories at all? The answer to the latter question is simply: Because we enjoy "comprehending" [...]. There exists a passion for comprehension, just as there exists a passion for music. That passion is rather common in children, but gets lost in most people later on. Without this passion, there would be neither mathematics nor natural science."

A. Einstein, «On the generalized theory of gravitation», *Scientific American* v.182, n.4 (1950)

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# STATISTICAL MECHANICS FOR COMPLEXITY

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## Conclusion: *Opening of reason*

### *Epistemology of L. Giussani – C. Tsallis*

- Importance of affective dynamics in rational experience
- Metaphysical realism
- Use of non guileless reasonableness
- Elementary experience and normative value of aesthetics
- Structural disproportion in the dynamics of reason

“Reason is an infinite embrace of reality [...] in this conception of reason as openness, as a window opened to an infinite field that one never ends up entering, every moment is novelty, a richness[...] If reason were the measure of things, every moment would instead be a tomb”

L. Giussani, *Introduzione*, in G. Leopardi, *Cara beltà*, BUR, Milano 1996, p. 26

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# STATISTICAL MECHANICS FOR COMPLEXITY

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## Conclusion: *Recognition of a vanishing point*

### *Epistemology of L. Giussani – C. Tsallis*

- Importance of affective dynamics in rational experience
- Metaphysical realism
- Use of non guileless reasonableness
- Elementary experience and normative value of aesthetics
- Structural disproportion in the dynamics of reason

“Reason is consciousness of reality according to the totality of its factors, and in the totality of its factors there is a vanishing point where the accounts do not add up: rational experience, instead of getting stuck, opens up in hunger and thirst for a different horizon.”

L. Giussani, *Si può (veramente!) vivere così*, BUR, Milano 1996

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## Conclusion

- Respect for analyticity, precision and forcefulness of science
- ⊗
- Aspiration for transcendental infinity/religiosity/recognition:  
(truth, beauty, goodness)

↓

**Science is a necessary instrument**

**Possibility of revelation**

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Thank<sub>q</sub> Constantino!