Laboratory evidence
of fractal and coherent structures in water.
Experimental results and theoretical understanding.*

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*V. Elia, et al. in preparation
G. Vitiello, Coherent states, fractals and brain waves,
New Mathematics and Natural Computation 5, 245 (2009);
Fractals and the Fock-Bargmann representation of coherent states,
Lecture Notes in Artificial Intelligence 5494, 6 (Springer 2009);
Fractals, coherent states and self-similarity induced noncommutative geometry,
Measurements by Vittorio Elia’s group in Naples†:

- Water in contact of naﬁon (INW, Iteratively Nafionized Water)

Measurement of

- the heat of mixing, \( Q_{\text{mix,NaOH}}^{E}/Jkg^{-1} \), with a NaOH solution 0.01 \( m/mol \ kg^{-1} \) vs electrical conductivity, \( \chi^{E}/\mu \ S \ cm^{-1} \) for INW

- the density \( d - d_0 \) vs specific electrical conductivity \( \chi^{E} \)

- the \( pH \) of samples of INW as a function of \( \log \chi \)

*** log-log straight line plots ***

log of heat of mixing, $Q^E$, with a NaOH solution 0.01 vs log of electrical conductivity, $\chi^E$ for INW
Fig. 2

Log \((d-d_0) \cdot 10^5\)

Linear Fit

\[ Y = 0.94205 \times -1,00231 \]

log of density \((d-d_0)\) vs log of specific electrical conductivity, \(\log \chi\) for IFW
$Y = -1.25376X + 6.14927$
Ho analizzato il primo minuto del file: è ragionevole pensare che tra 500 e 10000 Hz vi sia un andamento abbastanza lineare, fittato con la linea rossa; tuttavia, se si considerano i punti su tutto lo spettro, si può riconoscere anche un andamento parabolico (riportato con la linea blu).

\[
\log P = -5.64306 + 2.54753 \log f - 0.65529 (\log f)^2
\]

WHITE water...
Ho analizzato il primo minuto del file: è ragionevole pensare che tra 500 e 10000 Hz vi sia un andamento abbastanza lineare, fittato con la linea rossa; tuttavia, se si considerano i punti su tutto lo spettro, si può riconoscere anche un andamento parabolico (riportato con la linea blu).

\[
\log P = -5.64306 + 2.54753 \log f - 0.65529 (\log f)^2
\]

\[
\log P = 3.69998 - 2.42076 \log f
\]
Not only!…

Brain activity
Figure 11. Evidence is summarized showing that the mesoscopic background activity conforms to scale-free, low-dimensional noise [Freeman et al., 2008]. Engagement of the brain in perception and other goal-directed behaviors is accompanied by departures from randomness upon the emergence of order (A), as shown by comparing PSD in sleep, which conforms to black noise, vs. PSD in an aroused state showing excess power in the theta (3–7 Hz) and gamma (25–100 Hz) ranges. B. The distributions of time intervals between null spikes of brown noise and sleep ECoG are superimposed. C,D. The distributions are compared of log_{10} analytic power from noise and ECoG. Hypothetically the threshold for triggering a phase transition is 10^{-4} down from modal analytic power. From [Freeman, O’Nuillain and Rodriguez, 2008 and Freeman and Zhai, 2009]

last long enough to transmit 3 to 5 cycles of the carrier frequency [Freeman, 2005], and they also have the long correlation distances needed to span vast areas of primary sensory cortices. These attributes of size and persistence make them prime candidates for the neural correlates of retrieved memories.

The PSD of background noise from mutual excitation and dendritic integration contain all frequencies in a continuous distribution, which is necessary to support the appearance of beats in every designated pass band. Endogenous inhibitory negative feedback does not break this scale-free symmetry. Explicit breaking of symmetry (Mode 1) can occur by applying electric shocks that cause excitatory or inhibitory bias and initiate the band limited perturbations that are observed in the impulse responses (Fig. 7). Spontaneous symmetry breaking (Mode 2) can occur by a null spike. When that happens, the sensory input that activates a Hebbian assembly already formed by learning introduces into the broken symmetry a powerful narrow-band gamma burst (Fig. 8) that is facilitated by the increased synaptic gain, $k_e$, with learning (Fig. 1), the increased control parameter, $Q_m$, with arousal, and the asymmetric gain around the operating point for the KII set (Fig. 6).

The crucial step in perception is the phase transition from the excited microscopic assembly to the large-scale mesoscopic AM pattern. That possibility occurs when a null spike (Fig. 10,
We reasoned that if nLFP waveform similarity across sites arose as a sequential, loss-less process intrinsic to the cortical network, then nLFPs occurring \( n \) ms apart that formed part of a sequence (Figure 7B, top) would be more stable in their waveform similarity across each step in the sequence relative to amplitude-matched nLFPs separated by similar time intervals that were not part of a sequence (Figure 7B, bottom). Remarkably, nLFPs within a sequence were highly stable in their correlation relative to the initial nLFP; the median correlation of nLFPs at each position in the sequence relative to the first nLFP decreased only slightly from 0.94 to 0.86 in nine time steps in vivo (\( \approx 18 \) ms, Figure 7C, top) and from 0.78 to 0.75 in twelve time steps in vitro (\( \approx 12 \) ms, Figure 7C, bottom). In contrast, correlations between nLFPs separated by correspondingly larger intervals were significantly worse than their within sequence counterparts (\( p < 0.02 \) up to \( p < 10^{-3} \) by KS test), decaying to no better than comparisons of random nLFPs of similar amplitude within 15 to 30 ms (Figure 7C, open squares; median random correlations were 0.47 and 0.49 \( \pm 0.013 \) in vivo and 0.58 \( \pm 0.03 \) in six cultures, \( p < 10^{-4} \) when compared to within sequence correlation for all cases). In sharp contrast to this behavior of coherence potentials, sequences constructed predominantly of small or subthreshold nLFPs, i.e., before the transition to the regime of high spatial coherence (Figure 7A), decayed progressively to random in a manner that
Montagnier experiment (preliminary results, work in progress)
P = -0.80794 ν + 1.91763
log-log straight line plot
⇒ dynamical formation of self-similar fractal structures in water

self-similarity/coherent-state theorem
⇒ dynamical formation of coherent structures in water

‡G.Vitiello, New Mathematics and Natural Computation 5, 245 (2009)
Theorem:

The global nature of fractals emerges from coherent local deformation processes.

⇒

the dynamical formation of fractals
Let me consider as an example the Koch curve (Helge von Koch, 1904)§

Notice:
Koch was searching an example of curve everywhere non-differentiable ("On a continuous curve without tangents, constructible from elementary geometry")

By generalizing and extending this to the case of any other “ipervolume” $\mathcal{H}$ one considers thus the ratio
\[
\frac{\mathcal{H}(\lambda L_0)}{\mathcal{H}(L_0)} = p,
\]
and assuming that Eq. (2.1) is still valid “by definition”, one obtains
\[
p \mathcal{H}(L_0) = \lambda^d \mathcal{H}(L_0),
\]
i.e. $p = \lambda^d$. For the Koch curve, setting $\alpha = \frac{1}{q} = 4$ and $q = \lambda^d = \frac{1}{3^d}$, $p = \lambda^d$ gives
\[
q\alpha = 1, \quad \text{where} \quad \alpha = 4, \quad q = \frac{1}{3^d},
\]
i.e.
\[
d = \frac{\ln 4}{\ln 3} \approx 1.2619.
\]
$d$ is called the fractal dimension, or the self-similarity dimension.

Fig. 1. The first five stages of Koch curve.

With reference to the Koch curve, I observe that the meaning of Eq. (2.3) is that in the “deformed space”, to which $u_{1,q}$ belongs, the set of four segments of which $u_{1,q}$ is made “equals” (is equivalent to) the three segments of which $u_0$ is made in
- **Stage** \( n = 0 \): \( L_0 = u_0 \) (arbitrary initiator) it lives in 1 dimension

- **Stage** \( n = 1 \): \( u_{1,q}(\alpha) \equiv q \alpha u_0, \quad q = \frac{1}{3d}, \quad \alpha = 4 \) (the generator)

\( d \neq 1 \) to be determined. it does not live in 1 dimension.

The “deformation” of the \( u_0 \) segment is only possible provided the one dimensional constraint \( d = 1 \) is relaxed.

The \( u_1 \) segment “shape” lives in some \( d \neq 1 \)

\( d \neq 1 \) is a measure of the deformation of the dimensionality
• **Stage** $n = 2$: 

$$u_{2,q}(\alpha) \equiv q\alpha u_{1,q}(\alpha) = (q\alpha)^2 u_0.$$ 

• **By iteration:** 

$$u_{n,q}(\alpha) \equiv (q\alpha) u_{n-1,q}(\alpha), \quad n = 1, 2, 3, ...$$

$$u_{n,q}(\alpha) = (q\alpha)^n u_0.$$ 

which is the “self-similarity” relation characterizing fractals.

**Notice!** The fractal is mathematically defined only in the limit of infinite number of iterations ($n \rightarrow \infty$).

---

Normalizing, at each stage, with (arbitrary) \( u_0 \):

\[
\frac{u_{n,q}(\alpha)}{u_0} = (q \alpha)^n = 1, \quad \text{for each } n
\]

i.e.

\[
d = \frac{\ln 4}{\ln 3} \approx 1.2619.
\]

The non-integer \( d \) is called

fractal dimension, or self-similarity dimension.

Note that \( q \alpha = 1 \), i.e. \( \frac{1}{3^d} 4 = 1 \) is not true for \( d = 1 \), i.e. if one remains in \( d = 1 \) dimension

The value of \( d \), fractal dimension, is a measure of the deformation which allows to impose the “constraint” \( \frac{u_{n,q}(\alpha)}{u_0} = 1 = (q \alpha)^n \).
Now consider in full generality the complex $\alpha$-plane and the space $\mathcal{F}$ of the entire analytic functions (i.e. uniformly converging in any compact domain of the $\alpha$-plane).

Let $f(\alpha) \in \mathcal{F}$, $q = e^{\zeta}$, $\zeta \in \mathbb{C}$ and $N \equiv \alpha \frac{d}{d\alpha}$.

The operator $q^N$ acts in the whole $\mathcal{F}$ as

$$q^N f(\alpha) = f(q\alpha), \quad f(\alpha) \in \mathcal{F}.$$ 

---

For the coherent state functional we have:

\[ q^N|\alpha\rangle = |q\alpha\rangle = \exp\left(-\frac{|q\alpha|^2}{2}\right) \sum_{n=0}^{\infty} \frac{(q\alpha)^n}{\sqrt{n!}} |n\rangle, \]

and, since \( q\alpha \in \mathbb{C} \),

\[ a |q\alpha\rangle = q\alpha |q\alpha\rangle, \quad q\alpha \in \mathbb{C}. \]

Notice!

\[ \frac{1}{\sqrt{n!}}(q\alpha)^n \]

is the “deformed” basis in \( \mathcal{F} \), where coherent states are represented.
The link between fractals and coherent states is established by realizing that the fractal $n$th-stage function $u_{n,q}(\alpha)$, with $u_0$ set equal to 1, is obtained by projecting out the $n$th component of $|q\alpha\rangle$ and restricting to real $q\alpha$, $q\alpha \rightarrow \text{Re}(q\alpha)$:

$$\langle q\alpha|(a)^n|q\alpha\rangle = (q\alpha)^n = u_{n,q}(\alpha), \quad q\alpha \rightarrow \text{Re}(q\alpha).$$

The operator $(a)^n$ thus acts as a “magnifying” lens: the $n$th iteration of the fractal can be “seen” by applying $(a)^n$ to $|q\alpha\rangle$. 
Note that “the fractal operator” $q^N$ can be realized in $\mathcal{F}$ as:

$$q^N \psi(\alpha) = \frac{1}{\sqrt{q}} \psi_s(\alpha),$$

where $q = e^\zeta$ (for simplicity, assumed to be real) and $\psi_s(\alpha)$ denotes the squeezed coherent states.

$q^N$ acts in $\mathcal{F}$ as the squeezing operator $\hat{S}(\zeta)$ (well known in quantum optics) up to the numerical factor $\frac{1}{\sqrt{q}}$.

The $q$-deformation process, which we have seen is associated to the fractal generation process, is equivalent to the squeezing transformation.
Summarizing:

- The $n$th fractal stage of iteration, $n = 0, 1, 2, \ldots, \infty$, is represented, in a one-to-one correspondence, by the $n$th term in the coherent state series.

- Fractal generation linked to squeezed coherent states.

- $q^N$ is the fractal operator.
Conclusions

1. Measurements made by Vittorio Elia and his group in Naples on nafionazed water present fractal self-similar properties.

2. By resorting to the theorem by which fractal self-similar properties are described in terms of deformed (squeezed) coherent states, we conclude that

a. fractal self-similarity of these data signals the presence of squeezed coherent structures in the molecular organization of nafionazed water.

b. measurements in brain activity point to the formation of squeezed coherent structures (long range correlation) in brains in agreement with predictions of the quantum dissipative model of brain.

c. the preliminary analysis of the em signal in the Montagnier experiment shows the presence of squeezed coherent structures in diluted water solutions of DNA fragments and similar squeezed coherent structures are induced in the irradiated (signalized) water.
This introduction to the dissipative quantum model of brain and to its possible implications for consciousness studies is addressed to a broad interdisciplinary audience. Memory and consciousness are approached from the physicist point of view focusing on the basic observation that the brain is an open system continuously interacting with its environment. The unavoidable dissipative character of the brain functioning turns out to be the root of the brain’s large memory capacity and of other memory features such as memory association, memory confusion, duration of memory. The openness of the brain implies a formal picture of the world which is modeled on the same brain image: a sort of brain copy or “double” where world objectiveness and the brain implicit subjectivity are conjugated. Consciousness is seen to arise from the permanent “dialogue” of the brain with its Double.

The author’s narration of his (re-)search gives a cross-over of the physics of elementary particles and condensed matter, and the brain’s basic dynamics. This dynamic interplay makes for a “satisfying feeling of the unity of knowledge.”

"Prof. Vitiello writings provide a fundamental advance in the quantum theory of brain functioning, and astonishingly in the present book, without requiring any technical mathematics.”

Gordon Globus, Irvine, CA

...the clearest exposition of the theory of brain functions, based on the highly abstract and mathematical theory of Quantum Field. Professor Vitiello successfully carries out this difficult task without a single equation"

Yasushi Takahashi, Department of Physics, University of Alberta

...by comparing different formulations of analogues concepts, this book encourages various scientific community (physics, biology, neurophysiology, psychology) to refine a fruitful dialogue”

Francesco Guerra, Director Faculty of Mathematical, Physical and Natural Sciences, University of Rome “La Sapienza”

...an exciting and delightful book. The argument stems from his innovative use of Quantum Field Theory (actually a doubling of such field) to explain how brain processing are related to conscious of our external embedded in the world and at the same time our awareness of the aware self”

Karl Pribram, Center for Brain Research and Information Science, Radford University
Physicists believe quantum fields to be the true protagonists of nature in the full variety of its wonderful, manifold manifestations. Quantum field theory is the tool they created to fulfill their visionary dream of describing with a universal, unique language all of nature, be it single particles or condensed matter, fields or many-body objects. This is perhaps the first book on quantum field theory whose aim is to grasp and describe with rigor and completeness, but at the same time in a compelling, fascinating way, all the facets of the complex challenge it faces scientists with. It is a book that presents solutions but poses questions as well; hard, demanding yet fascinating; a book that can at the same time be used as a textbook and as a book of dreams that any scientist would like to make come true.

Mario Rasetti
Dipartimento di Fisica, Politecnico di Torino, Torino, Italy

This remarkable book dispels the common misconception that quantum field theory is ‘just quantum mechanics with an infinite number of degrees of freedom’, revealing vast new mathematical terrains, and new ways of understanding physical phenomena in both commonplace and exotic systems. Uniquely valuable, and covering material difficult or impossible to find coherently assembled elsewhere, it will be welcomed by students and researchers in all fields of physics and mathematics.

John Swain
Physics Department, Northeastern University, Boston, MA, USA
and CERN, Geneva, Switzerland

This book gives an overall presentation of the most important aspects of quantum field theory, leading to its macroscopic manifestations, as in the formation of ordered structures. The list of topics, all covered in full detail and easy-to-follow steps, is really impressive. The main features of the presentation rely on very simple and powerful unifying principles, given by the intermixing of symmetry and dynamics, under the general texture of quantum coherence. Most of the chapters share the typical flavor of the very intense personal research carried out by the authors over many years, but the style of presentation is always perfectly coherent, and all topics are presented in a mature and well-organized way.

I think that the book will be most useful for graduate students who are willing to be engaged in the fascinating task of exploring the full potentiality of quantum field theory in explaining the emergence of ordering at the macroscopic level, from the large-scale structure of the universe, to the ordering of biological systems. Of course, active researchers in all formation stages, and even mature scientists, will appreciate the intellectual depth and the scientific efficacy that the authors have transfused in their work.

Francesco Guerra
Dipartimento di Fisica, Università di Roma, “La Sapienza”, Italy

This book gives a very thorough treatment of a range of topics that are of increasing importance, from a rather unusual, and very instructive, point of view.

Tom W. Kibble
Theoretical Physics, Imperial College London, London, UK
with \( r_0 \) and \( d \) arbitrary real constants and \( r_0 > 0 \), whose representation is the straight line of slope \( d \) in a log-log plot with abscissa \( \theta = \ln r \):

\[
d\theta = \ln \frac{r}{r_0} .
\]

The constancy of the angular coefficient \( \tan^{-1} d \) signals the self-similarity property of the logarithmic spiral: rescaling \( \theta \rightarrow n \theta \) affects \( r/r_0 \) by the power \((r/r_0)^n\). Thus, we may proceed again like in the Koch curve case and show the relation to squeezed coherent states. The result also holds for the specific form of the logarithmic spiral called the \textit{golden spiral} (see Appendix A). The golden spiral and its relation to the Fibonacci progression is of great interest since the Fibonacci progression appears in many phenomena, ranging from botany to physiological and functional properties in living systems, as the “natural” expression in which they manifest themselves. Even in linguistics, some phenomena have shown Fibonacci progressions [14].

As customary, let in Eq. (7) the anti-clockwise angles \( \theta \)'s be taken to be positive. The anti-clockwise versus (left-handed) spiral has \( q \equiv e^{d\theta} > 1 \); the clockwise versus (right-handed) spiral has \( q < 1 \) (see Fig. 2); sometimes they are called the \textit{direct} and \textit{indirect} spiral, respectively.

In the next Section we consider the parametric equations of the spiral:

\[
\begin{align*}
x &= r(\theta) \cos \theta = r_0 e^{d\theta} \cos \theta , \\
y &= r(\theta) \sin \theta = r_0 e^{d\theta} \sin \theta .
\end{align*}
\]

III. SELF-SIMILARITY, DISSIPATION AND SQUEEZED COHERENT STATES

According to Eqs. (9), the point on the logarithmic spiral in the complex \( z \)-plane is given by

\[
z = x + i y = r_0 e^{d\theta} e^{i\theta} ,
\]

The point \( z \) is fully specified only when the sign of \( d \theta \) is assigned. The factor \( q = e^{d\theta} \) may denote indeed one of the two components of the (hyperbolic) basis \( \{e^{-d\theta}, e^{+d\theta}\} \). Due to the completeness of the basis, both the factors \( e^{\pm d\theta} \) must be considered. It is indeed interesting that in nature in many instances the direct \((q > 1)\) and the indirect \((q < 1)\) spirals are both realized in the same system (perhaps the most well known systems where this happens are found in phyllotaxis studies). The points \( z_1 \) and \( z_2 \) are then considered:

\[
\begin{align*}
z_1 &= r_0 e^{-d\theta} e^{-i\theta} , \\
z_2 &= r_0 e^{+d\theta} e^{+i\theta} ,
\end{align*}
\]

where for convenience (see below) opposite signs for the imaginary exponent \( i\theta \) have been chosen. By using the parametrization \( \theta = \theta(t) \), \( z_1 \) and \( z_2 \) are easily shown to solve the equations

\[
\begin{align*}
m \ddot{z}_1 + \gamma \dot{z}_1 + \kappa z_1 &= 0 , \\
m \ddot{z}_2 - \gamma \dot{z}_2 + \kappa z_2 &= 0 ,
\end{align*}
\]

respectively, provided the relation

\[
\theta(t) = \frac{\gamma}{2md} t = \frac{\Gamma}{d} t
\]
Esempi di strutture frattali
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Una rete fluviale
Esempi di strutture frattali
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