

A microscopic image of a complex, porous material, possibly a biological or synthetic structure. The image shows a dense network of interconnected, irregular shapes in shades of green and yellow, set against a darker, greyish background. The overall appearance is highly textured and complex, resembling a sponge or a porous medium.

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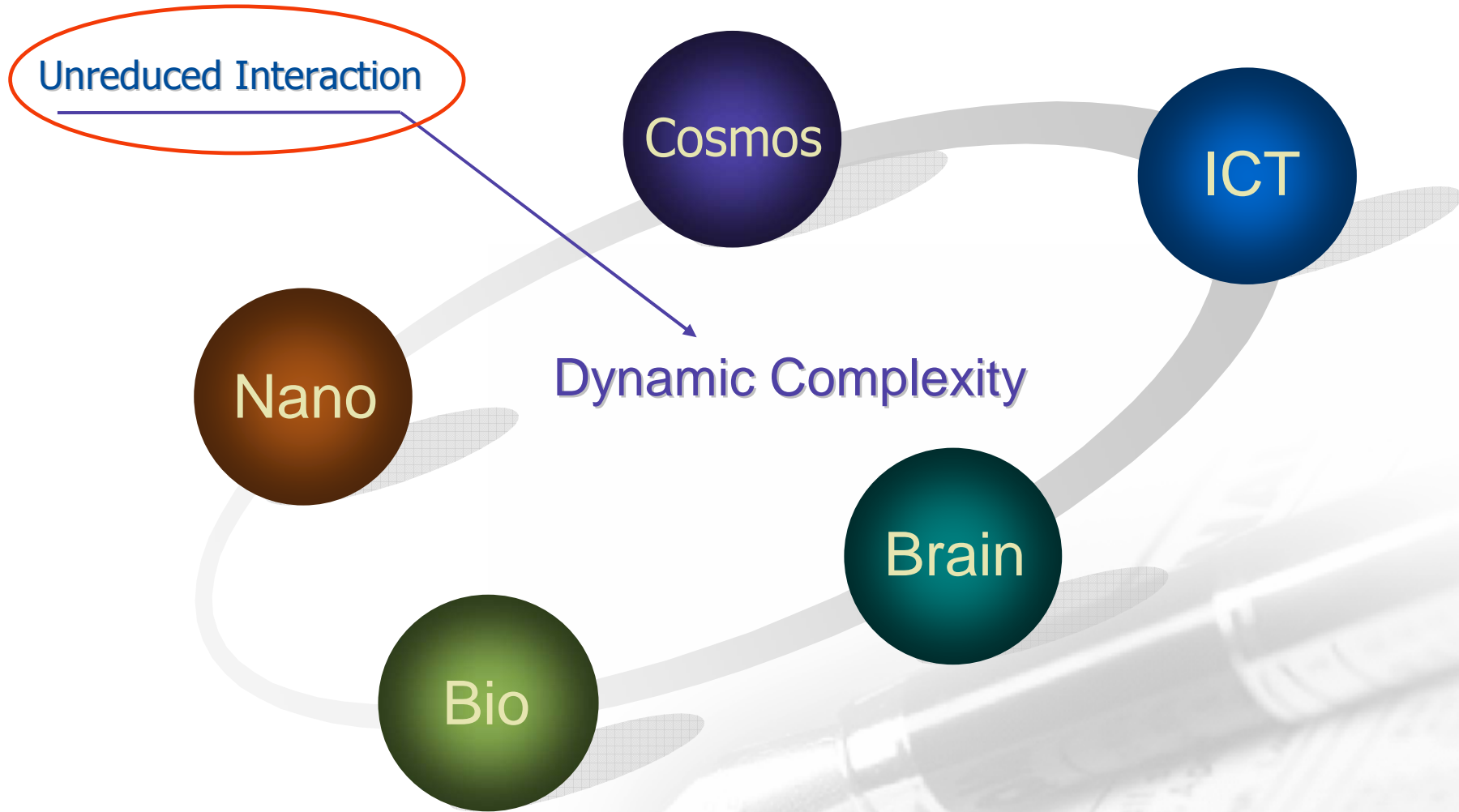
# UNIVERSAL SCIENCE OF COMPLEXITY

Consistent Understanding of  
Ecological, Living and Intelligent  
System Dynamics

# Escaping Complexity

- Can *real*, higher-complexity system dynamics be understood at the *level of rigour* of Newtonian science?
- The problem of *unreduced* many-body *interaction* (*unsolved* in Newtonian science)
- The unique possibility for a new progress of *fundamental science* (otherwise “ending”)
- **Universal Science of Complexity**

# Universal Science of Complexity



<http://arxiv.org/find/quant-ph,gr-qc,physics/1/au:+Kirilyuk/0/1/0/all/0/1>

# Multivalued Dynamics of Unreduced Interaction

Arbitrary many-body interaction process:

$$\left\{ \sum_{k=0}^N \left[ h_k(q_k) + \sum_{l>k}^N V_{kl}(q_k, q_l) \right] \right\} \Psi(Q) = E \Psi(Q), \quad Q = (q_1, q_2, \dots, q_N)$$

or

$$\left\{ h_0(\xi) + \sum_{k=1}^N \left[ h_k(q_k) + V_{0k}(\xi, q_k) + \sum_{l>k}^N V_{kl}(q_k, q_l) \right] \right\} \Psi(\xi, Q) = E \Psi(\xi, Q), \quad \xi \equiv q_0$$

The unreduced (nonperturbative) general solution is always *probabilistic* (phenomenon of *dynamic multivaluedness* = *intrinsic chaoticity*):

$$\rho(\xi, Q) = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q)$$

Dynamically determined probability

$$\alpha_r = \frac{N_r}{N_{\mathfrak{R}}}, \quad \sum_r \alpha_r = 1$$

# Unreduced Interaction Dynamics

Arbitrary interaction process in terms of (free) component eigenvalues:

$$h_0(\xi)\psi_n(\xi) + \sum_{n'} V_{nn'}(\xi)\psi_{n'}(\xi) = \eta_n\psi_n(\xi)$$

where the total system state-function is obtained as

$$\Psi(\xi, Q) = \sum_{n \equiv (n_1, n_2, \dots, n_N)} \psi_n(q_0)\varphi_{1n_1}(q_1)\varphi_{2n_2}(q_2)\dots\varphi_{Nn_N}(q_N) \equiv \sum_n \psi_n(\xi)\Phi_n(Q)$$

Usual perturbative (mean-field) approximations:

$$\left[ h_0(\xi) + V_{nn}(\xi) + \tilde{V}_n(\xi) \right] \psi_n(\xi) = \eta_n \psi_n(\xi), \quad V_0(\xi) < \tilde{V}_n(\xi) < \sum_{n'} V_{nn'}(\xi)$$

Unreduced general solution of the same problem:

$$\rho(\xi, Q) \equiv |\Psi(\xi, Q)|^2 = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q), \quad \rho_r(\xi, Q) = |\Psi_r(\xi, Q)|^2$$

$$\Psi_r(\xi, Q) = \sum_i c_i^r \left[ \Phi_0(Q) \psi_{0i}^r(\xi) + \sum_{n, i'} \frac{\Phi_n(Q) \psi_{ni'}^0(\xi) \int_{\Omega_\xi} d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\eta_i^r - \eta_{ni'}^0 - \epsilon_{n0}} \right]$$

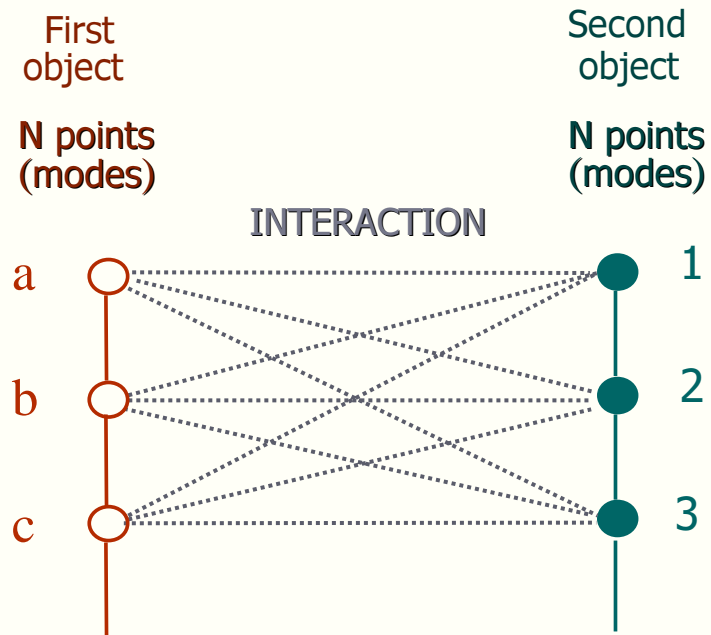
where  $\{\psi_{0i}^r(\xi), \eta_i^r\}$  are solutions of the *effective potential (EP)* equation

$$h_0(\xi) \psi_0(\xi) + V_{\text{eff}}(\xi; \eta) \psi_0(\xi) = \eta \psi_0(\xi)$$

$$V_{\text{eff}}(\xi; \eta_i^r) \psi_{0i}^r(\xi) = V_{00}(\xi) \psi_{0i}^r(\xi) + \sum_{n, i'} \frac{V_{0n}(\xi) \psi_{ni'}^0(\xi) \int_{\Omega_\xi} d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\eta_i^r - \eta_{ni'}^0 - \epsilon_{n0}}$$

Elementary length  $\Delta x = \lambda = |\Delta \eta_i^r|$ , time  $\Delta t = \Delta x / v_0$ , action  $\Delta A = V_{\text{eff}} \Delta t$

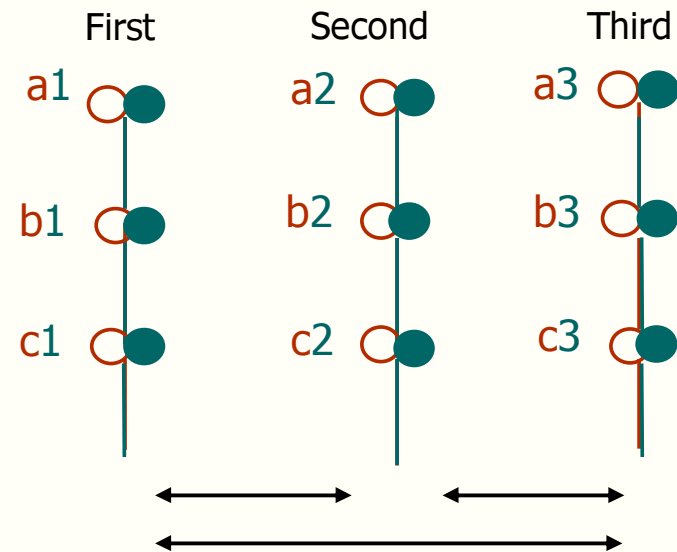
# Unreduced Interaction: Dynamic Multivaluedness (Chaos)



( $N \times N$ ) combinations  
of mode entanglement  
(**a1,a2,a3,b1,b2**, etc.)

⇓  
N-fold redundance

Dynamically redundant  
interaction result:  
incompatible  
system *realisations*



Permanent realisation change  
in *causally (dynamically) random* order

# Unreduced Interaction Complexity

UNIVERSAL DEFINITION OF DYNAMIC (INTERACTION) COMPLEXITY:

$$C = C(N_{\mathfrak{R}}), \quad \frac{dC}{dN_{\mathfrak{R}}} > 0, \quad C(1) = 0$$

where  $N_{\mathfrak{R}}$  is the (dynamically derived) *system realisation number*  
for example:  $C = C_0 \ln(N_{\mathfrak{R}})$ ,  $C = C_0(N_{\mathfrak{R}} - 1)$ , etc.

Universal dynamic complexity includes intrinsic *chaoticity*  
due to the *dynamically probabilistic* problem solution:

$$\rho(\xi, Q) = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q)$$

with the *dynamically determined probability*

$$\alpha_r = \frac{N_r}{N_{\mathfrak{R}}}, \quad \sum_r \alpha_r = 1$$



# Unreduced Complexity Measures

Two universal, *emerging* forms of complexity, *space* and *time*

$$\Delta x = \lambda = \left| \Delta_r \eta_i^r \right|, \quad \Delta t = \Delta x / v_0$$

Generalised *action*  $\mathcal{A}$  is the simplest combination of space & time:

$$\Delta \mathcal{A} = p \Delta x - E \Delta t$$

$\mathcal{A} = \int p dx \propto N_{\mathfrak{X}}$  is a universal *integral* complexity measure

*Differential* complexity measures:

$$\text{momentum } p = \frac{\partial \mathcal{A}}{\partial x} = \left. \frac{\Delta \mathcal{A}}{\Delta x} \right|_{t = \text{const}}$$

(*spatial* rate of realisation emergence)

$$\text{energy/mass } E = mv_0^2 = - \left. \frac{\partial \mathcal{A}}{\partial t} = - \frac{\Delta \mathcal{A}}{\Delta t} \right|_{x = \text{const}}$$

(*temporal* rate of realisation emergence)

*Dispersion relation:*  $p = E \frac{v}{c^2} = mv$ ,  $v = \frac{\Delta x}{\Delta t} \rightarrow$  causal relativity

# Generalised wavefunction (distribution function)

Total number of unreduced EP eigenvalues:

$N_{\max} = N_{\xi}(N_{\xi}N_q + 1) = (N_{\xi})^2N_q + N_{\xi} \rightarrow N_{\mathfrak{R}} = N_{\xi}$  "regular" realisations of  $N_{\xi}N_q$  eigen-solutions each + "incomplete" set of  $N_{\xi}$  eigen-solutions = *transitional realisation, generalised wavefunction, or distribution function*



*causal extension* of usual quantum-mechanical wavefunction  $\Psi(x)$   
transiently weak EP, disentangled components, system restructuring



Causally generalised *Born probability rule*:  $\alpha_r = |\Psi(X_r)|^2$



*Generalised Hamilton-Jacobi equation* for action-complexity  $\mathcal{A}(x)$

+ *causal quantisation rule*,  $\Delta\mathcal{A} = -\mathcal{A}_0 \Delta\Psi / \Psi$



*universal Schrödinger equation*

$$\mathcal{A}_0 \frac{\Delta\Psi}{\Delta t} \Big|_{x=\text{const}} = \hat{H} \left( x, \frac{\Delta}{\Delta x} \Big|_{t=\text{const}}, t \right) \Psi(x, t)$$

# Universal Regimes of Complex Dynamics

Two limiting regimes of complex dynamics:  
*multivalued self-organisation/SOC* and *uniform (global) chaos*

Universal criterion of global (strong) chaos:

$$\kappa \equiv \frac{\Delta \eta_i}{\Delta \eta_n} = \frac{\omega_\xi}{\omega_Q} \approx 1$$

or *resonance* of the main system motions

Criterion of quasi-regularity (self-organisation):  $\kappa \ll 1$  (or  $\kappa \gg 1$ )

As network intensity grows one *cannot avoid resonance* ("jam"):  $\kappa \sim 1$   
and therefore *essential dynamic randomness becomes inevitable*

**Highly complicated interaction networks cannot be close to regularity**  
Ordinary, unitary dynamic models and approaches are inapplicable

Let's transform the unitary approach *defect* (system failure)  
into the unreduced, complex-dynamic operation *advantage* :  
superior power and qualities

# Dynamically probabilistic fractal

Unreduced general solution of a problem:

$$\rho(\xi, Q) \equiv |\Psi(\xi, Q)|^2 = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q), \quad \rho_r(\xi, Q) = |\Psi_r(\xi, Q)|^2$$

$$\Psi_r(\xi, Q) = \sum_i c_i^r \left[ \Phi_0(Q) \psi_{0i}^r(\xi) + \sum_{n, i'} \frac{\Phi_n(Q) \psi_{ni'}^0(\xi) \int d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\eta_i^r - \eta_{ni'}^0 - \epsilon_{n0}} \right]$$

$\{\psi_{ni}^0(\xi), \eta_{ni}^0\}$  are solutions to a truncated problem:

$$\left[ h_0(\xi) + V_{nn}(\xi) \right] \psi_n(\xi) + \sum_{n' \neq n} V_{nn'}(\xi) \psi_{n'}(\xi) = \eta_n \psi_n(\xi)$$

treated by the same generalised EP method:

$$\left[ h_0(\xi) + V_{\text{eff}}^n(\xi; \eta_n) \right] \psi_n(\xi) = \eta_n \psi_n(\xi)$$

# Dynamically probabilistic fractal

Unreduced EP of the second level

$$V_{\text{eff}}^n(\xi; \eta_n) \psi_n(\xi) = V_{nn}(\xi) \psi_n(\xi) + \sum_{n' \neq n, i} \frac{V_{nn'}(\xi) \psi_{n'i}^{0n}(\xi) \int_{\Omega_\xi} d\xi' \psi_{n'i}^{0n*}(\xi') V_{n'n}(\xi') \psi_n(\xi')}{\eta_n - \eta_{n'i}^{0n} + \varepsilon_{n0} - \varepsilon_{n'0}}$$

describes second-level splitting into incompatible realisations

The unreduced general solution is the dynamically probabilistic fractal:

$$\rho(\xi, Q) = \sum_{r, r', r'' \dots}^{N_{\mathfrak{R}}} \oplus \rho_{rr'r'' \dots}(\xi, Q), \quad \rho_{\text{exp}}(\xi, Q) = \sum_{r, r', r'' \dots}^{N_{\mathfrak{R}}} \alpha_{rr'r'' \dots} \rho_{rr'r'' \dots}(\xi, Q)$$

with dynamic entanglement  $(\xi, Q)$  and dynamic probabilities:

$$\alpha_{rr'r'' \dots} = \frac{N_{rr'r'' \dots}}{N_{\mathfrak{R}}}, \quad \sum_{rr'r'' \dots} \alpha_{rr'r'' \dots} = 1$$

# Complex-Dynamic Interaction Network Properties

Huge efficiency growth of dynamically chaotic (multivalued) networks:  
Chaotic network efficiency is determined by the number of *all combinations of links*

$$N! \approx \sqrt{2\pi N} (N/e)^N \sim N^N \propto C \text{ (unreduced dynamic complexity)}$$

where the number of links  $N$  is very large itself

Unitary (regular) dynamic efficiency grows only as  $N^\beta$  ( $\beta \sim 1$ ).

The huge advantage in efficiency expresses *intrinsic creativity/adaptability* of the unreduced complex dynamics obtained at the expense of its *chaoticity*



**INTELLIGENCE, CONSCIOUSNESS, AUTONOMIC COMMUNICATION**

## Particular aspects and applications

- (1) Knowledge-based structure of intelligent communication networks
- (2) Holistic, two-layer dynamics of **advanced** intelligent network ("superbrain")  
Complex-dynamic meaning of *true* intelligence/consciousness (physics/0409140)
- (3) Intelligent network and its users *automatically* become more intelligent  
Intrinsically suited to complex-dynamic problem solution → *revolution of complexity*
- (4) **Universal symmetry/development of complexity:** unified guiding principle  
Transformation of *dynamic information* ("interaction potential") into *dynamic entropy*

# Evolution as complexity development

## UNIVERSAL MEANING AND CRITERION OF PROGRESS

- System evolution as a result of the symmetry of complexity: qualitative, irreversible, dynamically discrete (quantized) change (event): transformation of dynamic information,  $I$ , into dynamic entropy,  $S$ , while the sum, total complexity,  $C = I + S$ , remains unchanged:

$$\Delta C = 0, \quad \Delta S = -\Delta I = -\Delta \mathcal{A} > 0,$$

where the extended, nonlinear action  $\mathcal{A} = I$  is a unified measure of complexity-information,  $|\Delta \mathcal{A}| \sim |V_{\text{eff}}| \Delta t \rightarrow$  time arrow ( $E, L > 0$ )

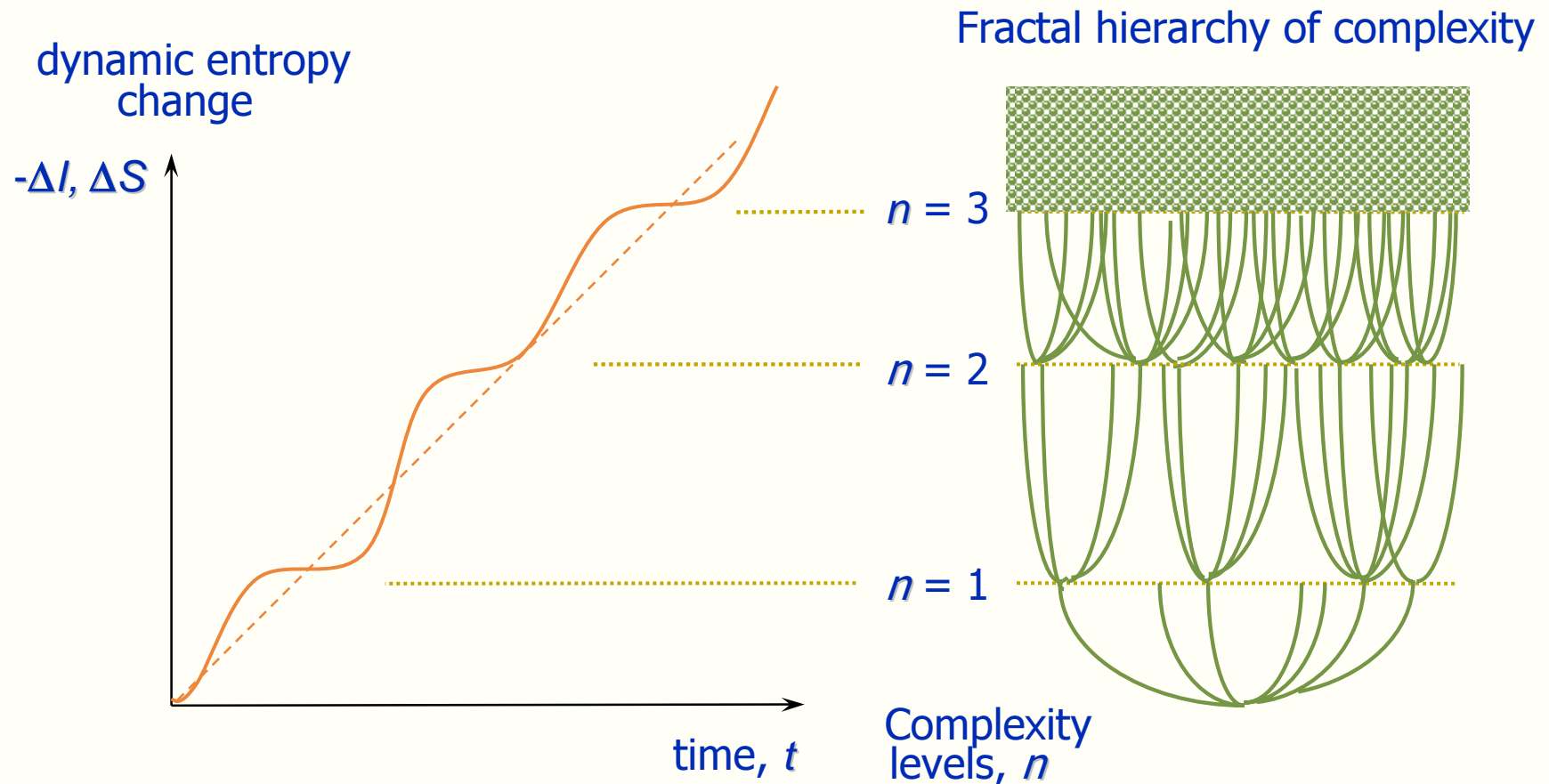
- Generalised Hamilton-Jacobi and Schrödinger equations:

$$\frac{\Delta \mathcal{A}}{\Delta t} \Big|_{x=\text{const}} + H \left( x, \frac{\Delta \mathcal{A}}{\Delta x} \Big|_{t=\text{const}}, t \right) = 0, \quad \hat{H} \left( x, \frac{\Delta}{\Delta x} \Big|_{t=\text{const}} \right) \Psi(x) = E \Psi(x)$$

- The universal meaning and purpose of any system evolution, progress, and existence: complexity development as a result of the symmetry of complexity  $\rightarrow$  teleological, purposeful dynamics

# Progress by complexity steps

## DYNAMICALLY DISCRETE COMPLEXITY DEVELOPMENT



Any structure creation is a *growth* of complexity-entropy



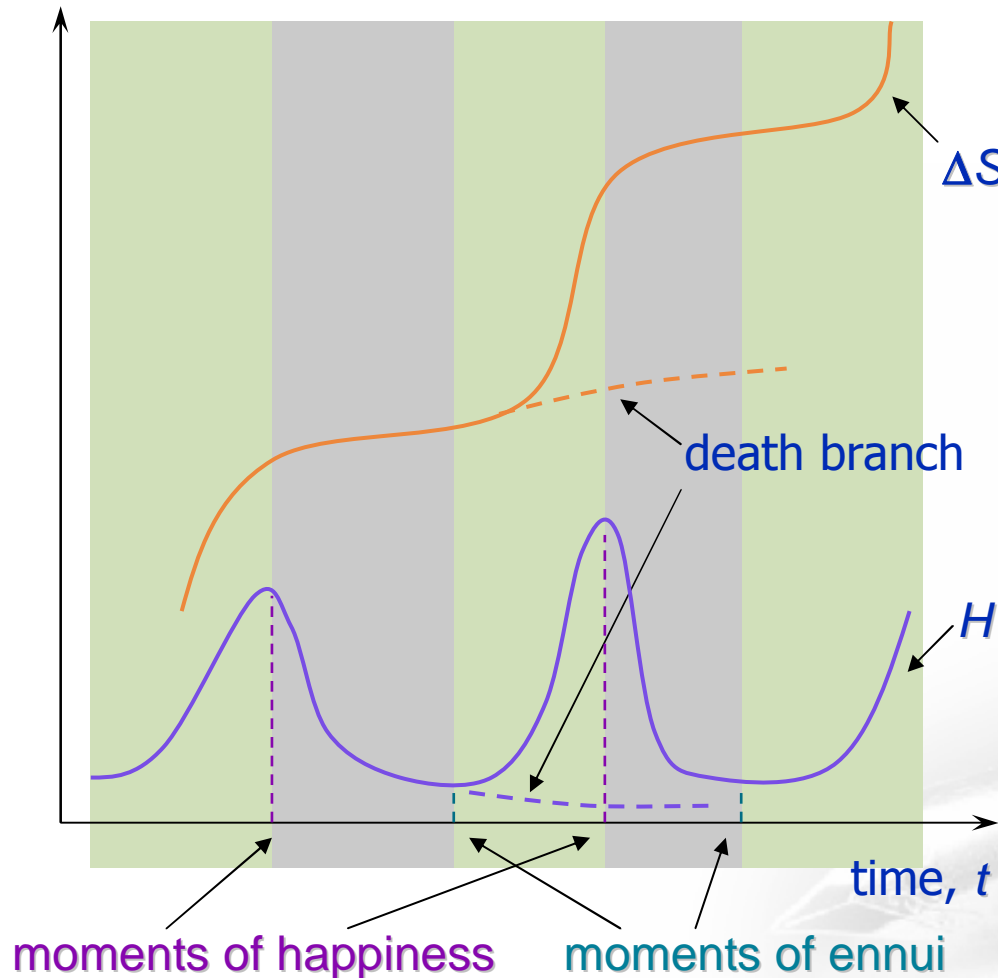
# “progress” vs “decline”

dynamic entropy change,  $\Delta S$ ,  
Hamiltonian (energy),  $\Delta S/\Delta t = H, E$

period of  
progress



period of  
decline



For both “progress” and “decline”:

$$H = \partial S/\partial t > 0$$

Progressive development (creation):

$$W = \partial H/\partial t = \partial^2 S/\partial t^2 > 0$$

Decline (decay, degradation):

$$W = \partial H/\partial t = \partial^2 S/\partial t^2 < 0$$

Max progress results (“happiness”):

$$\partial H/\partial t = \partial^2 S/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 < 0$$

Max decay results (“ennui”):

$$\partial H/\partial t = \partial^2 S/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 > 0$$

Transition *max* (“moment of truth”):

$$\partial^2 H/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 < 0$$

Decline crisis (“moment of sin”):

$$\partial^2 H/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 > 0$$

# Unified mathematics of complexity

DYNAMIC FRACTAL: UNREDUCED PROBLEM SOLUTION

UNIVERSAL SYMMETRY OF COMPLEXITY

- *Non*-uniqueness of any real problem solution: universal *dynamic multivaluedness*
- Explicit dynamic *emergence*, origin of *events* and *time*:  $A \neq A$  for any real  $A$
- Fractally structured *dynamic entanglement*: *rigorous* expression of *material quality*
- No “exact solutions”: meaning of *randomness*, *nonintegrability*, *noncomputability*, etc.
- *Dynamic* discreteness (*causal quantisation*), *nonunitarity*, dynamic origin of *space*

<http://arXiv.org/abs/physics/0502133>

# Science Progress Diagram

## NEW MATHEMATICS OF COMPLEXITY

Unitary science: only one from many real system realisations  
Universal Science of Complexity (USciCom): all system realisations

Unitary 1

Unitary 2

USciCom

Mechanistic  
discreteness:  
Numbers  
Classical figures  
No interaction  
No change  
No quality

Mechanistic  
continuity:  
Calculus  
Deformable shapes  
Trivial interaction  
Formal change  
No quality

Dynamic  
discreteness:  
Multivaluedness  
Dynamical fractal  
Full interaction  
Intrinsic change  
Full quality

<http://arXiv.org/abs/physics/9806002>

# Unreduced complexity features

## UNIVERSAL CONCEPT AND SCIENCE OF COMPLEXITY

- **Unreduced complexity >> usual imitations of complexity**  
Fundamental difference of *unreduced complexity* (dynamic multivaluedness) from any dynamically single-valued (unitary) *imitations of complexity*
- **Usual science = zero-dimensional projection of reality**  
The *whole* usual, unitary science, including scholar “science of complexity” (“chaos”, “self-organisation”, “nonlinear dynamics”, etc.), is the *simplest* possible, *zero-dimensional, point-like projection* of real, *multivalued* world dynamics
- **Unreduced complexity = natural completion of usual science**  
Universal science of complexity (*unreduced* interaction problem *solution*) is the explicit, causally complete extension of the unitary science (from one system realisation to their complete set)
- **Problem-solving power of the universal science of complexity**  
Unreduced complexity (dynamically multivalued solution) *solves stagnating problems* of unitary science (quantum physics, particles, field theory, gravity, cosmology, solid state, biology, etc.) and *completes* it up to the humanities (consciousness, ethics, aesthetics, development, etc.)
- **Complex system creation by unreduced complexity understanding**  
Only the *unreduced* dynamic complexity is suitable for *real-world* applications involving *new system design* (like autonomic communication networks, intelligent software, AI, machine consciousness)

# Sustainable knowledge

- **Today's knowledge development is *not* sustainable:**  
quickly *growing problems* of intensity, content, efficiency, creativity (e.g. usual ecological problems) → we need always more
- **Illusion of regularity:**  
regular, "industrial" operation mode inevitably leads to *degradation* at a high intensity stage (the case of usual developed industry)
- **Illusion of power:**  
power *cannot* increase *quality* by itself: increasing power capacities need another, qualitatively different dynamics → complexity
- **Only complex-dynamic creation can be sustainable:**
  - *system freedom* to change its own structure (true autonomy)
  - efficient management of *creation result* (intelligence)
  - *complex-dynamic* (chaotic) control → genuine security and *progress*
  - *permanent, natural* user-machine-network complexity *coevolution*
- **Today's bifurcation of knowledge/civilisation development:**  
Complexity Transition = Sustainability Transition = Creative Ecology