The Universe as a Social Process: a New Dynamical Conception of Physical Objects and their Interactions

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The present article proposes a new dynamical conception of physical objects in general, of their aggregative behavior as manifested on all scales of observation, and of the Universe as a "social" process in which the participating individual objects – including the so-called elementary particles – are all born and constituted as stable (or quasi-stable) *regimes of interaction*. We believe this new viewpoint, which differs significantly both from that of classical physics and from quantum theory as presently understood, might lead to a more coherent understanding of many natural phenomena which until now have been studied only in a piecemeal fashion and from divergent points of view in physics, chemistry, astronomy and biology. We consider it a strength of our approach that it arose not from abstract speculation, but from the discovery of concrete physical phenomena.

The ideas presented here go back to the discovery, four decades ago, of a previously-unknown type of self-organizing interaction among nonlinearly-coupled oscillating systems -- so-called argumental interactions -- and of the existence of discrete, "quantized" sets of stable regimes of oscillation in argumentally-coupled oscillators, having no equivalent in the classical mechanical theory of oscillations. Argumental interactions were the subject of extensive experimental, numerical and theoretical investigations during the 1970s and 1980s, reported mainly in Soviet physics journals. Among other things, research revealed striking similarities between the behavior of argumentally-coupled macroscopic oscillators, and the quantum behavior of atoms and other microphysical objects. [1] The standard experimental demonstration of the "Macroscopic Quantization Effect (MQE)" – a pendulum interacting with a spatially-inhomogeneous high-frequency magnetic field, and displaying a discrete set of stable amplitudes –, is so simple, that it ought to be in every physics classroom [2].

In recent years the present authors have been jointly pursuing new lines of investigation into argumental interactions and their possible significance for the foundations of physics. Among other things, the authors came to understand that *a stable mode or regime of interaction* among any given dynamic processes – insofar as it embodies some principle of self-regulation and maintenance (on average) of certain invariant parameters and characteristics – deserves to be regarded as *a true physical object* in its own right. Might it not be the case that *all* physical objects actually arise in this way? Furthermore, to the extent the dynamic process-regime underlying any given physical object involves the entire Universe directly or indirectly, the existence of *interactions* between physical objects becomes intelligible, at least in principle, as opposed to merely being postulated as is done in Newtonian physics. Pursuing these considerations, the authors were led to a new dynamic vision (or "topology") of the Universe which we shall sketch, in preliminary form, in the final section of this article.

It is useful to point out parallels between the authors' conceptual approach and the Nonlinear

Quantum Physics developed by José Croca and his group at the University of Lisbon [3,4]. Working independently and from a very different direction, Croca et al. have elaborated a dynamic conception of elementary particles as complex, nonlinearly interacting oscillatory processes involving localized as well as spatially extended components. The prospect of a paradigm shift toward a nonlinear causal quantum theory has found unexpected support from the beautiful fluid dynamic experiments of Couder et al. [5], in which typical quantum-physical phenomena such as the quantization of atomic orbits and quantum interference, are mimicked by the behavior of liquid silicon droplets on a vibrating table. A strong point of Croca's work is that it provides a precise theory and mathematical apparatus (including a nonlinear master equation) able to account qualitatively and quantitively for basic phenomena of quantum physics in a *causal* fashion, while at the same time yielding predictions for possible future experiments which would differ from those of standard theory and thereby provide a crucial test.

By contrast, the ideas and principles put forward in the present article are intended to be *independent* of any specific detailed physical theory or hypothesis, and are much broader in scope than quantum physics per se. Our considerations apply equally to physical objects on *all* scales of observation, providing a conceptual framework relevant to virtually every domain of science. Needless to say, these general ideas, however useful as a guide to future research, can in no way replace the hard work of developing precise theories for various classes of natural phenomena.

In order to make the authors' train of thought intelligible to the reader not familiar with the field of argumental interactions, we preface the presentation of our ideas with a short introduction to argumentally-coupled oscillators and the associated "Macroscopic Quantization Effect" (MQE).

1. The phenomenology of argumentally-coupled oscillators

Argumental interactions and the MQE were originally discovered in 1968 by Danil and Yakov Doubochinski, then students at Moscow University. The classical concrete example is the so-called argumental pendulum (Fig. 1): A low-friction pendulum with a natural frequency of 0,5 – 1 Hz and a small permanent magnet affixed to its end, interacts with the magnetic field produced by a narrow solenoid located under the pendulum's equilibrium position and fed by an alternating current of some higher fixed frequency (typically between 30 and 1000 Hz).

Setting the pendulum into motion, the following behavior is easy to observe.

1. When released from any given position, the pendulum's motion evolves into a stable, very nearly periodic oscillation, whose *amplitude* belongs to a *discrete set of possible values* (Fig. 2). In this sense the energy of the system has become *quantized*.

2. In each of the stable modes, the pendulum's frictional losses over a given period of oscillation are compensated in a self-regulated fashion by a transfer of energy from the field of the solenoid, thereby sustaining the pendulum's oscillation in a *quasi-stationary regime near to its own natural frequency*.

3. The pendulum's motion in a given regime is never strictly periodic, but constantly *fluctuates* in phase, frequency and amplitude around certain stable average values. This fluctuational "play" is essential to the mechanism of stability of the quantized oscillatory regimes.

In an impressive variant of the pendulum experiment, a whole array of pendula of different lengths and periods of oscillation is maintained, each near its own natural frequency and each having its own discrete set of stable amplitudes, by interaction with the field of a single elongated solenoid fed with high-frequency alternating current (Fig. 3).

Analogous phenomena of "quantized" regimes of interaction were demonstrated in a wide variety of other electromechanical systems, as well as in fluid-dynamical processes.

Coming back to the single-pendulum experiment just described, it is essential to note that strong *spatial inhomogeneity* of the magnetic field of the solenoid constitutes a necessary condition for the emergence of the MQE. The apparatus is designed in such a way, that the oscillating magnetic field exerts a significant influence on the pendulum only within a *narrow "interaction zone"* around the solenoid (Figure 4), outside of which the field strength drops rapidly to zero. This spatial inhomogeneity permits the pendulum to *self-regulate* its exchange of energy with the alternating field via small shifts (fluctuations) in its *phase* relative to that of the field. It is this crucial role played by *phase* and *phase fluctuations* in the emergence and maintenance of stable regimes of oscillation, which suggested use of the term "*argumental*" (i.e. angle- or phase-dependent) for the Doubochinski pendulum and for the type of phase-regulated interactions which occur between the pendulum and the alternating magnetic field in this device. The argumental mechanism was also shown to be the basis of a second remarkable phenomenon, discovered around the same time: When placed in a high-frequency EM field, electromagnetic resonators (such as LCR circuits), coupled to each other by inductive, capacitative and resistive couplings and free to move in space under the influence of the corresponding ponderomotive forces, show the tendency to group themselves into *stable spatial configurations*.

It became clear that phenomena, similar to those demonstrated by the argumental pendulum and the coupled resonators just described, must be *extremely widespread in Nature*. At the same time it was demonstrated that argumental interactions can provide an efficient mechanism for the self-organizing coupling and transfer of energy between oscillating systems whose frequencies can differ by several orders of magnitude. These results, while curiously little-known in the scientific community today, have led to some significant technological developments of current interest [6].

Extensive work on argumental interactions, carried out by Doubochinski and his collaborators in the Soviet Union, produced a detailed mathematical theory which accounts well for the essential features of the MQE and allows the values of the stable "quantized" amplitudes of argumentally-coupled systems to be calculated in various conditions. For the details of this theory, we refer the reader to the publications [7-9], which contain further references.

Among other things, the theory of argumental interactions makes it possible to investigate hypothetical cases and situations which are difficult to realize experimentally, but of great theoretical interest. A particularly important example is the argumental analog of the "elementary oscillator" which Max Planck employed in his original investigation of the spectrum of blackbody radiation [10]: A mass carrying an electric charge, fixed at the end of a spring and free to oscillate in the x-direction, interacts with an electromagnetic wave-field propagating along the same axis (Fig. 5). Investigations by mathematical and computational methods showed that when the wave frequency is large compared to the proper frequency of the oscillator, the interaction of the oscillating charge with the longitudinal force exerted by the wave field, automatically gives rise to a discrete array of stable amplitudes of the oscillator – independently of any quantum mechanical postulates.

These results suggested a possible *natural physical mechanism* for the emergence of discrete energy states in the interaction between an oscillator and an electromagnetic wave. *Could it be that interactions of the argumental type lie at the origin of the peculiar properties of microphysical objects, which we associate with Planck's quantum of action?* We shall not attempt to answer this question now, but permit ourselves the following remark.

The discovery of the Macroscopic Quantization Effect in argumentally-interacting oscillators suggests that the mechanism of quantization in the micro-world should be sought more in the *processes of interaction* of physical objects, than in the objects per se. Such an approach would be closer to the original standpoint of Max Planck, than the later (1905) suggestion by Einstein, according to which electromagnetic radiation should be regarded as already quantized, independently of its interaction with material systems [11]. However, at the time Max Planck carried out his fundamental investigations on the spectrum of blackbody radiation, his basic model for the interaction of matter with the electromagnetic field was an array of Hertzian oscillators exchanging energy with the field according to Maxwellian electrodynamics. The possible role of *spatial motion* of the oscillators was not explicitly considered. Indeed, the MQE and related phenomena arising from the interplay between mechanical and electromagnetic oscillations of differing frequencies, were not known at the time of Planck and Einstein. Perhaps the time is now ripe to reconsider these matters.

2. The participatory-generative character of argumental coupling

The argumental mechanism just described, gives rise to two extraordinary properties of argumental interactions, to which the authors attach *fundamental* significance. These properties – which are absent from the conventional forms of coupling of oscillating systems – are essential to the general conceptions we shall develop in the following section of this paper:

In each of the stable regimes of an argumentally-coupled system,

(1) the coupled system constitutes an ***individual dynamical object*** *with distinct characteristics of its own, generally very different from those of the component systems taken in isolation;*

(2) the participating oscillators retain (in the mean) very nearly their original frequencies and other oscillatory characteristics as in the uncoupled state. One could say that in the classical forms of coupling the component systems are ***enslaved*** *to the collective regime, while in argumental coupling they freely* ***participate*** *in it, conserving (in the mean) their own individual parameters and peculiarities. By virtue of its fluctuational "play", a single oscillator may* ***simultaneously*** *participate in many argumentally-couplings and stable regimes, each constituting a distinct dynamical object.*

The first property we shall call "generative", the second "participatory". In this section shall examine both properties more closely, and show how the combined *participatory-generative* character of argumental interactions leads to a possible mechanism for generating *an entire hierarchy of distinct physical objects*, starting from a given set of oscillators.

For the purposes of illustration, we examine the argumental pendulum as a system created by coupling two oscillating systems: (A) the pendulum, oscillating at or near its proper frequency under gravity and (B) the solenoid together with its high-frequency current source. In Section 1 we pointed out the qualitative difference between the pendulum's behavior for small amplitudes -- when it remains inside the interaction zone --, and its behavior at larger amplitudes, at which the argumental mechanism comes into play. This difference in behavior reflects a *fundamental difference in the type of physical coupling* between the two oscillating systems from which the total system is composed.

In the small-amplitude case we have a classical situation of “forced oscillations under a periodic external force" in which the two systems are very far from resonance. Due to the large difference between the frequency of the alternating current and the proper frequency of the pendulum, very little energy is transferred from the field into low-frequency oscillations of the pendulum. Instead, the pendulum’s natural oscillations are damped out and it becomes a “slave” of the electromagnetic field, executing forced oscillations at the frequency of the field. The original oscillatory regime (A) of the pendulum has ceased to exist, and we are left with a single, rigidly-coupled compound system (C). We could express the result of this classical form of coupling symbolically as follows:

A + B = C.

By contrast, in each of the stable regimes of the argumental pendulum the pendulum arm executes very nearly its natural periodic motion, while undergoing fluctuations in phase, frequency and amplitude as a result of its interaction with the field of the electromagnet. The argumental mechanism makes it possible for the low-frequency pendulum to exchange energy efficiently with the high-frequency field. The system of the electromagnet and its current source retains its basic frequency and amplitude characteristics, while at the same time experiencing periodic current fluctuations due to currents induced in the solenoid by the motion of the pendulum's permanent magnet. The oscillatory regimes A and B thus continue to exist in the compound system. We can thus express the result of the coupling symbolically as

$A + B = \{ A, B, (AB)_n \}$

where $(AB)_n$ represents one of the discrete series of stable regimes of the coupled system.

We think the participation of the oscillatory systems A and B in the stable regime of the coupled system AB, is much more typical of the way real objects exist together in Nature, than the rigid forms of coupling characteristic of both classical and quantum physics. *Nature works in a* ***participatory*** *manner*. The very fact that the Universe is heavily populated by individual physical objects of all kinds, attests to principles of organization whereby such objects retain their individuality and integrity while at the same time interacting with each other to create larger objects, in which they then participate. We shall return to this observation in the following section.

We now turn to the ***generative*** potential of argumental interactions. Here the essential point is to recognize that each of the stable oscillation regimes of a system, arising from the argumentally coupling of oscillating systems, deserves to be regarded as a *distinct physical individual* in its own right.

Consider, for example, an argumental pendulum oscillating in one of its stable quasi-stationary regimes. Such a regime is characterized not only by a definite mean amplitude and period, but also by a *cycle* of *exchange* and *transformation of energy* between the pendulum arm and the alternating magnetic field. In each half-period of the pendulum a certain definite portion of energy, corresponding on average to the frictional losses of the pendulum, is transferred from the magnetic field to the pendulum’s motion. That portion (“quantum”) of energy has been converted, in effect, from the frequency of the field to the much lower frequency of the pendulum, via the mechanism of phase-frequency-amplitude modulation described in Section 1 above. This cycle of transformation of energy is maintained over many periods (or indefinitely) and possesses an *active, self-regulating character*. One can observe, in fact, that the regime *actively* defends its stability and *actively* adapts and reacts to external influences, utilizing for this purpose a certain portion of its own energy flows (its "metabolic energy").

Clearly, a *functional regime* of this sort signifies something different from a *material object* in the everyday sense of the word. We consider, however, that a “something” which has definite physical parameters, that exists on the basis of a self-regulated flow of energy, that actively maintains itself, adapts and reacts to external conditions, deserves to be regarded as a *real physical object.* Naturally this reasoning applies not only to the argumental pendulum, but to the stable regimes of argumentally-coupled oscillators in general.

From this standpoint argumental coupling shows itself to be a powerful instrument for the generation of individual physical objects. Suppose we have a set of oscillating systems A, B, C, D, E, ... which are capable of entering into argumental interactions with each other. The argumental coupling of any pair of them produces an array of stable regimes, each of which constitutes an individual physical object. Thus, from A and B we can obtain objects $(AB)_1$, $(AB)_2$,...,$(AB)_n$,... etc., from C and D the objects $(CD)_1$, $(CD)_2$,...,$(CD)_m$, ... and so forth. Each of those objects, as a stable oscillatory regime with specific frequency, amplitude and phase characteristics, represents an oscillating system which is in principle capable of entering into argumental couplings with other oscillating systems. For example, the argumental coupling of $(AB)_n$ with $(CD)_m$ generates an array of individual physical objects $[(AB)_n(CD)_m]_1$, $[(AB)_n(CD)_m]_2$, ... $[(AB)_n(CD)_m]_k$ ... This process can in principle be applied again and again, leading potentially to gigantic numbers of individual physical objects, related to each other in a hierarchical manner. The new objects obtained at each stage form the basis for generating the next level of objects. Due to the participatory nature of argumental coupling, each newly-formed object maintains its individual existence and characteristic parameters, while participating in the formation and life of objects on higher levels of the hierarchy.

Naturally, the realization of such hierarchies of oscillatory regimes in concrete physical systems, can be limited by a variety of factors and conditions. Of particular interest are the conditions of stability of the functional regimes at different levels of the hierarchy, and the effects of “quantum jumps” in the regimes of participating systems.

Without entering into details of a concrete physical system, consider for example the effect of argumentally coupling two stable regimes, say $(AB)_3$ and $(CD)_5$, to obtain new objects of the type $[(AB)_3(CD)_5]_k$. The existence of any stable regime of the coupled system $(AB)_3(CD)_5$ clearly presupposes that the corresponding phase-frequency-amplitude fluctuations of the combined system must remain within the zones of stability of each of the participating systems $(AB)_3$ and $(CD)_5$. In case internal or externally-imposed fluctuations cause a system to "jump" to a different stable regime (for example $(AB)_3 \rightarrow (AB)_1$), this can trigger a chain of abrupt transitions in functional regimes of all the systems in which $(AB)_3$ participated, propagating upward in the hierarchy. Cascades of an analogous sort play an essential role in the mechanism of control of many natural processes, including especially in living organisms.

These brief remarks are intended only to give a preliminary glimpse of a vast domain of new oscillatory phenomena, which is opened up by the "participatory-generative" properties of argumental interactions. This domain has only barely begun to be explored experimentally, with the observation of "higher-order" regimes involving two or more pendula maintained in stable regimes by argumental interaction with a single electromagnet. Here is a rich field for future research.

3. Physical objects and their interactions

Having reviewed results from the experimental and theoretical investigations of argumentally-coupled systems, we are now in a position to present some of our ideas concerning the foundations of physics.

To avoid misunderstanding, we must stress that in this context the phenomena of argumental interactions provide nothing more than a useful, even indispensible *model* and *inspiration* for a new vision of the Universe. We do not claim that the argumental mechanism per se is the basis of existence of all physical objects, or anything like that. Determining the precise role and scope of argumental interactions in the physical world is an interesting and important task, but requires extensive investigations which have not yet been carried out. Thus, we shall not propose any grand formal theory, but rather *a new way of looking at physical objects and their interactions*, as suggested by the example of argumental interactions, and differing in important respects both from the viewpoint of classical physics and from that of modern quantum theory.

The study of Nature presents us with a seemingly inexhaustible number and variety of *individual physical objects*: galaxies, stars, planets, living organisms, molecules, nuclei, elementary particles etc., existing on widely-differing scales of space and time, and manifesting a character of wholeness and invariant features that lead us to regard them as distinct individuals. We observe a marked tendency on all scales, for physical individuals to interact with each other, to associate together in more or less stable groupings and to participate in the formation of larger objects having their own individual characteristics.

Science has not yet developed a unified approach to the origin, stability, interaction and "social behavior" of the many species of physical objects populating our Universe. Instead, one encounters widely divergent ideas and explanations, depending on the scientific discipline and the type of object involved.

One might argue that the reason for the great differences in conceptual approaches lies in the nature of the objects themselves, and the fact that they pertain to *different levels of organization* of physical reality. The authors, however, find it difficult to believe that the Universe would operate in a fundamentally different way on one level of organization, than on another. It seems far more likely that *the underlying principles of generation, maintenance and "social" interaction of physical objects in the Universe are everywhere very much the same;* and that the common principles have remained hidden owing to the lack of development of a suitable unified conceptual framework, and to certain habits of thinking passed down from classical (Newtonian) physics.

The discovery of argumental interactions and their generative-participative properties suggested to the authors a possible pathway towards the solution of this problem.

The first step is to adopt a general dynamical notion of what should be meant by the term "individual physical object" -- a notion along the lines we suggested in our discussion of the stable regimes of argumentally-coupled oscillators in the preceding section, and applicable to all levels of organization of the Universe. The decisive criterion is that an individual physical object must be conceived always as something inseparable from a specific “regime of functioning”, i.e. from a specific, active physical process by which the object maintains itself in a stable manner, interacting with and reacting to changes in its environment while retaining its essential characteristics. To put it more directly: *the real individual objects are for us the functional regimes themselves.* To the extent a system such as a star -- or a living cell -- can exist in various different stable or quasi-stable regimes, each of those regimes constitutes for us a *distinct object, a distinct physical individual*. By their very nature, functional regimes invariably involve cycles of flow and transformation of energy, and are thus oscillatory in nature.

The stable modes of the argumental pendulum provide the most transparent examples and models of distinct physical individuals in our sense. Here the details of the functional regimes and the mechanism by which they are "born", are most easily accessible to study.

In the case of the objects of Nature, we often have only limited knowledge of the functional regimes and their interrelations, and cannot always precisely distinguish different regimes clearly from one another. Nevertheless, it is a matter of very general observation that natural systems are found in distinct stable or quasi-stable dynamic states; that these states -- as individual physical objects in our sense -- can be recognized and classified in discrete categories according to their characteristic features; and that the transitions between such states, where they are possible, tend to be more or less abrupt and jump-like. In each case in which we are able to discern the internal structure of a physical object, we find that it is constituted from the interaction and coupling of other physical objects, which participate in it while maintaining their own individuality. Conversely, individual physical objects of every known species, up to at least the level of galaxies, are found to participate in some sort of larger objects (e.g. galactic clusters, superclusters). The transition of a physical system from one stable regime to another, can trigger a cascade of changes in the entire hierarchy of physical objects in which the given stable regime participates.

In all these respects we find a broad resemblance between the organization of physical objects in the Universe, and the hierarchies of stable oscillatory regimes generated by argumental couplings. This analogy becomes still closer when we adopt a criterion for what should be meant by the term *physical interaction*, which is consistent with the dynamic concept of "individual physical object" adopted above. A *true physical interaction* must be conceived of as a real dialog between individual physical objects: a process involving constant exchanges of energy, in which each object accommodates its functional regime to that of the other, without either of them losing its essential identity. When such a process of interaction evolves into a self-regulating, quasi-stationary regime, we speak of a coupling of the objects and of the birth of a *new physical object* as a result of that coupling.

Considering these matters from a fundamental point of view, we can hardly doubt that the emergence of individual physical objects, on the one hand, and of interactions among physical objects, on the other, represent two *complementary* aspects of a single physical reality. *The very same functional regime, by which a physical object maintains its individuality and identity, is at the same time the basis for its interactions with other objects.* The functional regime of any physical object involves the entire Universe directly or indirectly. Hence the functional regimes of all objects are constantly reacting to and accommodating to each other. This, we propose, is the ultimate source of the effects classical and quantum physics attribute to "fundamental forces" acting between the particles of matter.

The authors are perfectly aware that their proposed way of looking at physical objects and physical interactions may appear rather paradoxical, at first sight, and raises many questions. In closing we shall address only one of the most important of these, permitting ourselves at the same time to add some historical and methodological comments which may help clarify what has been said above.

Among the most important questions, is whether current empirical knowledge concerning atoms, electrons and other microphysical entities, justifies their being considered "individual physical objects" in our proposed dynamic sense. This question is immediately connected with the problem of the ultimate origin of gravitation and the other "fundamental forces of physics." The difficulty here is perhaps less one of empirical evidence, than it is habits of thinking going back to classical (Newtonian) physics, which regards "the elementary constituents of matter" as entities existing somehow in and of themselves, without requiring any activity or regulatory functions for their maintenance and stability.

This essentially static notion of the constituents of matter goes hand in hand with another drawback of classical physics: the lack of any intelligible explanation for the existence of *interactions* between physical objects. Indeed, without acknowledging any *activity* intrinsic to the existence and maintenance of physical objects, it is hardly possible to understand how physical objects could exert forces on each other. Classical physics avoids this problem by simply *postulating* the existence of "fundamental forces" such as gravitation, having no intelligible basis in the nature of the objects upon which they act. Although Newton himself expressed his dissatisfaction with this practice, it has had a deep influence on the habits of thinking of physicists up to the present day.

On the other hand if – as Newton's contemporary Leibniz had argued -- the essence of any physical object lies in a constant *activity*, extending implicitly to the entire Universe, then the existence of interactions between objects is no longer mysterious. *Forces* would then be a secondary effect of the *dialog* between the functional regimes of the physical objects, in the way we have suggested. But in order to realize this idea in the form of a truly dynamic theory of physical interactions, it would be necessary to know much more about the functional regimes of physical objects, including especially the microphysical particles that constitute material bodies. What does present-day science have to say, for example, concerning the functional regime of an electron? At first glance nothing at all. But the answer depends on how one interprets the evidence of quantum physics.

At the outset of the development of quantum physics Louis de Broglie recognized that the existence of an electron must somehow be inseparably connected with a *high-frequency oscillatory process, extended in space*. This and subsequent successes of Schrödinger's wave mechanics, should have been seen as a vindication of Leibniz's dynamical standpoint and a first step toward clarifying the functional regimes underlying microphysical objects Unfortunately, the early attempts by Schrödinger to develop an electromagnetic interpretation of the wave function were abandoned, as was also the interesting attempt by Nernst to understand quantum phenomena (and gravitation!) as a product of interactions with an oscillating medium [12]. The elaboration of quantum mechanics took a completely different direction. Lacking an intelligible notion of how quantization occurs *both* in microphysical systems and in macrophysical systems such as the solar system, the introduction of the quantum of action as a postulate of quantum mechanics led to a schism in the physical picture of the world. The prospect for understanding electrons, protons and other microphysical entities as essentially *dynamic* objects -- and thereby also of grasping the origin of the fundamental interactions between them -- receded into the future. In this context the work of José Croca and his group is of very great interest.

4. A New “Topology” of the Universe

In conclusion of this article we would like to summarize once more, in a few concise points, the overall conception or vision of the Universe which has been taking shape in the authors’ discussions. While not pretending to provide concrete answers to specific problems, we think it may nevertheless prove to be a fruitful starting-point for scientific investigations, and for a more coherent understanding of physical objects and their interactions, independent of the scale and level of organization in the natural world.

1. The Universe can be understood as a self-developing *social process* involving a very large (possibly infinite) number of interacting *individual systems* (*physical objects*) of different species and sub-species. Each individual object in the Universe is constituted by a *regime of mutual interaction* among some group or population of other objects. These objects *actively participate* in the life of the given individual and in the process of fluctuational "*play*", by which the individual maintains its stable existence and takes part in the social life of the Universe as a whole. The meanings we give to the terms "social process", “regime”, “physical object”, mutual interaction", "participation" and "play" will be clarified in the following paragraphs.

2. The relationship of participation of one object in another defines a natural *hierarchical ordering* among objects in the Universe. In respect to its "internal" life, each physical object constitutes a social system -- a *socium* -- of objects of a lower order; while in its "external" life it participates as an *individual* in objects (sociums) of a higher order.

3. Since each physical object is constituted by a regime of mutual interaction, and each of the interacting sub-objects in turn by their own regimes of interaction, and so on, we see that the existence of any physical object is based upon an entire chain of interactions and of objects, participating at different levels of its internal life. At the same time, no single physical object could exist in and of itself, in isolation, but depends for its maintenance and stability upon an entire ensemble of interactions and connections with "outside" objects -- in other words, on its participation in a larger “*social process”*. The most familiar case in physics for such a social process is a *wave.* To the extent such a process maintains certain invariant features over a certain space-time interval, and thereby manifests a distinct regime or mode of interaction, it constitutes a *distinct “higher-order” physical object* in relation to the participating objects.

4. A given object may interact with many objects simultaneously, may interact with objects at all levels of the hierarchy, and may participate in an arbitrary number of higher-level objects (sociums) at the same time. On the basis of its ability to participate simultaneously in multiple objects and interactions, each physical object can function as a *connection* between different objects and processes, as well as a *transformer of energy*. These social functions are essential to the nature of all real physical objects.

5. Changes in the interactions among physical objects -- including the emergence of new regimes of interaction -- constantly give rise to the *birth* (emergence, generation) of new objects, and to the *metamorphosis* (transformation, development) and eventually *death* (dissolution, disintegration) of existing ones. The processes of generation, transformation

and disintegration embrace each and every physical object in the Universe. Alterations in interactions also affect the relations of participation among objects in the Universe. Consequently, the hierarchical ordering is itself in constant flux.

6. There are no truly static objects in the Universe, no existence apart from activity and interaction. Although this has been acknowledged by many philosophers and physicists over the centuries, the task of elaborating a *strictly dynamic* conception of physical objects as participants in the social life of the Universe, involves a number of difficulties.

7. The term, *dynamic* signifies, first of all, that the essential nature of each physical object lies in some *ongoing process of transformation* -- a process of transformation of matter and energy, as we would say in the language of modern physics. The simplest example of a dynamic object (in this sense) is a periodic or oscillatory process, associated with a definite cycle of transformation of energy, and having a definite (more or less constant) *frequency*.

8. In order to be considered as a definite "thing", a physical process must possess some identifiable features, which remain unchanged (at least on the average) over some period of time. When a process maintains certain invariant characteristics and parameters over a certain interval of time, we speak of a "state" or "regime" of the process, existing over that period. This includes the case in which a process, while maintaining certain invariant features, at the same time goes through a series of transformations or phases, each of which constitutes a specific "sub-regime" of the given "macro-regime".

9. *To a first approximation, what we mean by a "physical object" is nothing but a state or regime of a dynamic process.* On closer consideration, we recognize that a state or regime of a process -- to the extent it can claim to be a real physical entity -- presupposes some *principle of organization* which *actively* maintains the given regime, its stability and characteristic parameters, constantly "balancing" the effects of changes in internal and external conditions.

10. The essence and individual identity of any physical object, lies exactly in this *organizational-regulative principle*, which -- in order to exist in reality, and not merely as an abstraction -- must be conceived of as a physical process in its own right, a "something" that is *constantly acting*.

11. These considerations have fundamental consequences. Firstly, we recognize an *inseparable* connection between the existence of invariant features characterizing a given physical object (regime), on the one side, and the constant *fluctuational activity* observed in every real physical object, on the other. These fluctuations are by no means merely perturbations or deviations from a hypothetical ideal state of complete invariance, as often assumed; on the contrary, they constitute the *life* of an object, embodying its organizational-regulatory principle in the form of an ongoing dynamic process. An object without fluctuations would not only be "dead", but could not exist at all.

12. Secondly, the natural fluctuational activity (“play”) of physical objects provides the basis for *mutual interactions* (or couplings) between objects, in which the participating objects retain their own identities, and for the *emergence of new physical objects as a result of such interactions.*

13. A *mutual interaction* (in our sense) is a *regime of continual modification of the dynamic activity of a group or population of physical objects, in which the activity of each object accommodates in a certain way to the activity of the others, while at the same time each object maintains its own integrity and characteristic individual features.* The latter condition implies that the modification in question necessarily occurs on the level of the *fluctuations* of the interacting objects, as a *modulation* imposed upon their activity.

14. The example of so-called argumental interaction of oscillating systems, which is based on a mechanism of amplitude-phase-frequency modulation of the participating oscillators, provides the best available example for how a mutual interaction of physical objects (in our sense of the term) actually occurs.

15. It is important to emphasize, that the requirements for a "mutual interaction" in our sense are much stronger than for the commonplace (Newtonian) notion of interaction. The latter merely signifies that objects exert some sort of influence on each other. In contrast, a mutual interaction in our sense can only exist where there is specific *regime* of modification and accommodation of the participating physical systems, having its own invariant features and organizational-regulatory principle. The establishment (birth) of a mutual interaction is invariably a complex process, involving a series of *developmental stages*.

16. We believe that *all effects, commonly ascribed to "forces" between material systems, ultimately derive from regimes of mutual interaction among physical objects, participating in those systems.* The fact, that such forces obey certain empirical-mathematical *"laws"* -- such as Newton's law of gravitation, for example -- is a reflection of the *invariant features* of the regimes of mutual interaction, which constitute the underlying dynamical basis for the effects commonly ascribed to "forces". For us, the notion of a regime of a dynamical process and of a physical object, are the *primary* realities in the Universe; "forces" are derived effects.

17. Once established, a mutual interaction in our sense necessarily constitutes a *dynamic object* in its own right: a distinct physical object with its own organizational-regulatory principle, its own invariant features and fluctuational characteristics, existing alongside and in addition to the interacting objects themselves. Since (in our view) *all physical objects are constituted by the mutual interaction of other physical objects*, the emergence of a mutual interaction represents the *general case* for the "birth" of physical objects in our Universe.

Bibliography

1. D.B. Doubochinski, J. Tennenbaum, *The Macroscopic Quantum Effect in Nonlinear Oscillating Systems: a Possible Bridge between Classical and Quantum Physics*. Paper delivered to Moscow seminar on "Atomic Structure, New ideas and Perspectives", January 2007. [http://arxiv.org/pdf/0711.4892]

2. J. Tennenbaum, *Amplitude Quantization as an Elementary Property of Macroscopic Vibrating Systems,* 21st CENTURY SCIENCE & TECHNOLOGY - USA Winter 2005 – 2006.

3. J.R. Croca, *Towards a Nonlinear Quantum Physics*, World Scientific 2003.

4. J.R. Croca and J.E.F. Aaújo (ed.) *A New Vision of Physis*, Center for the Philosophy of Science of the University of Lisbon (CFCUL), 2010.

5. A. Eddi, E. Sultan, J. Moukhtar, E. Fort, M. Rossi, and Y. Couder, *Path-memory induced quantization of classical orbits*, *PNAS* 107, 17515-17520, (2010). See also E. Fort, A. Eddi, A. Boudaoud, J. Moukhtar, and Y. Couder, *J. Fluid Mech .674, 433-464*, (2011).

6. For technological applications of argumental interactions and the MQE, as well as other relevant material, see the website: www.doubochinski.com

7. D.B. Doubochinski, Ya.B. Duboshinski, A.S. Magarchak, V.Chabanski, *Discrete modes of a system subject to an inhomogeneous high-frequency force,* Zh. Tech. Fiz. 49, 1160 (1979) [Sov. Phys.-Tech. Phys. 24, 642 (1979)].

8. D.B. Doubochinski, Ya.B. Duboshinski, *Wave excitation of an oscillator having a discrete series of stable amplitudes*, Dokl. Akad. Nauk SSSR, 265, N°3, 605 (1982) [Sov. Phys. Doklady 27, 564 (1982)].

9. D.B. Doubochinski, Ya.B. Duboshinski, *Amorcage argumentaire d'oscillations entretenues avec une série discrète d'amplitudes stables* -- *Argumental Excitation of Continuous Oscillations with Discrete Set of Stable Amplitudes,* E.D.F.-Bulletin de la Direction des Etudes et Recherches, Serie C, N°1, (1991).

10. M. Planck, *Über das Gesetz der Energieverteilung im Normalspectrum,* Annalen der Physik vol. 4, p. 553 ff (1901). [English translation http://dbhs.wvusd.k12.ca.us/webdocs/ Chem-History/Planck-1901/Planck-1901.html]

11. A. Einstein, *Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt,* Annalen der Physik 17, 132 (1905). [English translation http://www.esfm2005.ipn.mx/ESFM_Images/paper1.pdf]

12. W. Nernst, *Über einen Versuch von quantentheoretischen Betrachtungen zur Annahme stetiger Energieänderungen zurückzukehren*, Verhandlungen der Deutschen Physikalischen Gesellschaft 4, 83, (1916).

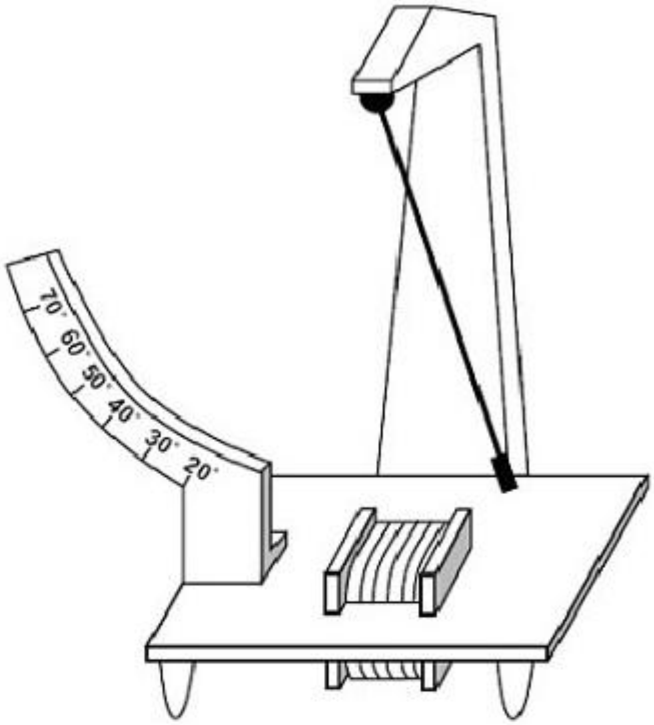


Figure 1 – The argumental pendulum.

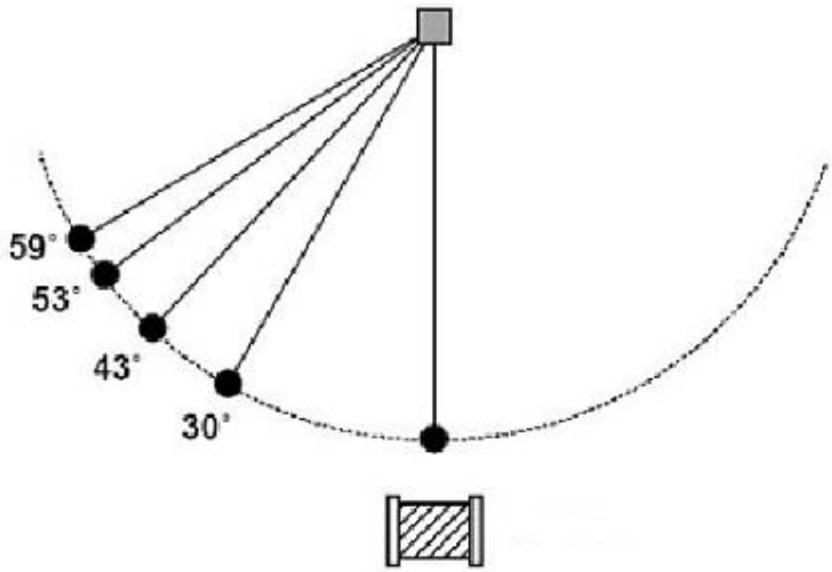


Figure 2 – Discrete amplitudes of the argumental pendulum.

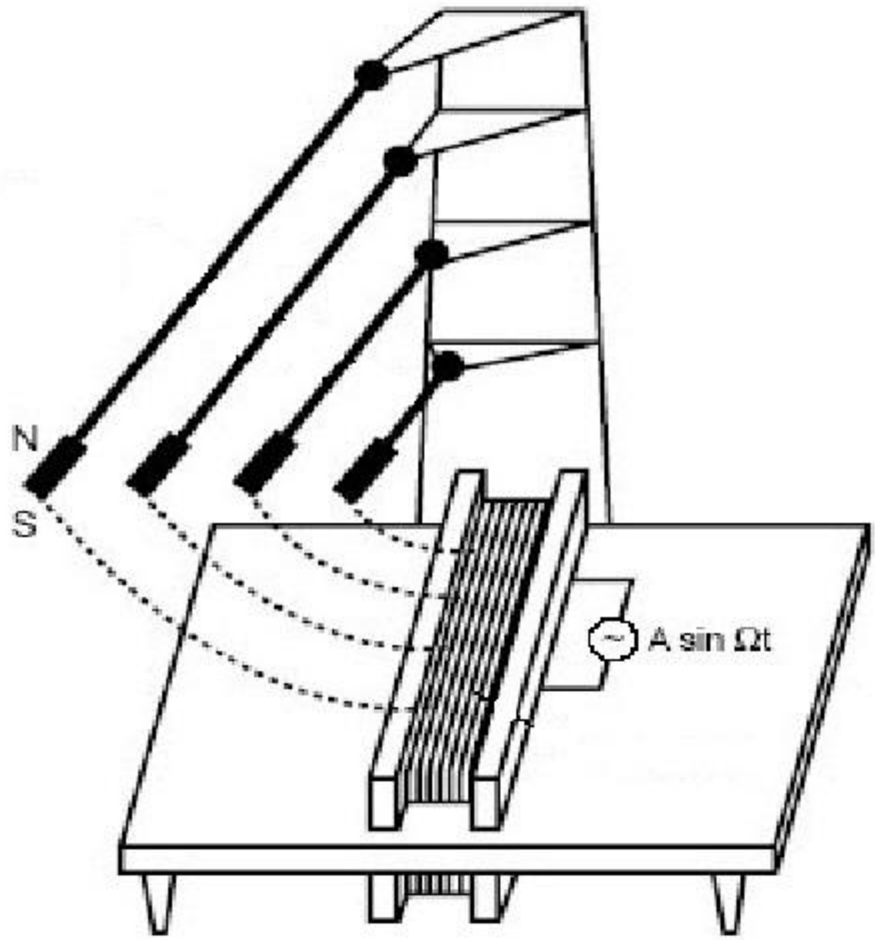
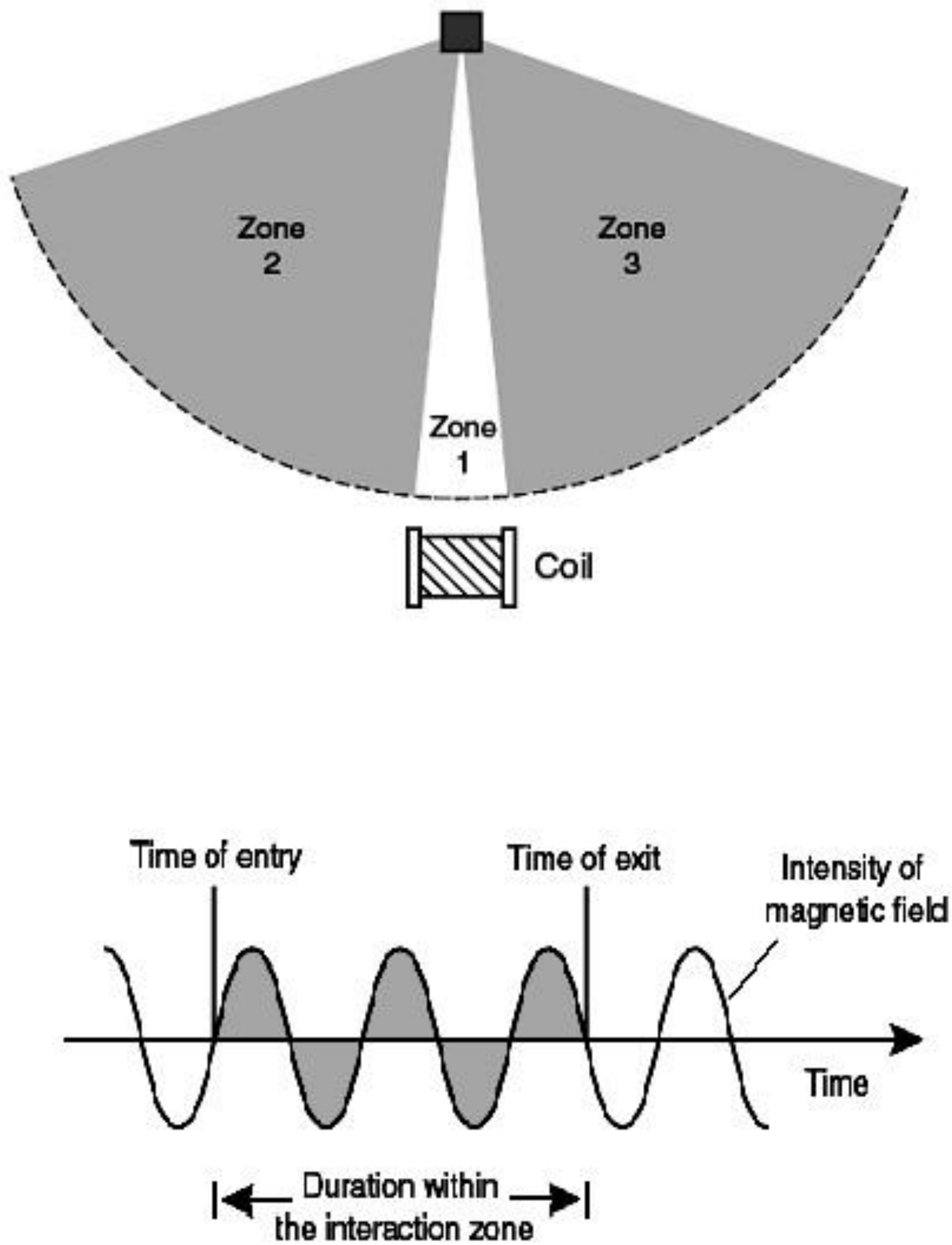


Figure 3 – Multiple argumental pendula "fed" by interaction with a single high-frequency source. The pendula can operate at different frequencies, each at any one of its own discrete series of "quantized" amplitudes.

Figure 4 – The effect of a single passage of the pendulum through the "interaction zone" (Zone 1 in the diagram) depends on the relationship of the phases of the magnetic field at the moments of entry and departure from the zone. In the example shown here, the pendulum has left the zone after a non-integral number of cycles of the field, thereby experiencing a net acceleration.



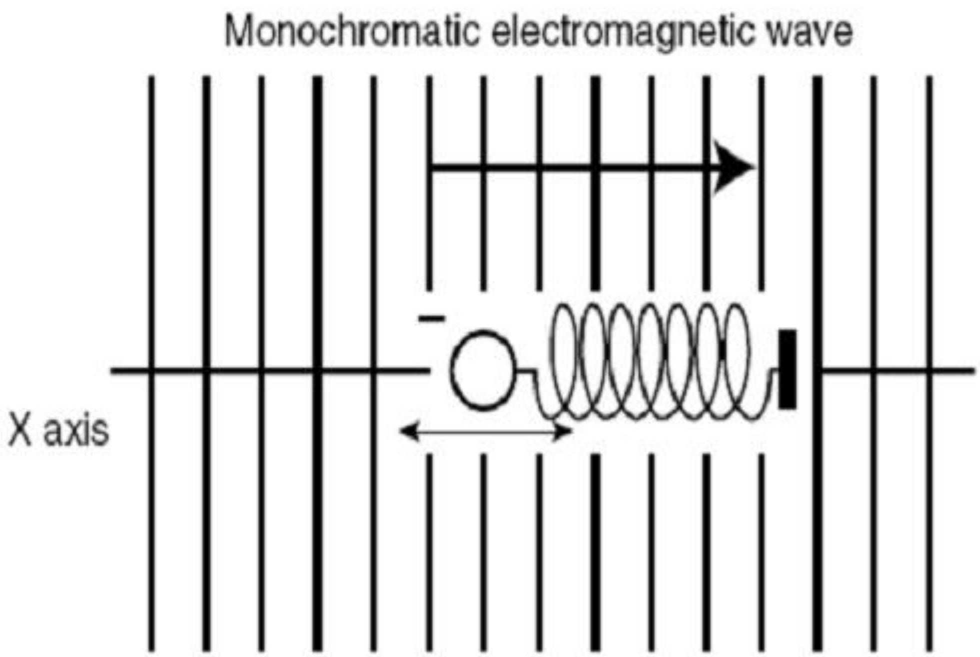


Figure 5 – The argumental analog of Planck's "elementary oscillator".