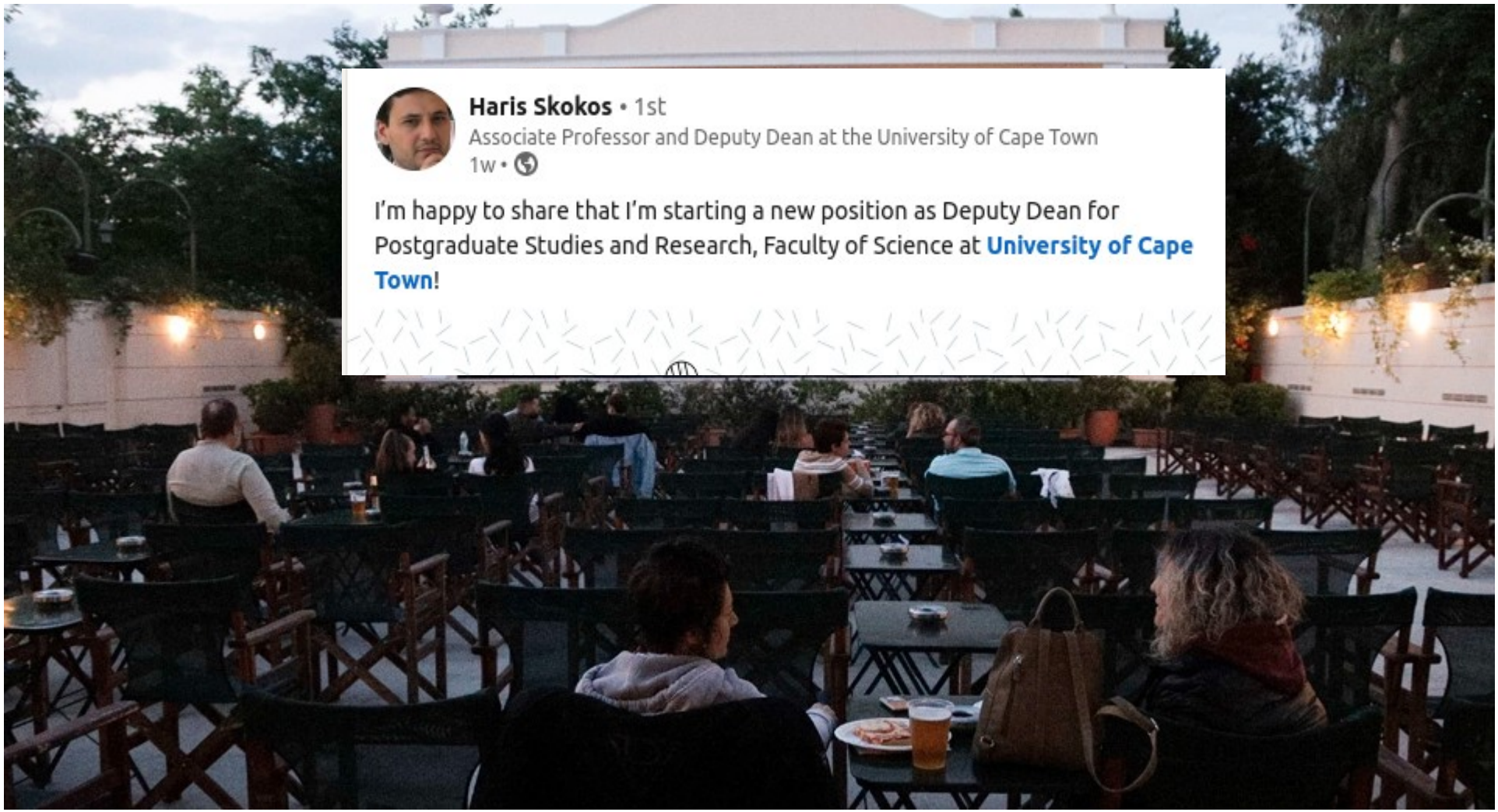
Επίκαιρα !


Haris Skokos • 1st
Associate Professor and Deputy Dean at the University of Cape Town
1w •
I'm happy to share that I'm starting a new position as Deputy Dean for Postgraduate Studies and Research, Faculty of Science at University of Cape Town!

Πέμπτη 17 Μαρτίου 2022

Ιχνηλατώντας την μουσική με την συμβολική δυναμική και την θεωρία της πολυπλοκότητας

Vasileios Basios

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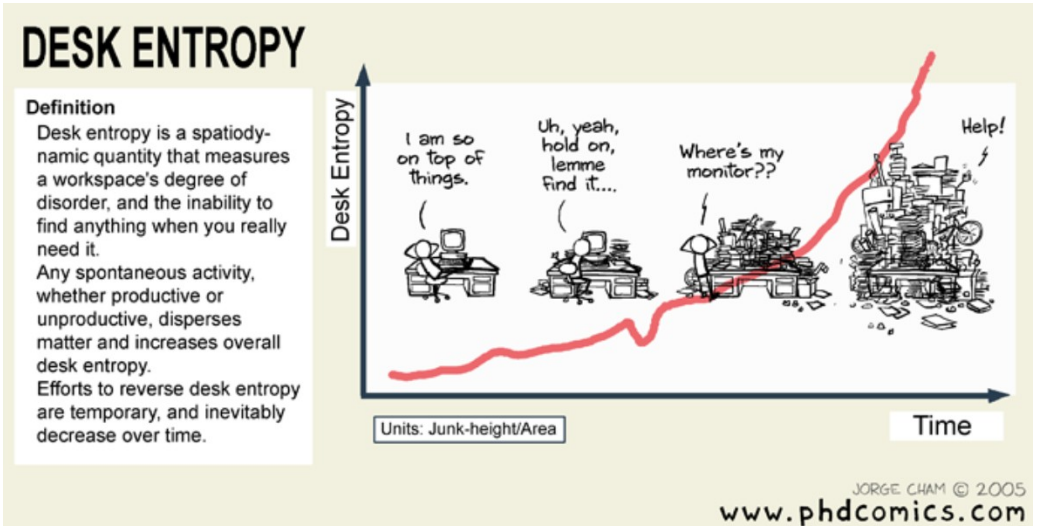
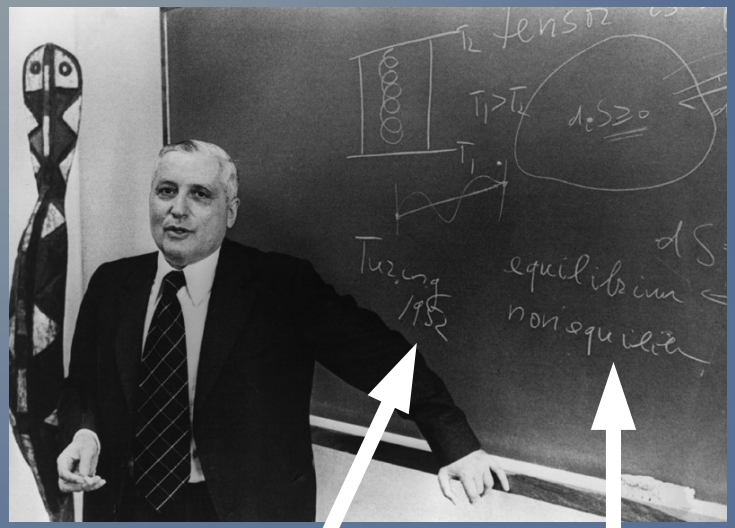
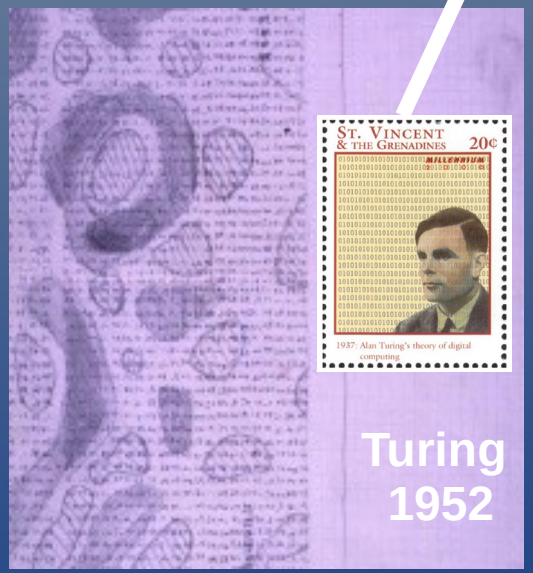
Interdisciplinary Centre for Nonlinear Phenomena & Complex Systems (Cenoli-ULB)
&
Département de Physique des Systèmes Complexes et Mécanique Statistique,
University of Brussels (ULB), Brussels.

Entropy
Order & Disorder







!

Prigogine Nicolis & Lefever
(Nobel 1979)

Turing's Morphogenesis

+

Entropy Production Theorem

+

Fluctuation Dissipation Theorem

=

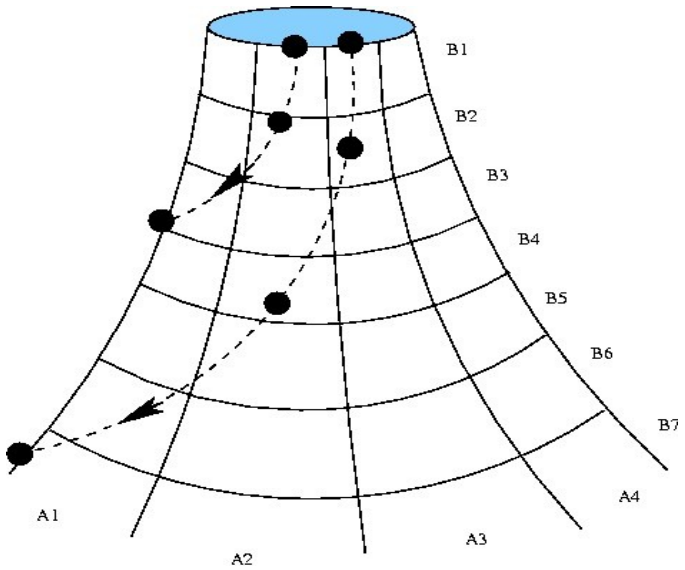
Dissipative Structures

+

Self-Organization & Pattern Formation

SYMBOLIC DYNAMICS: a seminal idea

Poincaré (1890s) & Maxwell:
Nonlinear dynamical systems can exhibit sensitive dependence on initial conditions

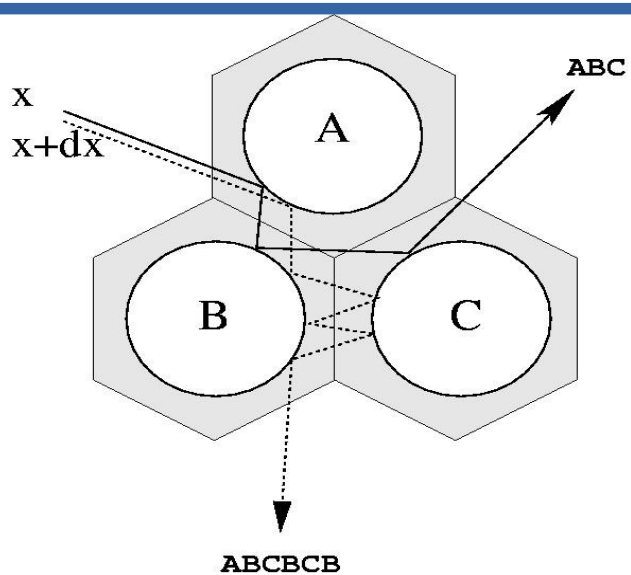


Hadamard (1898):
motion on negative curvature is sensitive to initial conditions

Artin, Heldund and Hopf: the motion on a surface of constant negative curvature is ergodic.

Krylov: A physical billiard is a system with negative curvature, along the lines of collision

Sinai: a physical billiard can be ergodic.




John von Neumann

ENTROPY

$$S = -\operatorname{tr}(\rho \ln \rho)$$

Statistical. Operator (1927)

$$\rho = \sum \eta_j \left| j \right\rangle \left\langle j \right|$$

$$S = -\sum_j \eta_j \ln \eta_j$$

$$\mathrm{H}(X) = \mathrm{E}[\mathrm{I}(X)] = \mathrm{E}[-\log(\mathrm{P}(X))]$$

$$\mathrm{I}(x) := -\log_b \left[\Pr\left(x\right)\right] = -\log_b \left(P\right)$$

Information content: surprise : bit

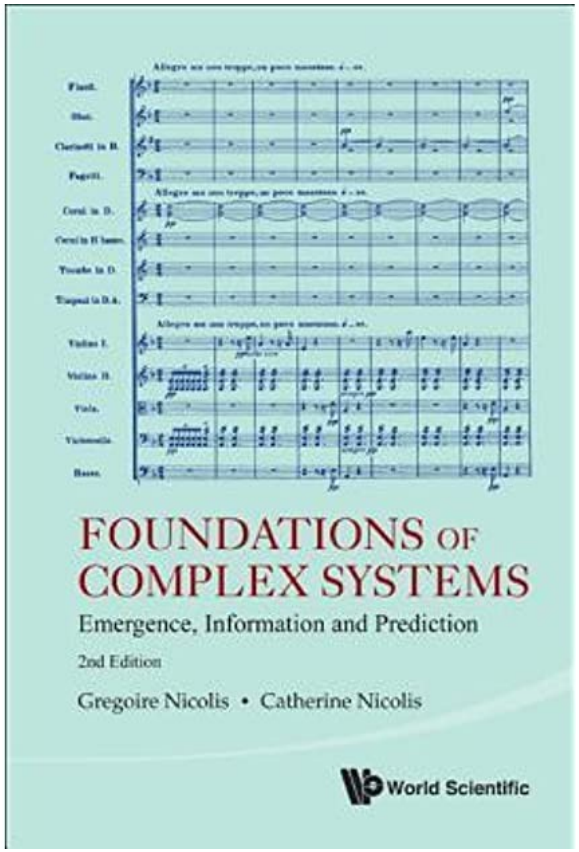

Claude Shannon

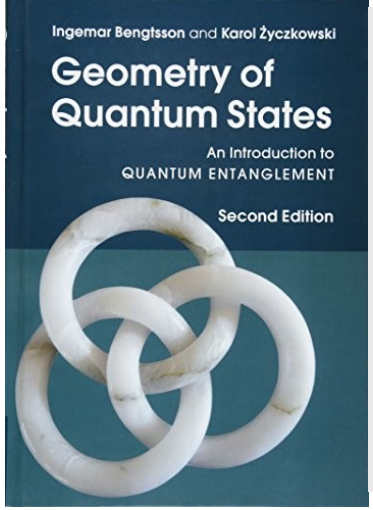
$$\mathrm{H}(X) = -\sum_{i=1}^{n} \mathrm{P}(x_i) \log_b \mathrm{P}(x_i)$$

X : Discrete Random Variable *with events* $\{x_1, \ldots, x_n\}$

*" … Shannon replied that the theory was in excellent shape, except that he needed a good name for "missing information". **"Why don't you call it entropy"**, von Neumann suggested. "In the first place, a mathematical development very much like yours **already exists in Boltzmann's statistical mechanics**, and in the second place, no one understands entropy very well, so in any discussion you will be in a position of advantage."*

John Avery "(2003) "Information Theory and Evolution. World Scientific"





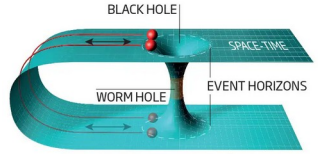
2.6 To see an analogy between the Shannon and the Havrda–Charvat entropies prove that [2]

$$S(P) \equiv -\sum_i p_i \ln p_i = -\left[\frac{d}{dx}\left(\sum_i p_i^x\right)\right]\Big|_{x=1} \quad (2.86)$$

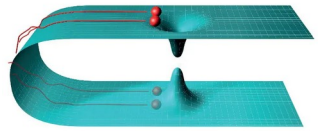
$$S_q^{HC}(P) \equiv \frac{1}{1-q}\left(\sum_i p_i^q - 1\right) = -\left[D_q\left(\sum_i p_i^x\right)\right]\Big|_{x=1} \quad (2.87)$$

where the 'multiplicative' *Jackson q–derivative* reads

$$D_q\,(f(x)) \equiv \frac{f(qx)-f(x)}{qx-x}, \quad \text{so that} \quad \lim_{q\to 1} D_q(f(x)) = \frac{df(x)}{dx}. \quad (2.88)$$



"Wormholes" connecting two black holes in different parts of space-time can exist – but only if particles on the black holes' surfaces are quantum entangled



Break the entanglement, and the wormhole snaps too, suggesting entanglement is the thread that binds space-time together

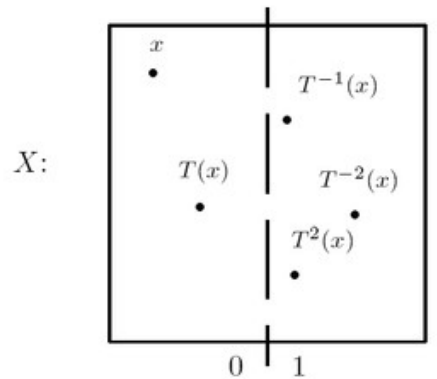
$$S = \frac{1}{4}\frac{c^3 k}{G\hbar}A$$

Bekenstein Hawking
Black Hole Entropy

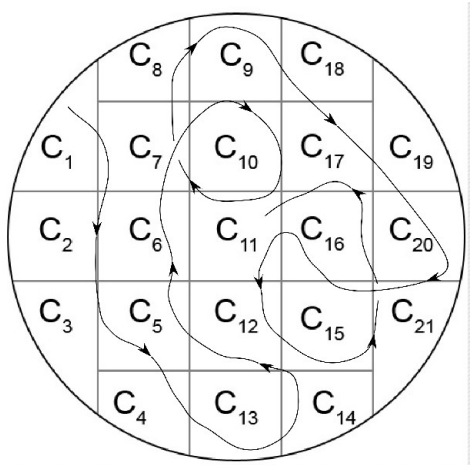
http://www.scholarpedia.org/article/Entropy

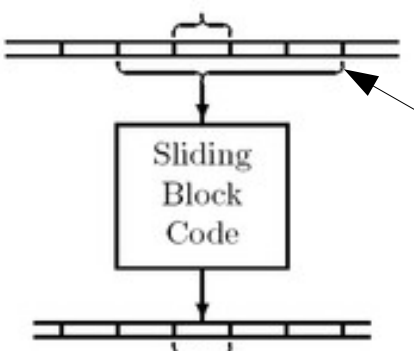
How to put Dynamics into Symbolic Dynamics & Entropy

State-space: $X = \{x\}$
Transformation: $x' = T(x)$
Coarse-Graining: $S(X)$
Alphabet: $\{a,b,c, \ldots\}$ e.g. $\{0,1\}$



⟶ Trajectory to Symbol-Sequence: $s(T(x))=\ldots 110.01\ldots$

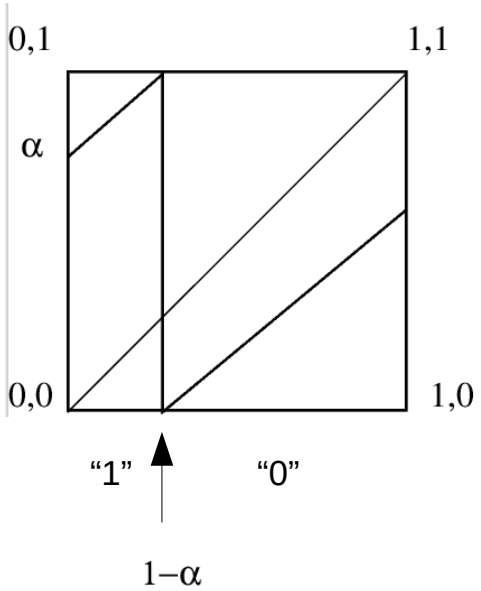




block of m-symbols

H(m)
Shannon-block-entropy

Dynamics → symbol sequence =
= TEXT with Grammar & Syntax

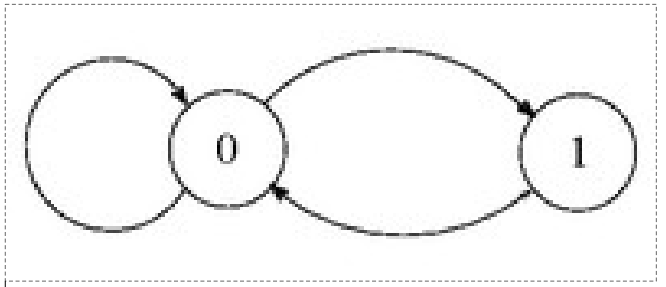


$$x_{n+1} = x_n + \alpha \pmod 1$$

Circle-Map

Golden Ratio

Fibonacci Sequence



S_0	0
S_1	01
S_2	010
S_3	01001
S_4	01001010
S_5	0100101001001

Shannon-Block Entropy

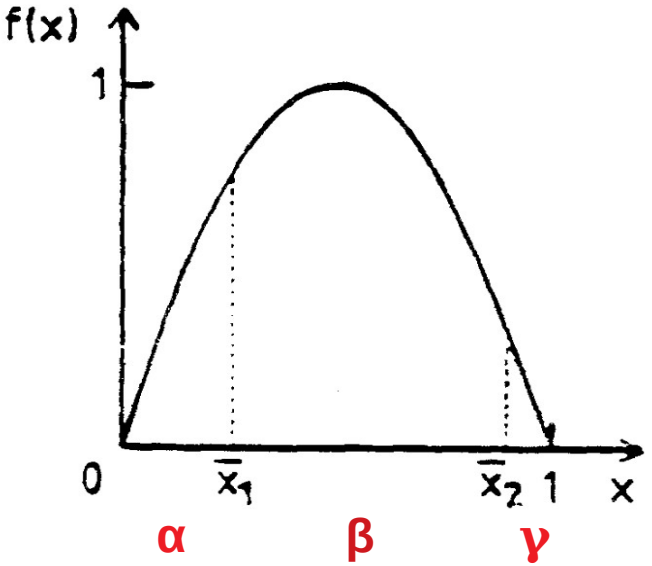
$$H(m) = -\sum_{\text{all } m\text{-words}} P(w) \ln P(w)$$

$$H = \log(m)$$

J. Stat. Phys. 54,3/4, **1989**

"Chaotic Dynamics, Markov Partitions,& Zipf's Law"

G. Nicolis, C. Nicolis, J.S. Nicolis



$$x_{n+1} = 4x_n(1 - x_n), \qquad 0 \leqslant x \leqslant 1$$

period-two orbit $\bar{x}_1 \simeq 0.345$, $\bar{x}_2 \simeq 0.905$

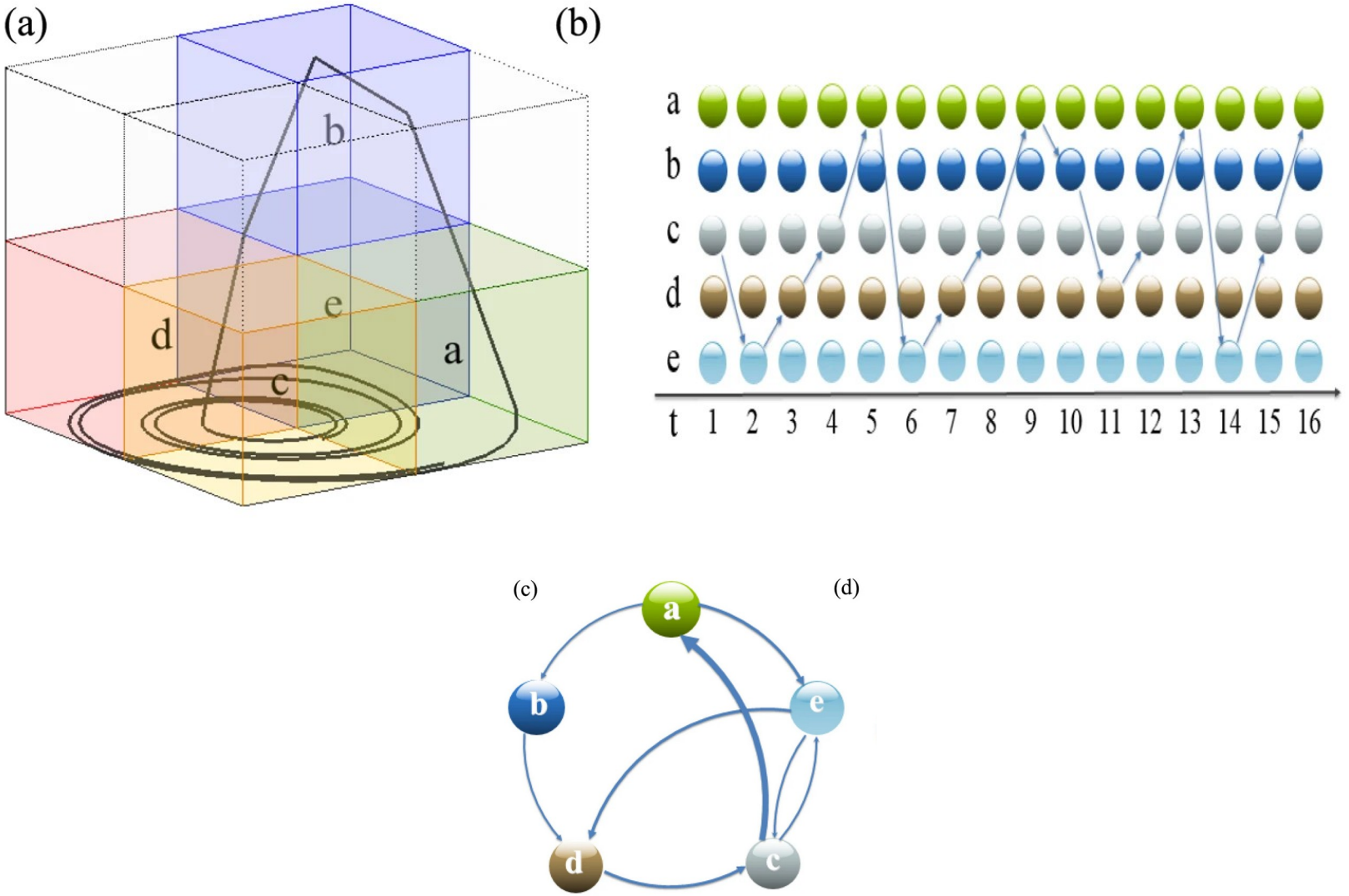
$$W = \begin{pmatrix} 1/2 & 1/2 & 0 \\ 0 & 1/2 & 1/2 \\ 1 & 0 & 0 \end{pmatrix}$$

$W_{21} = P(\alpha \to \beta)$

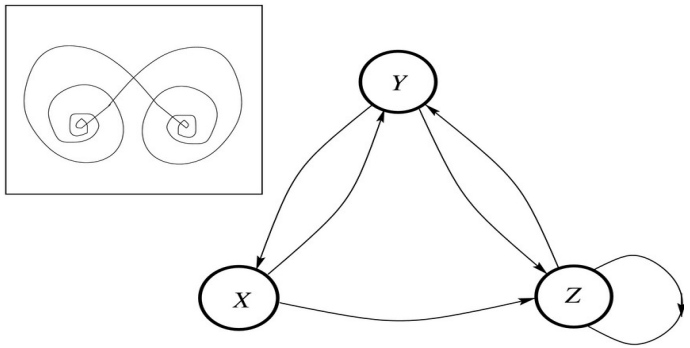
… etc.

$$P_{n+1}(i) = \sum_{j=1}^{N} W_{ji} P_n(j), \qquad i = 1, \ldots, N$$

$\alpha\alpha\beta\alpha\beta\alpha\alpha\beta\alpha\beta\gamma\beta\alpha\beta\alpha\alpha\alpha\beta\alpha\beta\alpha\alpha\beta\alpha\alpha\alpha\beta\gamma\beta\alpha\beta\gamma$ … etc.



Weng, T., et al.
"Memory and betweenness preference in temporal networks induced from time series."
Sci Rep 7, 41951 (2017)



Lorenz system of equations

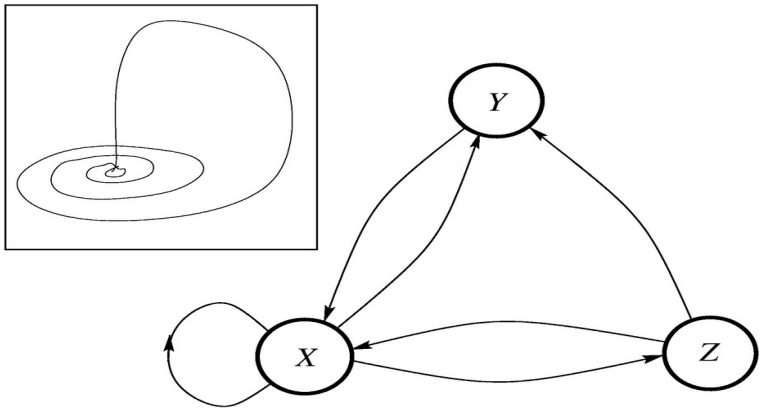
$$\begin{aligned} \dot{x} &= \sigma(y-x) \\ \dot{y} &= rx - y - xz \\ \dot{z} &= xy - bz \end{aligned}$$

$\sigma = 10, b = 0.25, r = 490,$
partition close to the average values of the variables.

$$\langle S_g \rangle = 0.2899 \text{(symbols/tu)} \qquad h_{KS} = 0.6077$$

Goëdel numbering assumption, OK.
Set of forbidden proto-words, "Lorenz' Grammar"

$$\mathcal{F}_L = \{XX, YY, ZX\}$$



Rössler system of equations

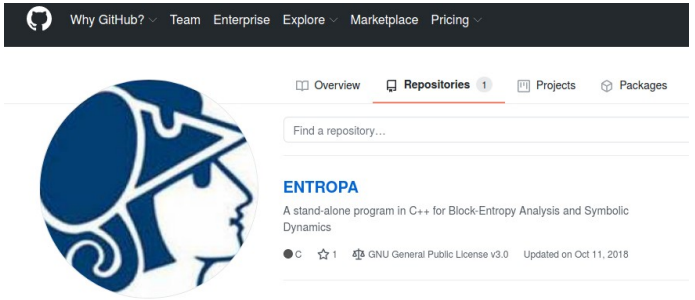
$$\begin{aligned} \dot{x} &= -y - z \\ \dot{y} &= x + ay \\ \dot{x} &= bx - cz + xz \end{aligned}$$

$a = 0.38, b = 0.30, c = 4.82,$
partition far away from the average values of the variables.

$$\langle S_g \rangle = 0.411 \text{(symbols/tu)} \qquad h_{KS} = 0.033$$

Göedel numbering assumption OK for "Rössler's Grammar".
Set of forbidden proto-words :

$$\mathcal{F}_R = \{YY, YZ, ZZ\}$$

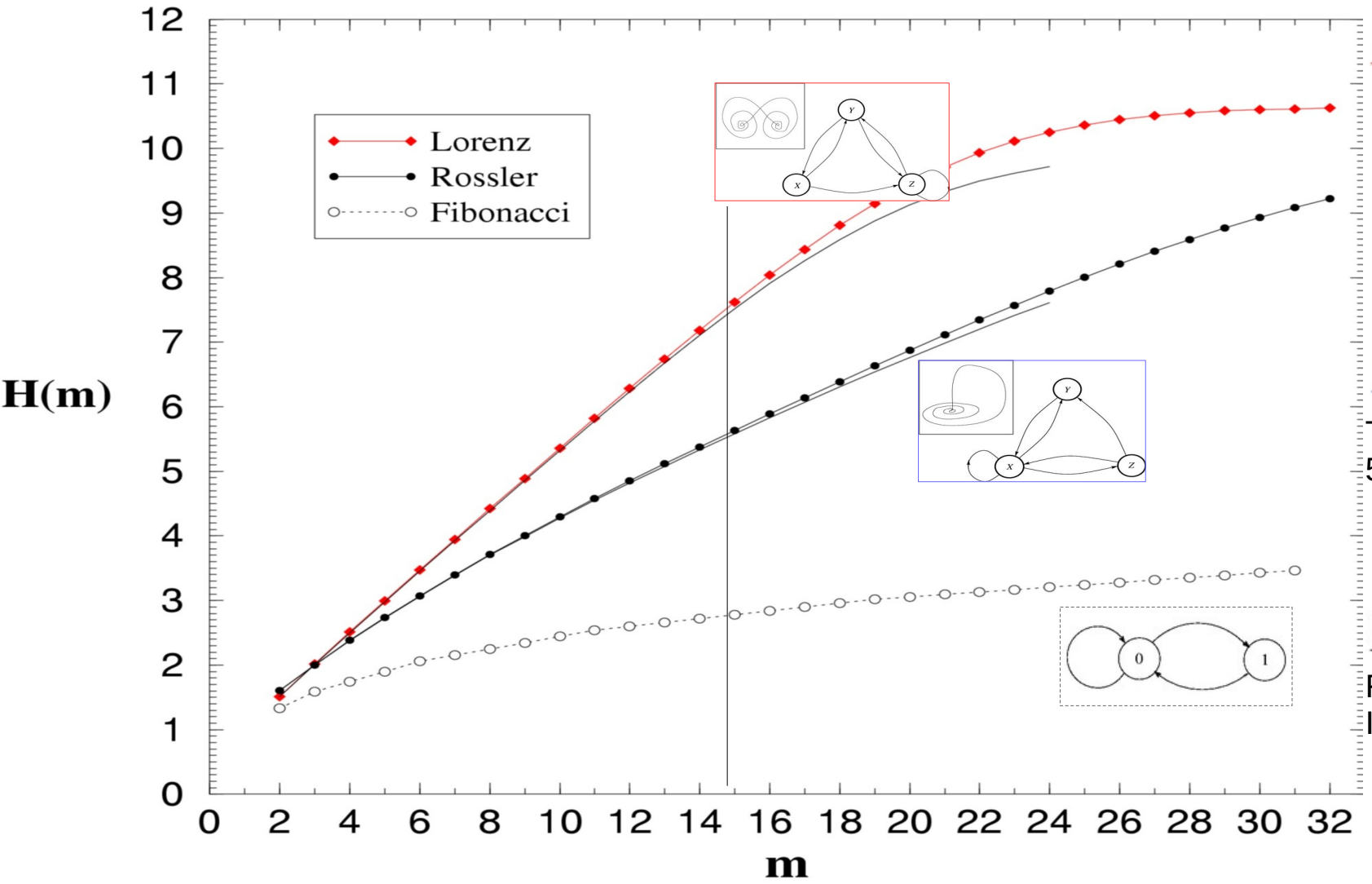


VaB
Alcamis

$$H(m) = -\sum_{\text{all } m\text{-words}} P(w) \ln P(w)$$

```
=======================================================
              THE RESULT OF THE PROGRAME
=======================================================
        L              !!            H(l)
=======================================================
       L = 2           !!      H[2] = 1.3862640858

=======================================================
       L = 3           !!      H[3] = 2.0793726444

=======================================================
       L = 4           !!      H[4] = 2.7722454071

=======================================================
       L = 5           !!      H[5] = 3.4643878937

=======================================================
       L = 6           !!      H[6] = 4.1553511620

=======================================================
       L = 7           !!      H[7] = 4.8436260223

=======================================================
       L = 8           !!      H[8] = 5.5277051926

=======================================================
       L = 9           !!      H[9] = 6.2034478188

=======================================================
       L = 10          !!      H[10] = 6.8624925613

=======================================================
```

```
01 = 2003       P1      =  0.250        h[1]    =0.346730
10 = 2003       P2      =  0.250        h[2]    =0.346730
00 = 2018       P3      =  0.252        h[3]    =0.347445
11 = 1975       P4      =  0.247        h[4]    =0.345359

=======================================================
total = 7999              H[2] = 1.3862640858
=======================================================

010 = 1004      P1      =  0.126        h[1]    =0.260503
101 = 989       P2      =  0.124        h[2]    =0.258472
100 = 1014      P3      =  0.127        h[3]    =0.261841
001 = 1013      P4      =  0.127        h[4]    =0.261708
011 = 999       P5      =  0.125        h[5]    =0.259829
111 = 976       P6      =  0.122        h[6]    =0.256689
110 = 999       P7      =  0.125        h[7]    =0.259829
000 = 1004      P8      =  0.126        h[8]    =0.260503

=======================================================
total = 7998              H[3] = 2.0793726444
=======================================================

0101 = 489      P1      =  0.061        h[1]    =0.170875
1010 = 515      P2      =  0.064        h[2]    =0.176625
0100 = 515      P3      =  0.064        h[3]    =0.176625
1001 = 507      P4      =  0.063        h[4]    =0.174874
0011 = 525      P5      =  0.066        h[5]    =0.178792
0111 = 487      P6      =  0.061        h[6]    =0.170426
1110 = 487      P7      =  0.061        h[7]    =0.170426
1101 = 500      P8      =  0.063        h[8]    =0.173328
0010 = 488      P9      =  0.061        h[9]    =0.170651
1011 = 474      P10     =  0.059        h[10]   =0.167480
1111 = 489      P11     =  0.061        h[11]   =0.170875
1100 = 499      P12     =  0.062        h[12]   =0.173107
1000 = 506      P13     =  0.063        h[13]   =0.174654
0000 = 498      P14     =  0.062        h[14]   =0.172885
0001 = 506      P15     =  0.063        h[15]   =0.174654
0110 = 512      P16     =  0.064        h[16]   =0.175970

=======================================================
total = 7997              H[4] = 2.7722454071
```



$H = hm$

Bernoulli, Markov,
No memory

$H = gm^{\mu}$

Text, Music, non-Markov
5-7 step memory

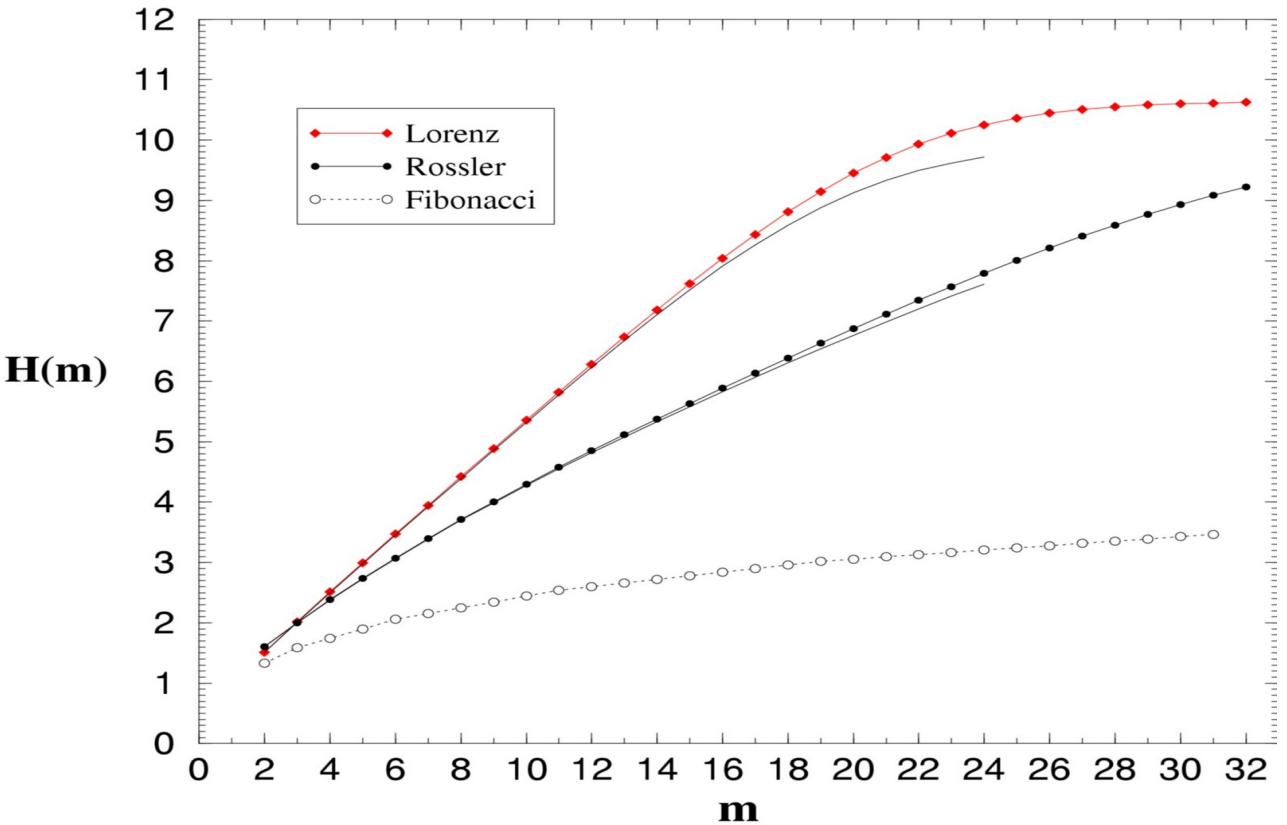
$H = \log(m)$

Fibonacci Bin. Seq.
Infinite memory

A Conjecture by Ebeling and Nicolis

In the course of their analysis of symbol sequences they proposed a general scaling law for the block entropy.

$$H_m = mh + gm^{\mu} (\log m)^{\nu} + e$$



$$H = hm$$

$$H = gm^{\mu}$$

$$H = \log(m)$$

The **Shannon Block Entropy** of the partition is :

$$H(m) = - \sum_{\text{all } m\text{-words}} P(w) \ln P(w)$$

where $P(w)$ is the probability of occurrence of each word, w, of length m

"The key is to realize that uncertainty represents potential information"
(David Applebaum)

Shannon-McMillan Theorem :
The probability of a word of length m to appear
is "penalized" according to Entropy scaling w.r.t. its length

$$P[w(n)] \approx e^{-H(m)}$$

J. Stat. Phys. 54,3/4, ***1989***
"Chaotic Dynamics, Markov Partitions,& Zipf's Law"
G. Nicolis, C. Nicolis, J.S. Nicolis

Vasileios Basios, Gian-Luigi Forti qnd Gregoire Nicolis
"Symbolic Dynamics Generated By A Combination Of Graphs"
Int. J. of Bifurcation and Chaos vol. 18, no. 08, pp. 2265-2274 (2008)

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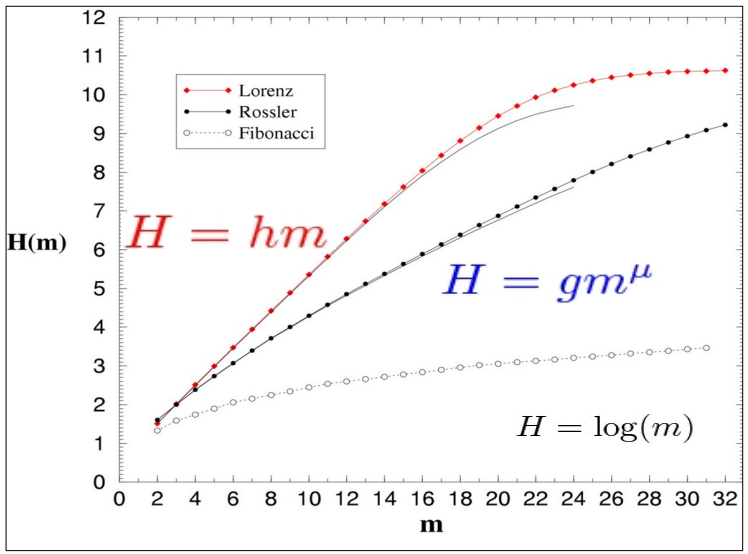
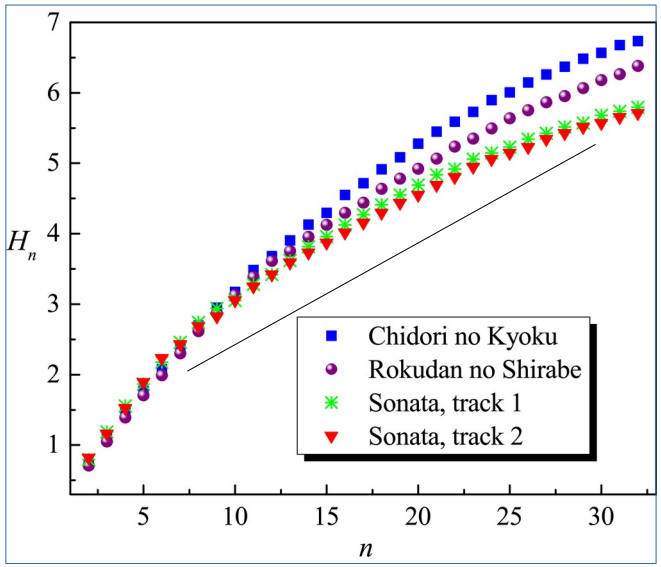




- *Measure of departure of "total randomness", complexity.*
- *Role of Constraints that underlie the dynamics of the symbol-sequence generating process (coarse graining).*
- *Context & Constraints as the key factors of the Emergence of Complexity.*
- *Shannon-Block Entropy scaling laws as an indicator of 'Semantic–Syntactic–Pragmatic' Information Interplay.*

VB, Gian-Luigi Forti and Grégoire Nicolis, **"Symbolic Dynamics Generated By A Combination Of Graphs"** Int. J. of Bif. and Chaos, 18, 08, 2265-74 (2008)

… Symbolic Dynamics

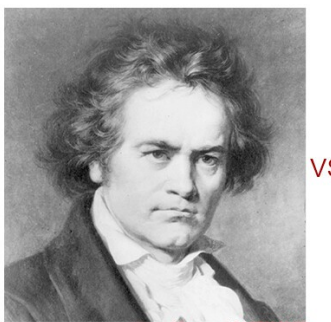
(paper + an AIP ‘Scilight’)

doi.org/10.33581/1561-4085-2020-23-2-102-112

Symbolic dynamics of music from Europe and Japan

Chaos 31, 053122 (2021); https://doi.org/10.1063/5.0048396

Vasileios Basios[1,a)], Thomas Oikonomou[2,b)], *and* Robin De Gernier[3]



Library of Congress, LC-USZ62-29499

VS.

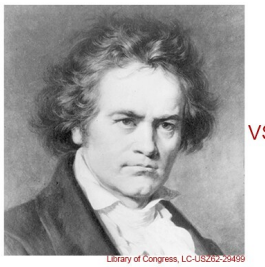
julianne hide/shutterstock.com

Scilight *“Differences in regional music show up in statistical analyses via symbolic dynamics”*, aip.scitation.org/doi/10.1063/10.0005137

The Alphabet (coarse-graining)

- *u* for up, when the tone of the note rises in comparison to the previous one
- *d* for down, when the tone of the note drops in comparison to the previous one
- *s* for sustains, when the tone of the note remains the same in comparison to the previous one.

The Dynamics



VS.

The original Texts:
Beethoven's Sonata Op.31,No2; Yatsuhashi Kengyoo's "Rokudan no Shirabe"; Yoshizawa Kengyoo II's "Chidori no kyoku"

The Entropy Quantities:

$$H(m) = -\sum_{\text{all } m\text{-words}} P(w) \ln P(w)$$

$$h_n = H_{n+1} - H_n$$

$$h = \lim_{n \to \infty} h_n$$

Entropy of the Source
(uncertainty of the next letter, "surprise") discrete analogue of the **Kolmogorov-Sinai Entropy**

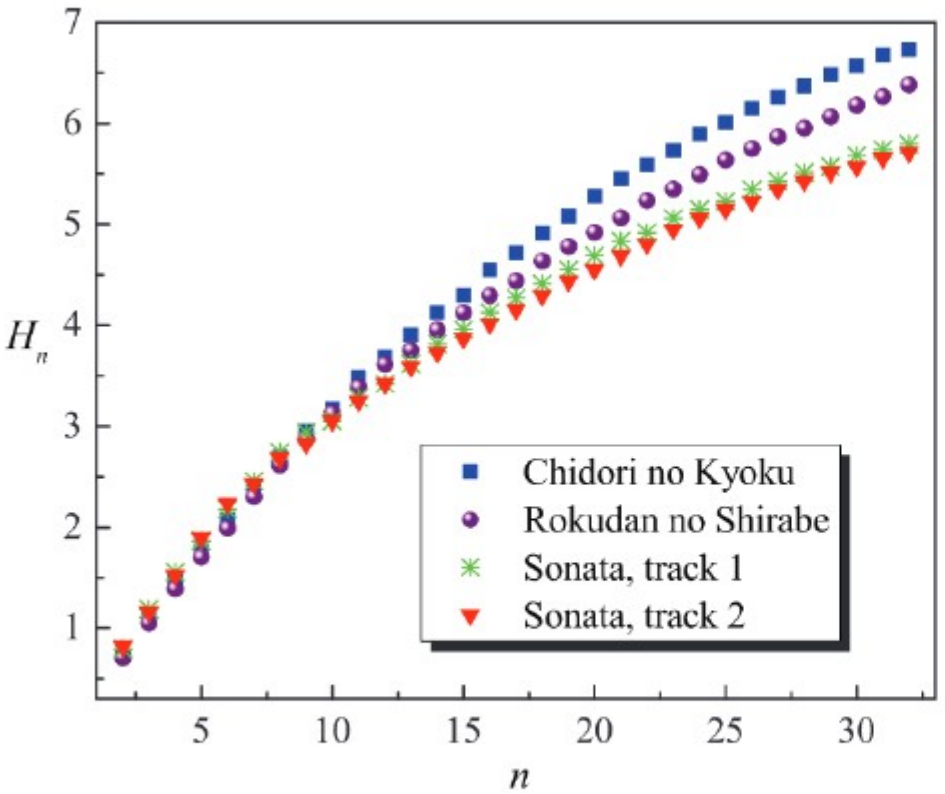


FIG. 5. Block-entropy H_n (in bits) vs word length n. Blue squares "Chidori no kyoku," purple dots "Rokudan no Shirabe," green crosses "Sonata for pianoforte Op. 31 No. 2, track 1," red triangles "Sonata for pianoforte Op. 31 No. 2, track 2."

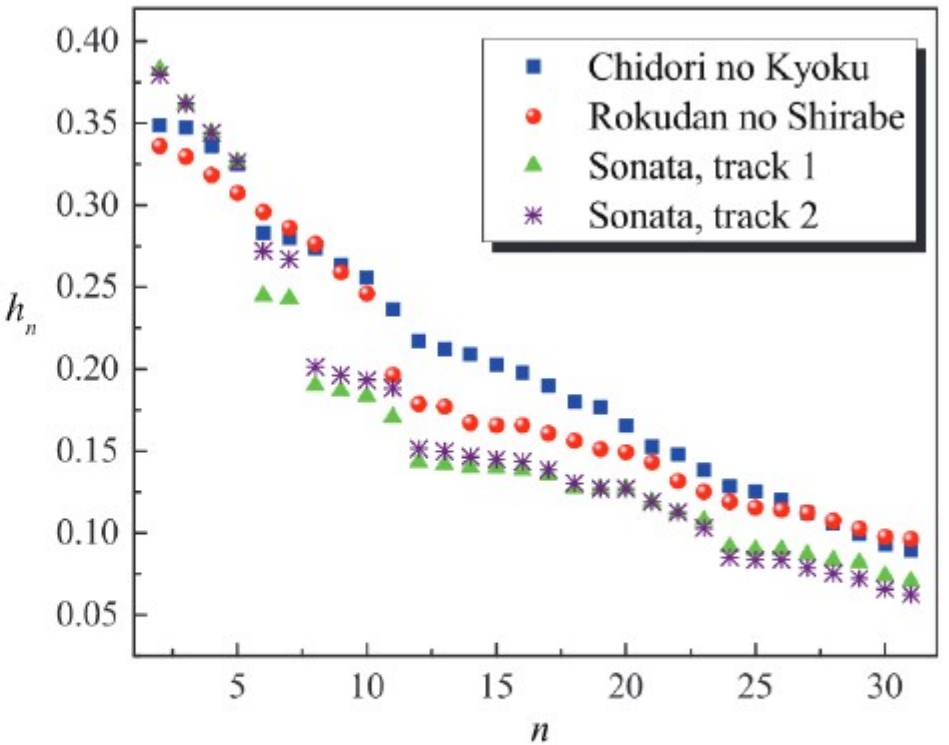


FIG. 6. Uncertainty h_n (in bits) vs the word length n. Blue squares "Chidori no kyoku," red spheres "Rokudan no Shirabe," green triangles "Sonata for pianoforte Op. 31 No. 2, track 1," purple crosses "Sonata for pianoforte Op. 31 No. 2, track 2."

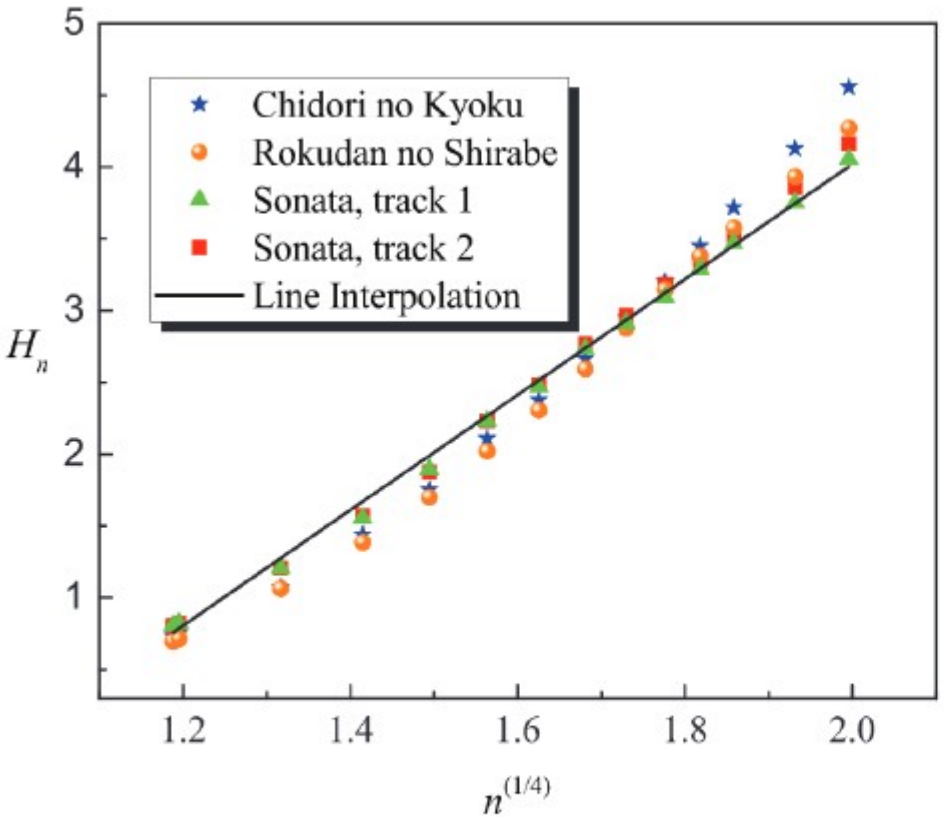


FIG. 8. Power law in $n^{(1/4)}$ of the block-entropy H_n (in units of $\log_3$) for Beethoven's Sonata.

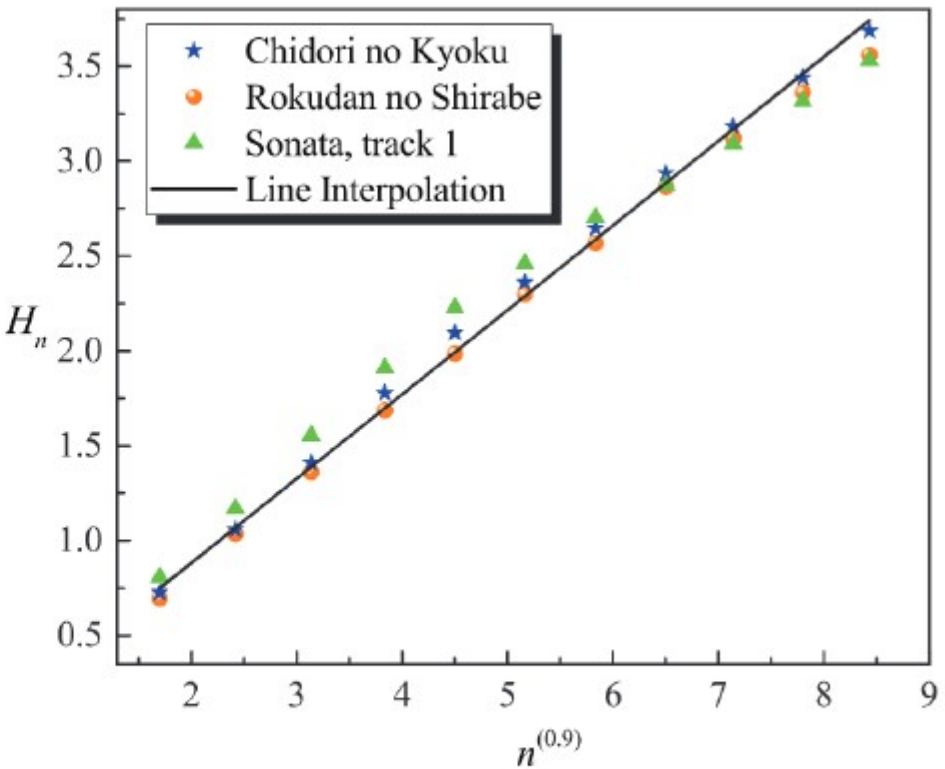


FIG. 10. Power law in $n^{(0.9)}$ of the block-entropy H_n (in units of $\log_3$) for *"Rokudan no Shirabe."*

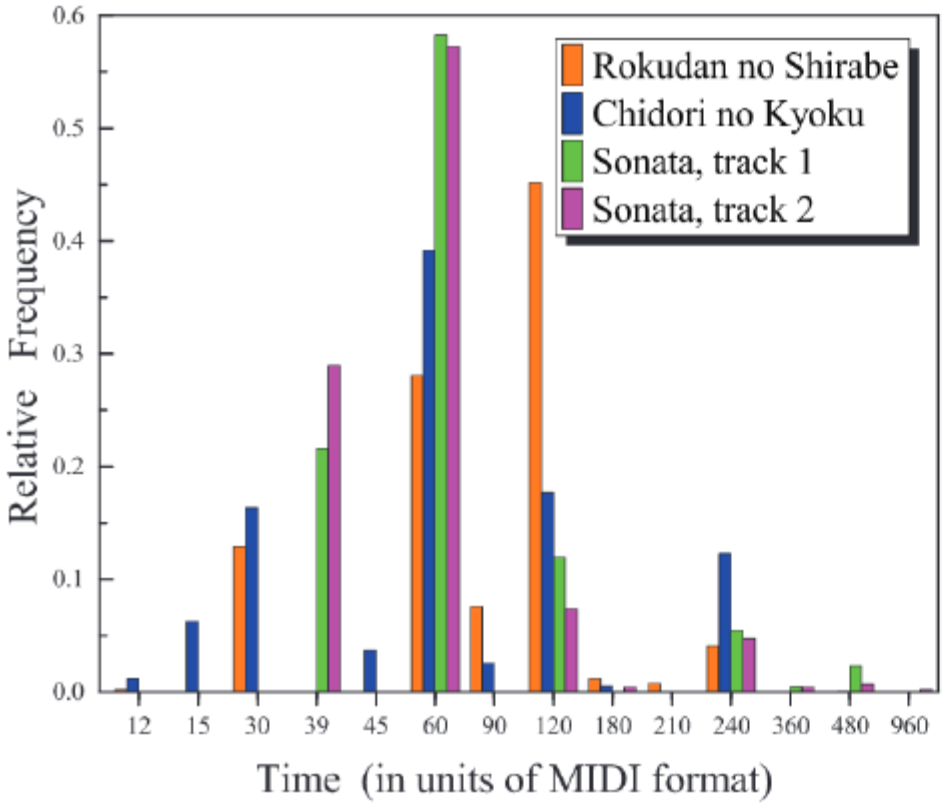


FIG. 7. Characteristic times in units of the .MIDI files.

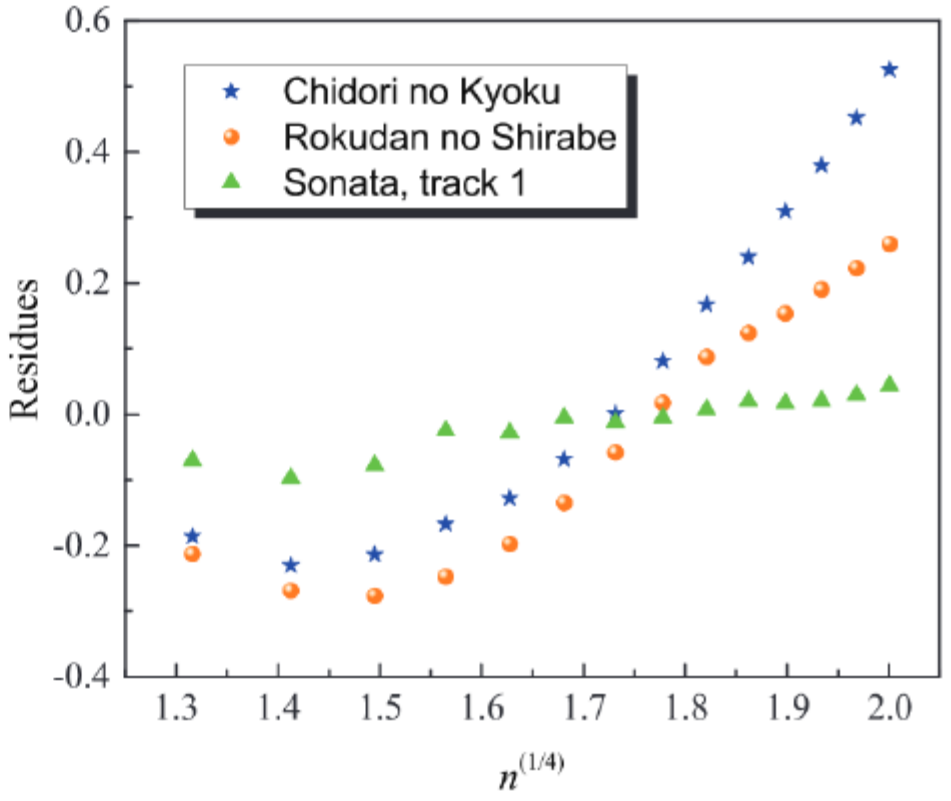


FIG. 9. Distance of the curves to the linear fit in Fig. 8.

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“Stem Materials: clues and path identification”
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7, 9 & 20 April 2021 (remotely)

Moretti, P.F., Grzybowski, B.A., Basios, V. et al.
“STEM materials: a new frontier for an intelligent sustainable world”.
BMC Mat 1, 3 (2019). doi.org/10.1186/s42833-019-0004-4

COMASAN: (biological information) **co**mplexity **m**athematical **a**nalysis of the **s**implest **n**eural-network

Stuart Kaufmann
“adjacent possible”

Yukio-Pegio Gunji
BIB-extended Bayesian

Pier-Francesco Moretti
CNR

Andrey Shilnikov
Sym.Dyn. in Neurons

Grammar & Syntax,
Semantics & Meaning:

“WE ARE NOWHERE”

“WE ARE NOW HERE”

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Schematic view of the concept of Stem Materials: understanding the functioning of living organisms and their interaction within the ecosystem (here represented in yellow as the marine gastropod mollusk named "pelican's foot") is approached through the integration of different aspects (in hexagons) which allows to identify building blocks (in red) to be assembled for a new generation of intelligent materials.

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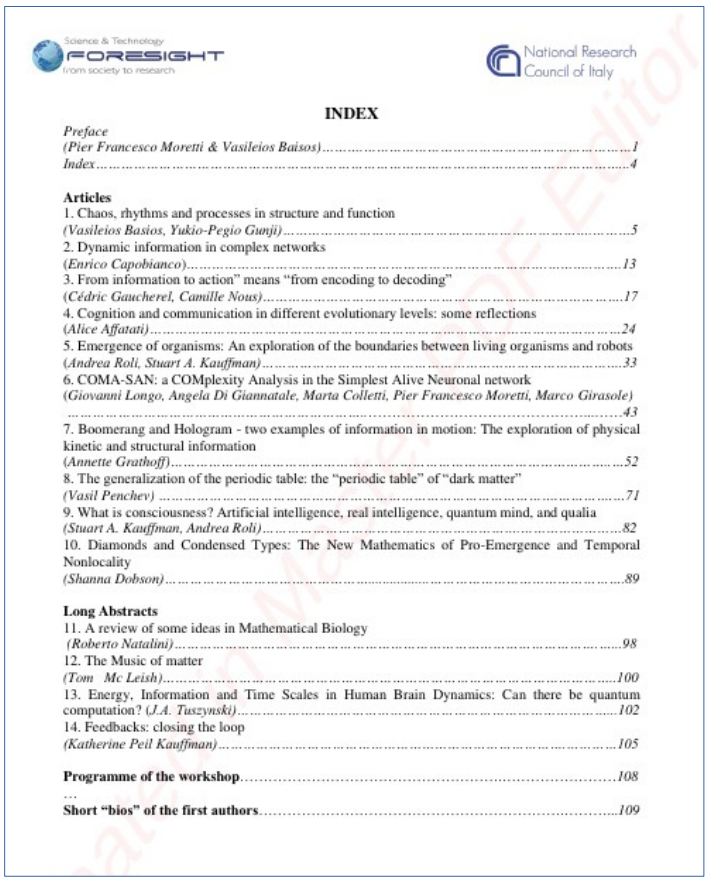

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