TRADITIONAL MATHEMATICS IS NOT THE LANGUAGE OF NATURE:
MULTIVALUED INTERACTION DYNAMICS MAKES THE WORLD GO ROUND

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Abstract

We show that critically accumulating "difficult" problems, contradictions and stagnation in modern science have the unified and well-specified mathematical origin in the explicit, artificial reduction of any interaction problem solution to an "exact", dynamically single-valued (or unitary) function, while in reality any unreduced interaction development leads to a dynamically multivalued solution describing many incompatible system configurations, or "realisations", that permanently replace one another in causally random order. We obtain thus the universal concept of dynamic complexity and chaos impossible in unitary mathematics.

This huge difference between the unreduced mathematics of real-world dynamics and strongly limited unitary "models" of traditional mathematics inevitably induces a growing series of "unsolvable" problems and other "mysteries" that culminate now in the crisis of the "end of science", where the stagnating unitary "science" in question includes only the described limitation of the traditional mathematical framework (unfortunately accepted as the unique possible basis for any scientific knowledge).

In this brief review, we show that science extension to the unreduced, dynamically multivalued mathematics of the intrinsically complex real-world dynamics provides stagnating problem solutions and reconstitution of the intrinsic causality and unity of science desperately missing in its artificially limited unitary framework. Painful stagnation of the latter should be replaced now by the unlimited new progress of the extended, causally complete knowledge of the universal science of complexity, which provides the urgently needed issue from the current impasse of the global civilisation development.

Dynamically single-valued models of the official science paradigm vs the unreduced dynamics of nature

Traditional mathematics is all about artificially invented, abstract, and irreducibly separated structures and rules that exist for their own sake and are then equally artificially, totally hypothetically attached to real-world phenomena with the help of ad hoc postulates and "experimental verification" remaining always incomplete and ambiguous. The resulting contradictory world image of official science is justified as the best possible one with a reference to equally abstract, *arithmetic* "incompleteness theorems" as if implying that *any* knowledge is fundamentally limited and can only be mechanically adjusted within a partially optimal (but globally incorrect) "model" of reality, inevitably separated from other models for the same, *physically unified* real world.

In this paper, we show why this conventional "language of nature" of traditional mathematics is not only not the best but *provably the worst possible* mathematical approximation of nature, while the *truly exact* mathematical image of the latter *does exist* within the *explicitly and essentially extended*, *reality-based mathematical framework* that provides a naturally unified, intrinsically complete, and problem-solving image and description of the real-world structure, dynamics, and unstoppable evolution [1-39]. This huge difference between the two mathematical systems and approaches stems from the totally abstract basis of traditional mathematics concentrated on its own, "conveniently" simplified and allegedly "beautiful" rules and structures as opposed to the intrinsically realistic character of the extended mathematical framework existing rather as a useful description of real-world structures and processes.

Correspondingly, the abstract picture of traditional mathematics starts from and stays concentrated on extremely simplified immaterial *structures*, while the reality-based approach of the *causally complete* mathematical framework and science considers structure-forming *interaction processes* involving *tangible* interacting entities and starting from the provably simplest configuration. The real-world structure and dynamics are then progressively and explicitly *obtained* as the hierarchy of interaction development results,

providing thus the intrinsically unified and causally complete picture of the world, in accord with its real emergence and evolution processes. In exchange, one must accept the respectively extended, dynamically multivalued results of real interaction processes, far from their grotesquely simplified images in the "exact" models of traditional mathematics.

It is easy to see that the mentioned *simplest possible* structure-forming interaction process includes two initially homogeneous material entities, or "protofields", uniformly attracted to each other. We show that already this simplest interaction process with generic parameters can produce the observed diversity of world structures, with all their intrinsic properties and dynamic regimes, if only we avoid any simplification of real interaction development [1-38]. It is important that there is a *well-specified mathematical reason* for this essential progress revealed within this crucial extension. We also naturally *derive* the *unified laws* of real-world dynamics, without any artificially inserted postulates, rules, or principles (dominating in the traditional science framework).

We can universally specify the mentioned key extension of the mathematical approach and analysis by considering a very general description of an *arbitrary many-body interaction process*, which includes the starting simplest interaction configuration that gives rise to the emerging world dynamics. This is a Hamiltonian kind of equation called here the *existence equation* as it simply describes the arbitrary interaction participants and configuration (and can eventually be confirmed as the truly universal formulation of any interaction problem) [1-6,17-20,23-33]:

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

where $h_k(q_k)$ is the generalised Hamiltonian of the k-th system component in its "free", "integrable" state (in the absence of interaction), q_k stands for the degrees of freedom of the k-th component, $Q=\{q_0,q_1,...,q_N\}$ by definition, $V_{kl}(q_k,q_l)$ is the interaction potential between the k-th and l-th components (it can be generalised to any number of irreducible interaction participants), $\Psi(Q)$ is the system state function describing its detailed configuration, E is the generalised energy value, and the summations are taken over all system

components numbered from $k,l=0$ to $k,l=N$ (the total number of interacting entities).

In the traditional mathematical approach, the full interaction description of eq. (1) is severely reduced to an "integrable" model with an "exact" solution, usually of a "mean-field" kind:

$$\left[h_0(\xi)+V_{nn}(\xi)\right]\psi_n(\xi)=\eta_n\psi_n(\xi), \tag{2}$$

where $\xi=q_0$ is a vector of major, usually configurational degrees of freedom, $\psi_n(\xi)$ are solution components in terms of the known eigenfunctions of interaction components, $V_{nn'}(\xi)$ are the mean-field matrix elements, and $\eta_n\equiv E-\varepsilon_n$ are the respective eigenvalues, with all essential interaction links being lost in this extremely rough scheme of the full interaction of eq. (1). In the *unreduced* interaction analysis by the *generalised effective potential method* [12,40] the same problem representation will rather look like [1-6,17-20,23-33]

$$\left[h_0(\xi)+V_{\text{eff}}(\xi;\eta)\right]\psi_0(\xi)=\eta\psi_0(\xi), \tag{3}$$

where the *effective (interaction) potential (EP)*, $V_{\text{eff}}(\xi;\eta)$, is given by

$$V_{\text{eff}}(\xi;\eta)=V_{00}(\xi)+\hat{V}(\xi;\eta),\ \hat{V}(\xi;\eta)\psi_0(\xi)=\int\limits_{\Omega_\xi}d\xi' V(\xi,\xi';\eta)\psi_0(\xi'), \tag{4a}$$

$$V(\xi,\xi';\eta)\equiv\sum_{n,i}\frac{V_{0n}(\xi)\psi_{ni}^0(\xi)V_{n0}(\xi')\psi_{ni}^{0*}(\xi')}{\eta-\eta_{ni}^0-\varepsilon_{n0}},\ \ \varepsilon_{n0}\equiv\varepsilon_n-\varepsilon_0\ , \tag{4b}$$

and $\{\psi_{ni}^0(\xi)\}$, $\{\eta_{ni}^0\}$ are the complete sets of eigenfunctions and eigenvalues of an auxiliary, truncated system of equations (here $n,n'\neq 0$):

$$\left[h_0(\xi)+V_{nn}(\xi)\right]\psi_n(\xi)+\sum_{n'\neq n}V_{nn'}(\xi)\psi_{n'}(\xi)=\eta_n\psi_n(\xi)\ . \tag{5}$$

Other solution components $\psi_n(\xi)$ are then found from solutions of eq. (3) as

$$\psi_n(\xi)=\hat{g}_n(\xi)\psi_0(\xi)\equiv\int\limits_{\Omega_\xi}d\xi' g_n(\xi,\xi')\psi_0(\xi')\ , \tag{6a}$$

$$g_n(\xi,\xi')\equiv V_{n0}(\xi')\sum_i\frac{\psi_{ni}^0(\xi)\psi_{ni}^{0*}(\xi')}{\eta-\eta_{ni}^0-\varepsilon_{n0}}\ , \tag{6b}$$

where $\psi_0(\xi)$ are the eigenfunctions and η eigenvalues of the effective dynamic equation, eq. (3).

We see that the unreduced interaction of eq. (1), in its *totally equivalent* effective formulation, eqs. (3)-(6), contains a much more complicated network of interactive dynamical links than any exact model of traditional mathematics, eq. (2) (including its perturbative versions). However, what is especially remarkable in this effective formation of the unreduced interaction problem is that it reveals explicitly the *unified* and *essential difference* of any real interaction process results from their reduction in the traditional approach. Mathematically, this key feature of the unreduced interaction process is revealed by the complicated nonlinear dependence of the generalised EP $V_{\text{eff}}(\xi;\eta)$, eqs. (4), on the eigenvalues η (and eigenfunctions $\{\psi_{ni}^{0}(\xi)\}$) to be found. Because of this dependence, the highest power of the characteristic equation for the eigenvalues of eq. (3) is multiplied by $N_{\Re} = N$ (where N is the number of all interacting modes or, in general, their combinations) as compared to any traditional model (2). This means that the total number of eigen-solutions for the unreduced problem of eq. (3) is also $N_{\Re}$ times greater than that for the reduced formulation of eq. (2). Physically, it implies that instead of a single system configuration as a result of its interaction development according to the reduced traditional problem formulation of eq. (2), one obtains $N_{\Re}$ such *equally possible* system configurations, or *realisations*, for the unreduced problem solution, eqs. (3)-(6). And since these plural realisations have "equal rights" to appear under the action of the system's driving interaction while being *physically complete* and therefore *incompatible* with one another, they are forced to permanently replace one another in *dynamically random* order thus defined [1-6,11,12,20,23-33,40]. This major feature of realisation plurality for any real interaction process is also confirmed by the graphical analysis of the effective problem solution [1,2,12,13]. It implies the dynamic, interaction-driven *splitting* of *any* system and process state, configuration, quantity, and behaviour into many interrelated, probabilistically changing versions.

Thus rigorously obtained, causally complete, *dynamically multivalued* solution to the unreduced interaction problem (1) provides immediately *several fundamental and qualitatively big novelties* relative to the traditional, *dynamically single-valued* mathematics framework (that may include purely formal, non-dynamic multivaluedness of abstract functions).

First of all, it is the property of *fundamental dynamic multivaluedness* itself, which means that *any* sensible, reality-based quantity and function has

this *dynamically multivalued* structure, being present in many *equally real* but *incompatible* versions forced to permanently replace one another in dynamically random order. In particular, the often implicit and apparently absolutely obvious *postulate of self-identity* of traditional mathematics, $\mathfrak{A} = \mathfrak{A}$, is *directly and strongly violated* in real-world mathematics as any its observable quantity or value $\mathfrak{A}$ permanently changes all the time and in addition does that in the truly probabilistic, absolutely unpredictable way:

$$\mathfrak{A} \neq \mathfrak{A}\,, \tag{7}$$

while the self-identity $\mathfrak{A} = \mathfrak{A}$ can now be understood only in the essentially extended sense of all realisations of the quantity $\mathfrak{A}$ with their respective dynamic probabilities (see below). One can also recall all those classical theorems of traditional mathematics about the *uniqueness of solutions* and objects for major structures, problems, and equations to see the huge degree of difference of real-world mathematics from its conventional simplification. At the same time, it is important to note that the *new mathematics of real-world complexity* [1-8,11,27] comes as the explicit *extension* of conventional schemes, including their (modified) dynamically single-valued branches but also many other, dynamically produced ones.

The next, closely related feature of real-world mathematics is the *purely dynamic, causal and universal origin of omnipresent randomness and probability*, or *chaoticity*, in the dynamically multivalued reality as opposed to their empirically based formal definitions in the traditional, dynamically single-valued framework. As all elementary system realisations are mutually incompatible and *equally real*, they will appear in the *causally, or dynamically, or truly random* order thus defined, and the dynamically, *a priori* determined *probability* α_r of each *r*-th realisation emergence is equal to that of any other one:

$$\alpha_r = \frac{1}{N_{\mathfrak{R}}}\,,\quad \sum_r \alpha_r = 1\,, \tag{8a}$$

where $N_{\mathfrak{R}}$ is the total realisation number introduced above and determined by the starting interaction configuration. Since many practically observed features may contain many very similar elementary realisations, which are not resolved empirically and therefore form combined realisations, the starting probability definition (8a) can be generalised as

$$\alpha_r = \frac{N_r}{N_{\mathfrak{R}}}\,,\quad \sum_r N_r = N_{\mathfrak{R}}\,, \tag{8b}$$

where N_r is the number of elementary realisations within the actually observed *r*-th combined realisation (this is the *multivalued self-organisation* phenomenon, see below). Since any real object or structure emerges from and is maintained by an interaction process, while any such real process produces dynamically multivalued results, we conclude that the fundamental dynamic randomness and probability thus defined are *universal* and *omnipresent* features, including the *externally regular* structures and processes. The well-known exactly solvable models of traditional mathematics are never real, even though they can externally approach the observed quasi-regular behaviour. But once we take into account their formally "small" deviations from real, extended and three-dimensional systems, we obtain qualitatively big difference for real object behaviour (including the internal chaoticity and unified time origin outlined below).

This *unified randomness and chaoticity concept* and definition is equivalent to the equally *universal definition of dynamic complexity* in the extended mathematical framework. Namely, the unreduced dynamic complexity C of any real object, system, or process is defined by any growing function of the number $N_{\Re}$ of system realisations or their rate of change, equal to zero for the unreal case of only one realisation [1-6,11,17-20,22-33]:

$$C = C\left(N_{\Re}\right),\ dC/dN_{\Re} > 0,\ C\left(1\right) = 0\ . \tag{9}$$

It becomes clear why no universal definition of complexity can be obtained within the conventional, dynamically single-valued mathematical description of reality left with hugely incomplete, external imitations of both complexity and chaoticity/randomness (the unreduced complexity is always zero in this case, $C\left(1\right) = 0$). The same is true for many related features and notions of the traditional framework, including *nonintegrability* (absence of a "closed", *unique* solution), *nonseparability*, *noncomputability* (genuine dynamic randomness), *uncertainty (indeterminacy)*, *undecidability*, *stochasticity*, *broken symmetry*, *free will*, etc., which acquire their consistent and universal meaning within the unreduced, *dynamically multivalued* picture of reality [1-11].

The dynamically multivalued structure of the unreduced interaction problem solution (3)-(6) has further internal development due to its dependence on the solutions of the truncated system of equations (5) that can be analysed with the help of the same generalised EP method revealing their own dynamic splitting into plural realisations of the next level. It will depend again on the eigen-solutions of a yet more truncated system of equations, and so on,

until we arrive, in a finite number of steps, at an integrable equation or system of equations. The obtained truly complete problem solution will contain thus many related levels of system realisations, which change one another in dynamically random order at every level containing, in general, various dynamic regimes, from the uniform chaos to the multivalued self-organisation. We call this universal emerging system (and eventually world) structure the *dynamically probabilistic, or multivalued, fractal* as it is provided, at each level of fractal structure, with the respective set of dynamically determined realisation probabilities of eqs. (8) [1,2,4-6,23-33]. Instead of the basic regularity and scale symmetry of usual, purely abstract and dynamically single-valued fractals, the dynamically probabilistic fractal of the unreduced system solution and real-world structure realises, in general, the absolutely exact (never broken) and universal dynamic symmetry of complexity (see below). Mathematically, the probabilistically fractal structure of this causally complete solution to the many-body interaction problem in terms of the observable system density $\rho(\xi,Q)$, $Q=\{q_1,...,q_N\}$, is therefore obtained as

$$\rho(\xi,Q)=\sum_{j=1}^{N_{\rm f}}\sum_{r=1}^{N_{\Re j}}{}^{\oplus}\rho_{jr}(\xi,Q)\ , \tag{10}$$

where $\rho_{jr}(\xi,Q)$ is the measured density for the r-th realisation at the j-th level of dynamic fractality, $N_{\Re j}$ is the number of realisations at the j-th level, $N_{\rm f}$ is the final or desired level number, and the dynamically probabilistic sum sign $\oplus$ implies that individual realisation densities $\rho_{jr}(\xi,Q)$ at each fractality level permanently emerge and disappear probabilistically, with the *causally derived* probabilities $\{\alpha_{jr}\}$ determined according to eqs. (8), irrespective of the number of events observed.

It is important to note also that contrary to the separable contributions from the interacting degrees of freedom $\{\xi,Q\}$ in the traditional solution, their combination within each realisation structure of the unreduced solution (3)-(6) is provided by their inseparably entangled mixtures describing the *material quality (texture)* of the emerging interaction result [1,2,4-6,23-33]. Thus obtained fractal and "living" (probabilistically changing) *dynamic entanglement* of the system components within the unreduced problem solution (10) is another qualitative difference from any traditional, inevitably abstract solution missing that real-world entanglement and the related *tangible* material quality (i.e. "separable" unitary models vs *nonseparable* reality).

Finally, major fundamental consequences of the dynamic multivaluedness feature of the unreduced interaction result are the *unstoppably and irreversibly flowing dynamical time* and *emerging, dynamically discrete, or quantised, and physically tangible space*, which are not separated any more from the traditional mathematical framework and then artificially inserted into its physical applications as purely abstract entities but are naturally present in the new mathematical framework [1-6,11,18-20,23-33]. The *real time flow* is created by permanent realisation change and its *intrinsic irreversibility* is due to the *causally random* choice of each next realisation. As there is a hierarchy of emerging interaction complexity levels, there is the respective hierarchy of time flows, from the universal "physical" time at the most fundamental levels of emerging elementary particle dynamics to the internal "local" time for any system or complexity level. Quantitatively, the elementary time flow period Δt is determined by intensity, or frequency, ν, of causally random realisation change, $\Delta t = 1/\nu$. The *naturally quantised and tangible space* is also created dynamically by the above entanglement of interacting system components within each emerging realisation as well as by system's "quantum jumps" between its discrete realisations. The physically real space is thus literally "woven" from the interacting degrees of freedom by the unreduced interaction dynamics itself, and similar to the above physically real time flow is present in the entire hierarchy of complexity levels, from the "embedding" physical space of the lowest complexity level to the fundamental space elements (its generalised *points* and *length*) for any real interaction dynamics at higher complexity levels. The generalised space point size r_0 is determined by the neighbouring η eigenvalue separation for the effective existence equation (3) within one realisation, $r_0 = \Delta_i \eta_i^r$, while the generalised elementary space length Δx is due to the characteristic eigenvalue separation between different realisations, $\Delta x = \Delta_r \eta_i^r$. We can now rewrite the dynamic multivaluedness expression (7) in a further extended version:

$$\mathfrak{A} \neq \mathfrak{A} = \{\mathfrak{A}_r\} \Rightarrow \mathfrak{A}(t,x) \,. \tag{11}$$

It is important to emphasize that this quantised and causally random, or *nonunitary* (i.e. highly uneven and unpredictable), internal structure of the unreduced interaction dynamics constitutes the key difference from the dynamically single-valued, or *unitary* (i.e. basically smooth and predictable), character of the traditional model of reality. That is why the latter *cannot*

provide any consistent concept of *dynamic randomness, or chaos*, which is naturally present in the unreduced, multivalued interaction dynamics.

The described features (7)-(11) of the essential mathematical extension of the causally complete world description in the *universal science of complexity* [1-38] relative to the traditional extremely simplified model are supplied with the *intrinsically unified world structure* in the form of the *fundamental dynamically probabilistic fractal* (see above, eq. (10)) and the *unique and absolutely universal law* of *conservation and transformation, or symmetry, of the unreduced dynamic complexity* (9), which unifies and extends *all* known (correct) laws and principles of traditional science. The universal symmetry of complexity describes the emergence, dynamics, and evolution of the dynamically probabilistic fractal of the unified world structure by the *unstoppable transformation* of the latent, potential form of interaction complexity measured by the *generalised dynamic action-complexity* $\mathcal{A}$ to its completely unfolded and tangible form of *generalised dynamic entropy-complexity* S, with the universal conservation of their sum, the total system complexity $C = S + \mathcal{A}$:

$$\Delta S = -\Delta \mathcal{A} > 0 \ . \tag{12}$$

The differential form of eq. (12) gives the *generalised Hamilton-Schrödinger formalism* for the universal description of system dynamics at a given complexity level [1,2,4-6,18-20,23-33]. The obtained totally unified and emergent world structure, dynamics, and evolution, from elementary particles to superior levels of consciousness, summarises the essential *completeness* of *real-world* description in the universal science of complexity and its *new mathematics of complexity*, eqs. (7)-(12).

This causally complete universality of the extended description is confirmed by the *unified classification of all possible dynamic regimes*, from the *uniform*, or *global* (i.e. explicitly strong), *chaos* with a few essentially different realisations to the *dynamically multivalued self-organisation* or, in general, *self-organised criticality* with many similar realisations for (externally) quasi-regular structures and dynamics [1-6,10,11,20,22-24,27-32], where the border between those limiting regimes is determined by the rigorously specified value of the *chaoticity parameter* (the ratio of major system frequencies).

The ultimate validity of a world description framework is verified by real problem solutions and the related overall completeness of the world picture. The *reality-based* mathematics of unreduced interaction complexity has the inherent advantage in this respect relative to empirically driven but

purely abstract guesses of traditional mathematical language ending up in unsolvable mysteries, inexplicable paradoxes, and "hard" problems of standard fundamental physics strangely growing in number instead of being solved. As demonstrated by applications of the universal science of complexity [1-39], we obtain indeed the causally complete and intrinsically unified picture of reality with the help of the new complexity mathematics, without "quantum mysteries" and other "dark" matters on lower, physical complexity levels, as well as reliable genomics, integral medicine, and consistent concept of consciousness at superior levels of the same hierarchy of unreduced interaction complexity. It is important that there is no artificially inserted and abstract entities in this emerging-world description, including physically real and irreversibly flowing time, dynamically quantised and tangible space (see eq. (11)), and all "intrinsic" particle properties like mass, electric charge, spin, and fundamental interactions (now dynamically derived and unified). The same is true for all major physical quantities like energy-mass, momentum, action, and entropy that now obtain their extended meaning as forms of universal dynamic complexity entering the unified and never broken law of the universal symmetry of complexity, eq. (12). The unrestricted power of the extended mathematical framework covers all superior complexity levels without any loss of rigour, thus closing the "eternal" gap between the "exact" sciences and the humanities/arts in the traditional science framework.

Needless to say, the severely limited, dynamically single-valued models of the standard description with the zero value of unreduced dynamic complexity (9) cannot correctly reproduce even the simplest objects and properties of the real, dynamically multivalued world, replacing them with abstract schemes that demonstrate only formal and physically incomplete "confirmation by experiment" but always dominate in the official science system as the only one and best possible kind of science. The artificial restriction of the unitary picture of official science, retaining *only one* realisation from their huge number and unlimited, *dynamically unified* variety, gives rise to the well-known multitude of irreducibly separated and heavily incomplete unitary "models", each of them based on its own preferred system realisation (e.g. "particles" vs "waves" in standard quantum mechanics). The emerging inevitable contradictions and blunders of traditional mathematics applications are reviewed in the next section, together with the related limits to further progress and acute crisis in the official science practice and organisation naturally disappearing in the extended science of complexity.

Limits and blunders of traditional mathematics: The price we pay for the illusive simplicity of dogmatic knowledge

As becomes clear from the previous section, zero-complexity imitations of a high-complexity world underlie irreducible and fatal limits of standard unitary science (including the official "complexity science") and it cannot be otherwise within the traditional knowledge paradigm, irrespective of unitary model details or the computation power applied. Visible relative successes of unitary science (its famous "unreasonable effectiveness") until this last epoch of stagnation and decadence are due to the high enough starting efficiency of the empirical trial-and-error research using the quickly growing power of experimental technologies. However, this unitary trial-and-error efficiency is limited by dynamic complexity of studied real objects and phenomena providing *too many* empirically guided guesses, especially after some invisible *complexity threshold* [2-5,28-32,36]. This is related to the phenomenon of *exponentially huge efficiency* of complex interaction dynamics for large enough systems of modern interest [2-6,20,23-32], which cannot be even approximately imitated by any unitary theory, approach, or technology. Moreover, even the behaviour of relatively simple but real and therefore complex-dynamical objects cannot be causally understood within the traditional dynamically single-valued approach if one tries to obtain their *causally complete* description only with the help of empirical research technologies. This is the true reason for the postulated mysteries and inexplicable paradoxes in the "rigorous" science framework during the revolution of the "new physics": since the very beginning, it was actually the hidden *complexity revolution* that can be fully realised and successfully applied only now, within the dynamic multivaluedness paradigm [1-4,11-21].

The persisting old and increasingly appearing new mysteries, dark matters, hidden dimensions, and various other "hard" problems of traditional, unitary science framework provide very visible manifestations of this glaring gap between the over-simplified theory and complex-dynamic reality, culminating now in the *deep crisis* of official, *unitary* science, with the emerging destructive tendencies in the *planetary civilisation development* (instead of the

new progress within the unreduced complexity paradigm [1-8]). But as the obviously failing, artificially restricted doctrine of conventional science persists in its absolute domination and massive, technologically sophisticated experiments (e.g. mega-projects of official science), we shall review below several most important limits and blunders of scholar science applications, from the lowest complexity levels of fundamental physics to the highest levels of life sciences, the science of consciousness, and the humanities (including socio-political and development sciences and applications) [1-39].

Starting from the *lowest levels of fundamental physical entities* involving space, time, elementary particles, fields, their interactions, intrinsic and dynamic properties, we note, first of all, a *glaring major deficiency* of unitary science picture and mathematics that *do not even try* to provide any idea of the *physical origin* of these fundamental and physically real entities giving rise to all higher-level objects of the perceived reality. Instead, the unitary theory postulates their simplified and purely abstract mathematical images (actually nothing more than symbolic notations) obeying to postulated and abstract "laws" of equally unexplained physical origin, which are then "experimentally confirmed" with many sheer contradictions, blank spots, legalised "mysteries" and inexplicable "paradoxes". This deeply corrupt but "generally accepted" basis of standard unitary science (the single possible kind of science, according to its own attitude) has the obvious explanation in terms of the causally complete picture of the universal science of complexity, where all real entities *explicitly emerge* in unreduced interaction processes, starting from the *provably simplest* configuration of the lowest-level interaction at the origin of the Universe [1-4,11-21]. As those real, unreduced interactions are not even considered in the unitary science paradigm, being replaced by their grotesque imitations just killing all real emergence phenomena, the question about the physical origin of real-world structures does not appear either and they are simply postulated, in their totally abstract and simplified version of unitary mathematics. It is precisely this extremely reduced and totally formal image of reality that is given the status of "objective scientific truth" in the standard science framework, which provides then very elaborate and resource-consuming "experimental verification" schemes for such fundamentally and grotesquely incomplete picture while justifying the related contradictions by other imitation schemes of the same unitary mathematics, such as "Gödel's incompleteness theorems" about abstract arithmetical structures.

The elementary *causality principle* being thus arbitrarily *violated* in the standard science framework, it is left with equally *arbitrary guesses* involving the hugely limited formal structures of unitary mathematics provided with the status of the ultimate objective truth about the physically real world (this is the famous "unreasonable effectiveness of mathematics in the natural sciences"). However, the finally obtained unreasonable level of old and new unsolved problems, "objective" mysteries and "dark" matters shows that the real-world behaviour is quite reasonable after all, as opposed to its heavily reduced imitation within the unitary science paradigm (see the previous section) that *cannot* produce the consistent real-world picture in principle, because of its specific, totally artificial restrictions.

The *consequences* of such unitary theory domination for fundamental physics development and applications are fatal scientifically ("the end of science" [41]) and progress-killing practically [1-4,7,8,11]. This conclusion is further supported by the problem-solving power of the causally complete knowledge extension of the universal science of complexity (or "quantum field mechanics", at the lowest complexity levels of fundamental physics [1-4,11-21]) and the related practical development possibilities [1-5,7,8,15-24]. All the conventional science "mysteries", "paradoxes", knowledge gaps and "unsolvable" problems do not even appear in the intrinsically complete knowledge paradigm of the universal complexity science closely following the real-world structure emergence and unreduced dynamics. Physically real, tangible space, as well as naturally, unstoppably, and irreversibly flowing time are obtained as a result of unreduced, dynamically multivalued interaction in the *provably simplest* system of two initially (effectively) homogeneous, physically real entities, the gravitational and electromagnetic protofields, uniformly attracted to each other, together with the physically emerging elementary field-particles (each of them being a *complex-dynamic, multivalued and chaotic process* of quantum beat), their intrinsic properties, dynamically unified interactions, quantum and relativistic behaviour (now *causally derived* as *naturally unified* manifestations of unreduced interaction complexity).

This *explicitly emerging* system of interacting simplest first-level structures of the world then gives rise to higher complexity sublevels, in the form of *quantum chaos* (nondissipative, Hamiltonian interaction configuration), *quantum measurement* (slightly dissipative interaction) and *classical behaviour emergence* in elementary bound systems (even totally isolated) like

atoms. This progressive and strictly causal (physically continuous) emergence of ever higher complexity levels of the world structure in the respective hierarchy of unreduced interaction processes continues till the highest complexity levels of living, intelligent and conscious systems, as described by the *universal*, *rigorously derived* and never broken law of the *symmetry (or conservation and transformation) of complexity*, which gives rise to *all* known laws, relations and principles, now naturally, dynamically unified and properly extended to their causally complete versions. We see that due to our *unreduced, non-simplified interaction analysis*, we obtain an internally highly uneven (and therefore "living" and creative), fractally structured but intrinsically continuous, *causally emergent* world picture, while the traditional, unitary mathematics and science approach gives a locally smooth but intrinsically incomplete and everywhere disrupted, artificial assemblage of single-valued linear pieces of the heavily deficient abstract imitation of reality. Correspondingly, in the latter case, every new, nontrivial structure, feature, or property can only be postulated, in one form or another, and never really, causally explained. The fact that those postulates appear as technically "exact" statements of traditional mathematics (up to unsolvable "mysteries" and only in exact sciences, i.e. at lower complexity levels!), as if implying its totally esoteric, "magic" underlying role in the world structure and dynamics [40-48], does not eliminate those glaring and now deadly limiting deficiencies of the collapsing unitary science paradigm.

The *concrete advantages* of the *causally complete* picture of unreduced dynamic complexity at its lowest levels of fundamental physics include physically realistic, dynamically derived, totally consistent, and unified explanations of the observed elementary entities, their numbers, intrinsic properties, and dynamics, without any redundant, "detected" (the Higgs boson) or yet unknown, "hidden" or "dark" entities or dimensions [1-5,12-24]. We obtain, in particular, the causally derived, fundamental origin of *both* the elementary particle *and* nuclear *mass spectrum* limited from above by their *already observed* highest values (of the order of real, modified Planck mass $M_{\mathrm{P}} \sim 10^2\ \mathrm{GeV}$), without any "hierarchy problem" for the elementary particles related to the senseless, *wrong values* of conventional, formally calculated Planck units (which appear in so many applications of scholar fundamental physics and cosmology leading to *huge losses*, due to this provably wrong feature alone). As a result, we can clearly see the *objectively justified* necessity of

the *qualitative change of the entire research strategy in high-energy physics and cosmology*, involving the efficiency of multi-billion experimental efforts and priceless knowledge advances in these research directions. Beyond any coincidence, this conclusion and the underlying progress is related to the obtained causal, dynamic, unified, and physically realistic *origin of mass-energy* as a (differential) *form of dynamic complexity* further amplified by similar results for other intrinsic particle properties, including electric charge and spin.

Among characteristic "unsolvable" problems of the standard mathematical framework of fundamental physics that do not even appear in the extended approach of the mathematics of complexity (7)-(12), we mention the famous *wave-particle duality* together with a bunch of associated quantum features (such as the famous "quantum entanglement") formally postulated but remaining "mysterious" within any unitary science scheme (including the pseudo-realistic "interpretations" of Bohmian mechanics, or the pilot wave theory). The origin of this problem is in the fundamental *absence of explicit structure emergence* in any dynamically single-valued "model" of unitary science, while the *dynamically multivalued* result of any *real* interaction process, on the contrary, includes the *unstoppable sequence* of structure emergence phenomena as its *intrinsic and major content* (see eqs. (7), (10), (11)), so that in the case of elementary field-particles appearing as a result of the underlying protofield interaction process, their localised, corpuscular state of a "particle" as such is *permanently transformed* into the extended, undular state and back, forming the real structure of space and the naturally irreversible flow of time, with the causally random choice of each next localisation centre [1-4,14-21]. Moreover, due to the universality of our description, eqs. (1)-(12), this spatially chaotic *quantum beat (self-oscillation) process* within any massive elementary particle is generalised to higher complexity levels, with a similar unstoppable sequence of "localised" and "extended" system states taking respective forms within various well-defined dynamic regimes [1-6,9-38].

The next higher complexity level, that of *interacting elementary particles*, contains the naturally obtained *genuine quantum chaos* that maintains and extends the standard correspondence principle, thus solving the respective stagnating problem of unitary theory [2-5,12,17-20,22-24]. This result has important consequences by demonstrating the *fundamental impossibility of unitary quantum machine operation* (including quantum computers), even for "pure" quantum systems protected from any noise and "decoherence"

effects.[1] By contrast, the "magic" properties incorrectly attributed to always "expected" unitary quantum computation can be obtained in a quite different way, with the help of *complex-dynamical, essentially chaotic quantum and classical nano- and micromachines* due to the *exponentially huge efficiency of unreduced complex dynamics* realised, in particular, in natural living and intelligent systems [2-6,20,22-29]. It is difficult to overestimate the importance of these rigorously substantiated conclusions in view of gigantic investments in the fields of quantum computation and nanotechnology, now largely wasted in wrong directions supported by standard, unitary mathematics.

This group of complexity sublevels includes the purely dynamic *emergence of classical behaviour* of *elementary bound systems* like atoms due to the spatially chaotic behaviour of their components (without any "decoherence" effects of unitary theory) [1-5,17-20,22-24]. Classical behaviour emerges thus in a purely intrinsic, dynamical way, in a totally isolated system as a *higher complexity sublevel* of permanently localised systems (the simplest case of the universal *dynamically multivalued self-organisation* regime, see below), including the causally explained "striking" effects of quantum behaviour "revival" in large molecules or superfluid macroscopic states. In this way, all the "mysteries" of conventional theory are consistently resolved, while the deficient "interpretations" of unitary quantum theory become redundant.

Note, however, that the unitary science idea of *classical chaos* at this higher complexity level as being due to "Lyapunov instability" and "exponentially diverging trajectories" appears to be *fundamentally wrong* either, together with all its unitary mathematical machinery, despite the fact that contrary to the quantum chaos case, classical chaoticity thus obtained seems to be "real". Even from a general point of view, one may note that a "fundamental", purely dynamic, qualitatively specific, and omnipresent phenomenon strangely depends here on the time of observation and the purely external factor of "initial random deviations" of a system trajectory/state that introduce the main feature of randomness from outside, irrespective of the following regular system evolution. In reality, we deal here with the characteristic

[1] Note that even apart from thus specified mechanism of unitary quantum dynamics violation by quantum chaos effects, quantum computers could not obtain any useful results for systems with dynamic complexity values above their essentially quantum dynamics (including any classical system and related usual calculations with well-defined "localised" results). This is the absolutely general and fundamental consequence of the symmetry (conservation) of complexity mentioned in the previous section that forbids any sensible simulation of a complexity level dynamics by a system from a lower complexity level (see the "complexity correspondence principle" below).

scheme of unitary *complexity imitation*, where being unable to obtain any genuine randomness/complexity within its effectively one-dimensional (and basically even zero-dimensional, point-like), inevitably *regular* dynamics, conventional theory invents external "signatures" of chaoticity/complexity and then plunges into its favourite "shut-up" calculation mode, with basically wrong but infinitely "interpretable" results.

In the case of unitary classical chaos description, we have probably the most popular case of the general unitary mathematics blunder of *false exponential dependencies* silently extended beyond the narrow limits of their applicability, where they are indistinguishable from power-law dependencies, which gives, in particular, ambiguous Lyapunov exponents as chaos signatures [1,2]. Those false exponential dependencies originate in the first, linear term of the power series expansion of the right-hand side function in the general evolution or dynamic equation, which inevitably produces the illusion of "exponential" (time) dependence for the system trajectory/state that has no meaning, however, beyond the limits of its validity, where the single linear term of the series expansion also becomes incorrect. For the false "Lyapunov exponents" techniques, this leads to their senseless, often erratically structured "spectra" (though often suitably "adjusted"), while in reality one deals with randomly structured but statistically power-law system wandering, with its very rapid, spatially chaotic transitions between slowly (e.g. linearly) evolving realisations. It is easy to see that an attempt to imitate this highly uneven real evolution with a smooth exponential function would usually produce nonsensical jumps between small and huge values of "Lyapunov exponents" for respective evolution moments [1,2] that often can be "properly adjusted" by choosing the "right point of view" (or time intervals) but will remain totally misleading "signatures" of *fundamentally absent* unitary randomness. A variable and complicated relation between the real, dynamically multivalued chaoticity and these simulated unitary "signatures" may exist, but it can hardly be of any efficient use or universal value.

Instead of impossible unitary quantum computers and conventional classical "chaos" without dynamic randomness, the unreduced, dynamically multivalued complexity concept leads to the truly fantastic but this time provably real possibilities of *complex-dynamical nanobiotechnology* on the border between quantum, transient ("quantum measurement") and elementary classical systems with *explicitly chaotic* dynamics, where this *genuine chaoticity* is

now not an obstacle but the basis of the resulting *superior efficiency* ("exponentially huge power") that gives rise, in particular, to the "magic" properties of natural living and intelligent systems [2-6,20,22-29]. We show rigorously that this nano-scale border between quantum and classical world is characterised by the *irreducibly high dynamic randomness* (the regime of "global", or "uniform" chaos in the universal description of multivalued interaction dynamics [1-6,10,22-32]) because the competing mode frequencies or level spacings are of the same order (like Bohr's frequency for electrons) thus satisfying the general criterion of strong chaoticity. Therefore, contrary to the popular statement, there is *no* "plenty of room at the bottom", where one could place many very small components and control their regular, unitary behaviour, according to the standard nanotechnology concept. While the conventional science approach "solves" the problem by silently replacing nanoscopic with microscopic components, where the much more regular regime of multivalued self-organisation can be realised, the possibility of truly nanoscopic, quantum-and-classical, transient, and largely chaotic systems of "generalised quantum measurement" with superior efficiency still exists and may give rise to the whole new state of "living", or "active", condensed matter. This superior efficiency obtained due to the genuine, multivalued "parallel" dynamics of interacting system elements concentrated in small volumes can find promising applications at the intersection of nanotechnology, life sciences and artificial intelligence. The "payment" for this considerable progress is also evident: one should abandon the artificially limited space of traditional, unitary mathematics and start using the extended possibilities of the unreduced mathematics (7)-(12) of real-interaction complexity.

Another important group of applications of this "complexity revolution" (transition from unitary to the dynamically multivalued description) at fundamental complexity levels, from elementary articles to macroscopic physical phenomena, is the urgently needed development of *new energy sources* combining high, practically unlimited power stock with vanishing ecological impact. They can obviously be based only on a hierarchy of strong-interaction processes and therefore involve unreduced dynamic complexity that cannot be adequately treated within the restrictions of traditional, unitary mathematics. This fundamentally substantiated conclusion is confirmed by the long-lasting absence of progress in this direction, despite a big variety and intensity of efforts applied. Both plasma and nuclear interaction processes, for example,

involve a lot of intrinsic chaoticity that would need the causally complete understanding of the unreduced complexity concept and its dynamically multivalued mathematical framework. This inference is valid for any other physical processes in truly sustainable energy sources indispensable for further progressive development of the global civilisation (see also below).

The processes of emergence and evolution of extremely large structures of the universe studied in *cosmology and astrophysics* belong to the unreduced complexity science par excellence as confirmed by the last-time growth of stagnating, "unsolvable" problems and paradoxes in the traditional, unitary cosmology framework (still considered the "best possible" model by its own estimates). The explicitly mechanistic, "exactly solvable" Big Bang schemes and unitary space structure dynamics inevitably give rise to contradictions of "dark matter", "dark energy", universe age, inflation, "fine-tuning", and entropy-growth problems, as well as many other explanatory gaps. In our analysis of the general principles and main results of the unreduced, complex-dynamic cosmology and astrophysics we show that all these diverse problems of unitary space science are indeed related to the artificial limitations of its traditional mathematical framework and can be universally resolved in the extended framework of dynamically multivalued interaction dynamics, so that all the "missing" entities and contradictions of unitary cosmology are due to the *neglected plurality of system realisations* (beyond one, grotesquely simplified unitary shape) [1-4,18-20]. It is important to note that such progress towards the causally complete cosmology and astrophysics is closely related to the equally consistent and unified origin of elementary entities and components of the universe obtained in the *same* theory, including space, time, elementary particles, their properties, interactions, and dynamics. It is evident why it could not be otherwise, in any theory, and since it is not the case for the standard theories of fundamental physics, it is clear that the related unitary cosmology picture *cannot* be even approximately correct.

In the complex-dynamic cosmology framework we show, first of all, that contrary to a major assumption of the unitary cosmology, the t*otal energy of the Universe can only be positive* and actually large, comprising just the *chaotically evolving* multiplicity of all those plural interaction realisations of all scales that are so definitely lost in the standard theory. As a result, the universe emergence, evolution, and dynamics on all scales look now not as mechanistic "expansion", "contraction", "oscillation", or "rotation" but rather as

permanent structure creation, destruction, and other nonlinear and open "dissipative processes" just contributing to the large positive energy balance and maintaining the system's general dynamic stability in accord with the universal symmetry of complexity (12), beyond any mechanistically fixed shape or motion permanence. This provides a *consistent and causally complete alternative* to the Big Bang contradictions, while other proposed or implied alternatives (that can be generalised as "steady-state" or "infinite-universe" models) often involve well-specified criticism of the Big-Bang deficiencies (e.g. [51-54]) but can hardly suggest a *suitably complete* picture replacing it as they tend to use the *same, dynamically single-valued* interaction description *excluding* any intrinsic structure emergence and thus the real time flow (which is a *practically important* problem in cosmology). They propose thus various unrealistic cases of generalised steady-state cosmology, where the standard unitary model of the conventional Big Bang is replaced by other, presumably less deficient but still unitary and therefore improbable models.

In particular, the apparent "dark matter" effect is due to the missing (truly) chaotic motion components in standard unitary models, while it just shows the effective (average) number of system realisations in the complex-dynamic cosmology, which also explains its high variability and other features [2,4,19]. The cosmological redshift effect is due to the intrinsic small dissipativity of the emergent photon structure inevitable in the causally complete picture of the world structure creation, where a nonlinear spatial dependence is quite natural and has nothing to do with any mechanistic expansion of the universe. One can also obtain various special redshift effects from particular objects like quasars because of unusually large protofield parameter changes around such objects, which would explain respective observed anomalies.[2] It is important that these and other causally complete explanations of the observed cosmological features are obtained within the *same, dynamically unified picture,* which also accounts for all the properties of the fundamental universe constituents. It includes the *unified law of universe evolution and*

[2] In a more general sense, the same is true for the *"dark energy"* effect, since the underlying large-scale spatial dependence of the photon energy dissipation can well include nonlinear components that have nothing to do with the Big-Bang expansion speed. Another related cosmological "mystery" of unitary theory, the so-called *cosmological constant problem* does not even appear in the universal science of complexity because its universal symmetry of complexity forbids any, even "virtual" appearance of *massive* particles, allowing only much smaller massless fluctuations of the electromagnetic protofield related to massive quantum beat processes and naturally adapted to their equilibrium density.

dynamics on every scale, the *universal symmetry of complexity*, containing *new structure emergence* as its natural and omnipresent process.

The latter feature of the unreduced complex-dynamic cosmology extends it to the ultimate fundamental scale of a theory of *any* structure emergence in the universe, including all higher-complexity phenomena, such as life, intelligence, and consciousness. We obtain it here as a unified, externally highly uneven but internally continuous process of naturally adaptable (e.g. "fine-tuned") structure emergence, starting from the initial simplest configuration of two homogeneously interacting protofields.

Further higher levels of this unified complex-dynamical structure emergence representing particular interest are due to *biological, living systems* and their multilevel complexity hierarchy. Unitary life science has the same problem as unitary complexity science: it cannot even provide any scientifically rigorous and universally applicable definition of the main entity in question, life and complexity respectively, using instead various inconsistent imitations and "signatures". At the same time, the power of purely empirical change of living systems has grown dramatically in recent decades due to the tremendous technological progress. Those intellectually blind but technically omnipotent changes of the unreduced complexity of life become not simply inefficient but also increasingly dangerous and unpredictable in their results.

It is not surprising that our *definition of life* is based on the unified definition of complexity by the unreduced interaction analysis (7)-(12), where life starts at a high enough level of unreduced dynamic complexity (9). Specifically, it is the next big complexity level above that of biochemical molecular interactions (since a living system must be able to control its chemical dynamics, in accord with the universal principle of complex-dynamical control specified below). All the "magic" properties of life (mainly due to their autonomous adaptability and sustainable reproduction) are rigorously explained within this complex-dynamic concept of life including the *exponentially huge dynamic power P* of unreduced interaction processes, where great combination numbers of chaotically changing parallel interactions produce astronomically big values of the exponential function argument in the estimate of such big enough system's power (like $P \propto N_{\Re} \sim N^N$, where $N \sim 10^{12} - 10^{14}$ for genome or brain interactions) [1-6,20,26-34].

A convenient visual representation of the unreduced life dynamics is provided by the *probabilistic dynamical fractal* of unreduced interaction

processes [1,2,4-6,23-33], eq. (10), which takes particularly efficient, often directly observable forms just for living organism structure and dynamics [25-27]. It shows explicitly the origin of the above exponentially huge efficiency of life dynamics, which is especially important for the cases like that of *highly interactive genetic programmes*, where one tends to have an illusion of quasi-linear interaction dynamics in the dominating unitary science approach, while in a *real genome* "everything interacts with everything else", even at the level of individual nucleotide bases. It means, in particular, that every pseudo-local genome change will influence unpredictably the *entire* genome dynamics, not necessarily immediately but often in the form of a "delay-action genetic bomb" [2,26,27]. Those extremely dangerous, technically powerful but conceptually blind manipulations of unitary genetics should be replaced by the *provably reliable complex-dynamical genomics*, with its causally complete analysis of all major interactions involved.

The same is true for other biological and medical applications, where one should obtain the causally complete picture of the system's dynamical fractal with all essential links of its interaction dynamics. Such *individually* structured multidimensional fractal "maps" of real organism dynamics will form the complex-dynamical basis of the *integral medicine* [2-6,25-27], as opposed to simplified, one-dimensional and averaged, schemes of unitary medicine reflecting the complexity-suppressing and life-killing (!) reduction of traditional mathematics.

All biological applications, including the theory of evolution, urgently need such decisive *complexity transition* today as they entered in the *acute crisis* of the *intrinsic deficiency* of the dominating unitary approach. Both the efficiency of natural evolution and inefficiency of modern medicine (with the COVID-19 pandemic being just one impressive example among so many others) ask for such qualitative extension whose major basis is provably demonstrated by the unreduced complexity mathematics (7)-(12) and its outlined biological applications [1-6,25-27].

The same revolution of unreduced dynamic complexity is equally urgently needed at further superior complexity levels, those of *intelligent and conscious behaviour*. While inefficient mega-projects of official science in respective fields of brain science, artificial intelligence and science of consciousness are not missing (equipped with increasingly powerful instruments), the very notions of intelligence and consciousness, in their causally complete,

truly consistent versions, are always *absent* in the invariably unitary framework of scholar research. Similar to other complexity imitations within the unitary science paradigm, it invents instead a long list of empirically based ad hoc "signatures" of intelligent and conscious behaviour that cannot replace the irreducible, unified essence of these phenomena and remain therefore practically useless in applications.

As mentioned above, intelligent and conscious kinds of behaviour naturally emerge in the universal science of complexity as *high enough complexity levels* of *unreduced, dynamically multivalued* (and thus *essentially chaotic*) interaction processes, where the effect of *exponentially huge dynamical power* of such large enough interaction processes explains the observed "magic" features of intelligent and conscious behaviour [1-4,6,27-32]. Specifically, the unreduced dynamic complexity level $C = C\left(N_{\Re}\right)$, eq. (9), of any *intelligent system* contains at least the same (in reality greater) realisation number $N_{\Re}$ as its entire environment (with many independent systems and interaction processes). *Conscious behaviour* starts at a superior complexity level of intelligent systems, where all those images of the elements of unreduced perceived reality can in addition be artificially and arbitrarily (independently) manipulated by the conscious system, creating thus its own artificial "world of imagination" (which is therefore much richer than the entire perceived reality).

The universal complexity science provides concrete interaction mechanisms leading to emergent intelligent and conscious behaviour thus defined and having all the observed features of these kinds of behaviour in their unreduced and naturally unified versions [28,29]. It is the *generalised quantum beat* pulsation of the interacting chemical and electromagnetic subsystems of the brain ensuring the major intelligent perception function, in combination with the *brainfunction* dynamics described by the *generalised Schrödinger equation*. This level of complex intelligent brain dynamics is the superior-complexity analogue of the *essentially quantum behaviour* at the much lower complexity level (thus starting the real-world reproduction in the brain from the extended version of its lowest complexity levels), which explains many observed similarities between them. Conscious behaviour naturally emerges from this unconscious, "quantum" intelligent behaviour similar to classical behaviour emergence in the form of elementary bound systems (as described above). Those "classical", permanently localised images of real objects can then be freely arranged in the conscious brain dynamics. The *rigorous* and

universally applicable theory of these emergent kinds of intelligent and conscious behaviour provides *efficient problem solutions and applications* for both natural and artificial systems [28-32] that *cannot* be obtained in principle within the severely reduced framework of the standard unitary approach (which explains the persisting stagnation of the latter).

Among the most important applications of this universal complex-dynamical theory of intelligence and consciousness, we can mention the unreduced versions of artificial intelligence and machine consciousness, their specific features and relation to conventional, regular and imitative, systems called "artificial intelligence" (and often even "real", or "general" artificial intelligence), various "intelligent" (complex-dynamical or imitative) information and communication systems, and universal laws of their dynamics and design [2,6,28-32]. These applications have also extremely important social implications for further civilisation development, where they become now indispensable, after the attained well-defined limit of the *complexity threshold* (which is the *real singularity* of modern world development, without any esoteric flavour of unitary thinking speculations). And while the conventional, unitary computer systems may be insufficient for the full-scale performance of artificial intelligence and machine consciousness (let alone their unreal and strongly limited "quantum" versions), the *complex-dynamical (essentially chaotic) nanosystems* on the border between quantum and classical interactions (also in the form of "active", or "living", condensed matter) described above [2-5,22-24] may be just suitable to become the basis of the necessary superior power and "magic" properties.

These advanced applications of the universal science of complexity at superior levels of unreduced dynamic complexity involve efficient manifestations of the *three universal complexity principles* [2-6,24,27-32] derived from the *universal symmetry of complexity* and useful in applications at any level of real-world dynamics. They provide rapid and efficient development estimates and design guidelines for various systems and processes even without detailed calculations.

The *complexity correspondence principle* emphasizes interesting or useful interaction mainly between systems of comparable complexity (rigorously and universally defined according to eq. (9)). In means, in particular, that a system or process of certain complexity level can be efficiently controlled, simulated, and described only in terms of a system from a *higher* complexity

level. This rigorously obtained conclusion directly expresses the qualitative difference between the unreduced intelligence/consciousness (of both natural and artificial origin) and their unitary versions, e.g. in ordinary, regular computer systems and networks. It also immediately shows the *impossibility of unitary quantum computation application* to *any* systems from higher, classical complexity levels, including any ordinary "exact calculations", even *irrespective* of any detailed interaction limitations (which are actually due to genuine quantum chaos, as mentioned above).

The *complex-dynamical control principle* proves the impossibility (and therefore inefficiency) of traditional, unitary, or exact, system control and restrictive development management (e.g. in traditional unitary "ecology") because of the always present irreducible chaoticity and unstoppable entropy-complexity growth in the multivalued dynamics of real systems (see eq. (12)). It proposes instead the *optimal entropy-complexity growth* with the maximum efficiency of complex system dynamics using, in particular, the intrinsic power of unreduced chaoticity as described above. It is the choice in favour of the properly structured "living" and "intelligent", autonomous (natural) system dynamics, including complex computer and communication systems [28-32].

The *unreduced (free) interaction principle* generalises the exponentially huge power of unreduced interaction processes in multicomponent higher-complexity systems described above, which provides superior, "magic" features to living and intelligent systems. Such features can be efficiently developed in natural systems and created in artificial structures if only we consider their unreduced, multivalued, and fractally structured (multilevel) dynamics, instead of the grotesque simplification of traditional unitary (or "linear") approach just killing the essential features of the unreduced system complexity. The reliable complex-dynamical genetics and integral medicine approaches mentioned above provide examples of essential applications of this principle.

These universal complexity principles and the underlying symmetry of complexity, eq. (12), are particularly indispensable for applications of the universal science of complexity at superior complexity levels of *social system dynamics and development* [1-8,33-37], which become *critically important* in the modern epoch of *complexity threshold*, or "globalisation", introducing the time of *catastrophically inefficient* methods and approaches of traditional, unitary governance, social structure and thinking paradigm. The key feature of the *mathematically rigorous* vision of the universal complexity science remaining

exact at *all superior complexity levels* of traditional "humanitarian", "artistic" and "spiritual" knowledge is the *unstoppable* growth of entropy-complexity at the expense of action-complexity, eq. (12), that cannot be replaced by any steady-state dynamics, however "ideal" or desirable it may look within respective socio-economic theories. This fundamental *absence of stability* is expressed in the above complex-dynamical control principle and leads to *two qualitatively different forms* of entropy-complexity growth, either in the form of global *social degradation* on the "death branch" of the unified $S(t)$ development curve or in the form of global *progressive development*, with a pronounced entropy-complexity growth towards higher complexity levels.[3] In the modern *transitional epoch*, we live within the *bifurcation period* of the critical choice between those two qualitatively different ways of entropy-complexity growth: the previous complexity level development is definitely finished, while the transition to superior complexity levels can start in the form of the new progress or else be *inevitably* replaced by the irreversible global degradation and eventual destruction of the existing civilisation complexity. These unified complexity development possibilities can be described also as the *generalised birth, life, and death* of a complex system [1,2,6,33].

We then specify the particular features of the current complexity threshold and the necessary complexity transition in social structure and dynamics, including the *new, reason-based governance* of the *intrinsically creative, Harmonical social structure* (as opposed to the current *Unitary social structure and dynamics*), *creative (complexity-increasing) production processes*, and the *new kind of settlement, infrastructure and lifestyle*, all of it based on the *new content, organisation, and role of the causally complete knowledge* of unreduced dynamic complexity [1-8,33-37]. One cannot overestimate the importance of this unified, unprecedented, and now *rigorously specified complexity revolution* in the modern critical epoch of *inevitable* change towards either the new progress or the already emerging, equally strong degradation.

[3] Note that while the unitary, dynamically single-valued analysis of traditional science *cannot* produce any real change and respective time flow in principle, it tends to relate any creative, ordering dynamics to entropy decrease as if violating the generalised second law and explained by a greater entropy increase elsewhere. The dynamically multivalued analysis of the new mathematics of unreduced complexity, eqs. (7)-(12), shows that the real entropy-complexity always grows in *any* interaction processes, including structure creation in the totally closed system, due to the *omnipresent chaoticity* of real interaction results. In the case of development science, it means that the creative branch of progressive development corresponds to a *much greater and quicker growth* of entropy-complexity (in the form of *dynamically multivalued self-organisation* or *self-organised criticality*) than that of global degradation of the social death branch of the unified development curve [33,34].

Thus rigorously substantiated complexity revolution includes *natural knowledge unification* including all fields of traditional *non-scientific (non-exact), spiritual, artistic and esoteric knowledge*, now properly *extended* and appearing as quite *causal manifestations of superior complexity levels*, sometimes beyond direct empirical perception tools of modern science and technology [1-8,11,38]. In particular, we provide the rigorously specified definitions and dynamics of all "fuzzy", aesthetic and ethical, notions from the conventional humanities, such as *beauty* (the relatively high level of unreduced dynamic complexity), *good* (optimal, progressive growth of entropy-complexity) and *evil* (absence of good, degradation instead of progress), or *beatitude* (superior complexity level of the Harmonical system with the unstoppable progress, or permanent omnipresent good). We demonstrate thus the unlimited range of application (i.e. *real universality*) of the unreduced complexity concept, without any loss of its *mathematical rigour and causality* that further includes the *edge research* of the currently not directly perceivable complexity levels [2-4] usually considered as spiritual and other esoteric knowledge.

We must finally emphasize once again the necessity of the complexity revolution in *science organisation and development* itself, unifying the extended, causally complete knowledge of the universal science of complexity with the qualitatively new, intrinsically creative and problem-solving organisation of scientific activity used as a basis for the reason-based and provably progressive world governance at all levels [1-8,11,33-37]. Contrary to the dominating Unitary (centralised, administrative and corrupt) system of science organisation reproducing its severely limited, dynamically single-valued content and creating now *only obstacles* to further knowledge progress, the qualitatively extended organisation of the intrinsically creative science should be based on the unreduced interaction complexity taking the form of the *multilevel system of freely interacting, independent, problem-solving and competing enterprises of all scales* realising the living *market of ideas* and underlying the *creative governance* of the Harmonical, reason-based and unstoppable civilisation development. The huge difference between the current deeply corrupt and quickly degrading Unitary social system reflecting the end of *unitary* science development [1-8,11,41,55-64] and the *unlimited* progress of the Harmonical system guided by the causally complete knowledge of the universal dynamic complexity is what we are losing within the traditional mathematics and knowledge paradigm or can gain by the complexity transition towards the unreduced paradigm and mathematics of real-world complexity.

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