"ALEXANDRU IOAN CUZA" UNIVERSITY

IASI, ROMANIA

FACULTY OF PHYSICS

CONTRIBUTIONS TO THE STUDY OF MICRO AND MACRO SCALE EFFECTS USING NON-LINEAR DYNAMICS

PHD THESIS SYNOPSIS

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We hereby announce that on 10.10.2015, at 10:00 hrs. in L1 room, miss Maria Boicu will present in a public session her PhD thesis with the title **Contributions to the Study of Micro and Macro Scale Effects Study Using Non-Linear Dynamics**, with the aim of gaining the scientific title of doctor in the fundamental domain Exact Sciences, Physics.

The thesis committee is composed of the following:

Chairman: Professor Diana Mardare, PhD, Headmistress of the “Alexandru Ioan Cuza” University’s Doctoral School, Iasi, Romania

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We would like to invite you to attend this public session.

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Keywords: Extended Scale Relativity Theory, fractal curves, fractal logical elements, Hubble effect, chaos evolution scenarios, fireball

Table of Contents

In Chapter I a new way for the differentiability-fractality transition is specified by admitting the classical mechanics precepts in microcosmos though the Kepler problem (the Mariwala Theorems). A thorough discussion of the hydrogen atom quantum mechanics is presented, concluding that it is rather a harmonious sequel of classical mechanics than a disavowal of this way reasoning.

Firstly, the mechanical problem has been analysed, which is defined as well as it can be: a Kepler problem. In the microscopic domain this problem differs from its classical version only by the fact that light prevails over the gravitational phenomena, blurring it. On the contrary, gravitation is, in the classical version, the exclusive phenomenon, to whom the motion described by the model must correspond.

In our opinion the classical mechanics precepts are completely admissible in microcosmos: this is a mathematical theorem, the Mariwalla theorem, and not a hypothesis. It stipulates that the classical Newtonian model for describing motion is transcendent of the spatial and temporal scales, on the condition that the motion is governed by a potential associated to a force which has a value that is inversely proportional with the square distance between the point that generates that force and the point that moves under its effect.

This chapter focuses on this point by rendering an analysis made by Edwin Wilson in 1924, which concludes that in the quantum hypotheses of Niels Bohr, the potential associated to a central force responsible for the motion of the electron in the atom is not unique. Indeed, if in the classical case, the problem of this motion can be solved by the potential associated to the force that is inversely proportional to the square distance, the quantum postulates are the expression of an added potential: the potential associated to a central force with a value inversely proportional with the cube distance.

Having reached this point we focused on the history of these two forces. Firstly we concluded that Newton knew them very well himself. Looked upon separately they lead to essential results, as Newton found in its work *Principia*. Namely, the potential associated to the force which is inversely proportional to the square distance leads to the elliptical trajectory of the Kepler problem, while the potential associated to the central force which is inversely proportional with the cube distance leads to logarithmic spirals.

A logical analysis of these conclusions made by Newton from a classical natural philosophy point of view leads to the same conclusions as the one found in the classical model of the hydrogen atom: sooner or later the atom will be destroyed. Indeed, an electron that moves along a logarithmic spiral will inevitably either leave the atomic structure, or be swallowed up by the nucleus, these being in perfect accordance with the energetic depletion of the planetary model. Thus, in a classical framework, the physics theory is in accordance with the phenomenology. The drawback of the logarithmic spiral based model is however that, in compliance with the classical precepts, such an atom cannot be stable. Indeed, the classical stability is defined especially by the fact that the motion described in the model must have a closed trajectory, and the logarithmic spiral is, obviously, a closed trajectory.

Based on the fact that the force which is inversely proportional to the cube distance breaks the "Mariwalla symmetry", i.e. the fundamental symmetry of the classical model that describes the atom, but nonetheless convinced by the fact that the quantum reasoning must be a logical sequel of the classical natural philosophy, we searched for an explanation. It came to us through the duplicity of the quantum condition, which refers, on one hand, to the action, and on the other hand, to the kinetic moment, physical quantities of the same nature, if we are to analyse them by their dimension. The role of the kinetic moment in the quantum problem of the hydrogen atom has a special history, which leads foremost to improving the quantum postulate, which began with Arnold Sommerfield in 1916. Classically speaking, this improvement takes into account the rotation of the orbits as wholes, subject known also by Newton. It has the essential classical result that the central force which is inversely proportional to the cube distance can be rather considered as a transition force between elliptic orbits.

At this point, the idea of "transition between elliptic orbits" makes us think of the Bohr postulate, according to which the light is caused by the transition between elliptic orbits. This chapter shows that the idea of quantization describes a phenomenon universal to the world in which we live in and that transition is totally natural in a classical framework: it takes place between electron orbits, with the condition they are properly described, i.e. by means of a classical Kepler problem in a general regard. We highlighted the fact that the spatial transition points between orbits are always on a logarithmic scale. We proved that, from the point of view of the light, this is the trajectory on which the electron does not emit an electromagnetic field. Therefore, as long as the light is a electromagnetic phenomenon, no discrepancy between the classical and quantum natural philosophies can be found, because the logarithmic spiral is not a trajectory, but the geometric place of the transition points between orbits which are determined by the force inversely proportional with the square distance.

From the calculus technique's point of view, this chapter highlights the universal validity of the *Hannay classical angle*, which has here a special significance: it describes the motion of the force centre concordant with the quantum transition from orbit to orbit. The drawn conclusion allows us to hope that, by describing the motion of the force centre as a stochastic phenomenon, we will be able to define the physical transition from chaos to determinism in the microscopic domain, on the one hand. On the other hand, it opens up a new mathematical way for introducing fractality – a phenomenon that seems obvious in our world even at the level of our usual senses – in the description process of natural phenomena.

Admitting that fractality is an obvious phenomenon in our universe, and in order to be able to better describe natural phenomena, in Chapter II we devise a motion theory in an constant arbitrary fractal dimension, set on a three-dimensional manifold that is dependent both on spatial coordinates and on the scale resolution. Such an approach can be set apart from the usual scale relativity theories (see the works of Nottale & co.) due to the fact that the principles and implications of non-differentiability are thoroughly explained and not just accepted per se.

The fundamental hypothesis upon which this theory is built is that of the fact that the motions of the structural entities of a complex system take place on continuous and non-differentiable curves in a three-dimensional manifold. Thus the spatial coordinates are fractal and the time is not a fractal, it being assimilated to the affine parameter of the motion curve. Moreover, the resolution scale δt identifies, through the substitution principle, with the spatial differential dt, i.e. $\delta t \equiv dt$, thus resulting that the resolution scale is a motion independent variable.

In such a framework the geodesics equation has been obtained and from this, both its Schrödinger form, in a wave function representation, and its Madelung form, in its hydrodynamics representation, specific to flow processes, have been obtained. Moreover, in the hydrodynamics representation of the geodesics equation various dynamics are analysed: at fractal scale the finite energy solution generates fractal logical elements, it also implying, based on the dilaton associated to the fractal potential, "memorizing" and "anomaly" effects in nanostructures. At differential scale, the solution of the fractal hydrodynamics equations system for a free particle "mimics" at a cosmological scale, through dark matter, the Hubble effect, while the numerical solutions of the same equations system, in the absence or the presence of the energy equation, simulates ablation plasma dynamics. By separating the velocity fields (the differential from the fractal one), and neglecting the convective effects, current oscillations in ablation plasma are induced.

In Chapter III a scale relativity theory in an arbitrary constant fractal dimension on a space-time manifold is developed. We did not, however, had in mind a practical application to this theory.

By analysing a particle's motion on a continuous and non-differentiable curve on a three-dimensional Euclidian manifold, we observed a "discrepancy" between the spatial coordinates and the time coordinate considered as an affine parameter of the motion curve. If the spatial coordinates are fractals, then not the same can be said about the time coordinate, which is not a fractal. This "discrepancy" has a "apparently abnormal" immediate consequence: the particle moves on a infinite length curve in a finite time interval so that its velocity becomes infinite. Such a situation is physically absurd.

In order to eliminate this "apparent contradiction" we supposed that the time coordinate is also a fractal. Thus all the implications that non-differentiability from the classical scale relativity theory in a constant arbitrary fractal dimension remain valid, except that the affine parameter of the four-dimensional motion curve is the own time τ, situation in which the scale resolution, $\delta\tau$, becomes through the substitution principle $\delta\tau \equiv d\tau$.

After presenting the consequences of the four-dimensional motion curves on a space-time manifold non-differentiability, the geodesics equation is built for a complex four-vector field, based on a generalized scale covariance principle. This equation is reduced either to a fractal Klein-Gordon type equation in its wave function representation or to the fractal hydrodynamics set of equation (the four-impulse conservation law and the 4-states density conservation law) in the Madelung representation. This model allows both for the existence of a resolution scale dependent arbitrary limit velocity, and, through the four-potential, for a fluctuating own mass. In the particular case of motion on four-dimensional Peano curves on Compton scale, the double solution theorem of de Broglie results are obtained.

These previous results imply the following:

i) On a space-time manifold any structural entity of a complex system is in a permanent interaction with a fractal medium, through the specific fractal potential;

ii) On a space-time manifold the fractal medium identifies with a fractal fluid described by the states density and four-impulse conservation laws. We have obtained the fractal hydrodynamics equation on a space-time manifold. For non-relativistic motions of the structural entities, which take place on Peano curves at Compton scale, the fractal medium identifies with the "sub-quantum" Bohm medium;

iii) The specific fractal potential is induced by the fractal velocity four-vector. Although the fractal velocity four-vector does not define the current mechanical motion, it contributes to the energy and impulse transfer;

iv) On a space-time manifold every interpretation of the fractal potential must highlight the "self-interactive" nature of the four-impulse transfer. While locally, in E_3, the energy is "stored" in a kinetic, potential etc. form, such as in the classical case, only the total is preserved. So that, by negating any form of Brownian motion as a result of the interaction with the external medium, the reversibility and "being" are provided by the specific momentum and energy conservation laws.

v) This model allows for the generalization of the Einstein relation that defines the energy, both through the existence of a critical velocity imposed by the resolution scale, and through the presence of the fractal potential as a measure of a system's chaoticity, property which is specified by the non-differentiability of the motion curves.

In Chapter IV it is shown that the various chaos transition scenarios (period doubling, cuasi-periodicity, sub-harmonic bifurcations cascade, intermittences etc.) can be "mimicked" in the dissipative approximation of motion by simultaneously using both the Schrödinger type representations (the integral and the fractional ones), and the hydrodynamics representation of the geodesics equation. In order to achieve this, for the first representation the integral and fractional "cloning" property of the wave function in a rectangular one-dimensional potential well is used, while for the second representation, the possibility of defining different Reynolds number of critical values that "induce" turbulence is employed. We are practically discussing about chaos state gaining through stochastization in the Schrödinger representations backed by a chaos state gaining through turbulence in the hydrodynamic representation.

In this chapter we present the experimental results that illustrate the competition between three chaos transition scenarios (intermittency, cuasi-periodicity, and sub-harmonic bifurcations cascade) in a plasma system, by analysing from a non-linear dynamic point of view the temporal series which correspond to the current oscillations collected by an electrode, in front of which a dynamic state "fireball" is generated. By using the tension applied on the excitation electrode as a control parameter, chaos transitions has been gradually observed along with regular oscillations windows.

A theoretical model in the framework of the Scale Relativity Theory has been developed. In this model we supposed that, due to collisions, the plasma particles (electrons, ions, and neutral particles) move on continuous and non-differentiable curves, i.e. fractal curves. The equivalence between the fractal hydrodynamics formalism and the Schrödinger type equations has been established. The potential applied to the electrode was modelled as a one-dimensional rectangular potential well. The chaos evolution criteria have been obtained by applying the integral and fractional cloning mechanism. In the dispersive approximation of motion the various chaos evolution criteria have been "mimicked" as mixtures of cnoidal oscillation current modes for various non-linearity degrees. Our results are in good compliance with the experimental ones.

Publications

List of scientific papers published in ISI indexed journals into phD domain

[1]. Agop M., Dimitriu D.G., Vrajitoriu L., **Boicu M.,** *Order to Chaos Transition in Plasma via Non-Differentiability: Experimental and Theoretical Investigations*, Journal of the Physical Society of Japan 83, 054501(2014) 1-11

Impact factor : 1.585
Influence Score : 0.644

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Impact factor : 1.343
Influence Score : 0.134

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Impact factor : 1.343
Influence Score : 0.134

Total Impact factor: 4.271
Total Influence Score : 0.912
Individual ISI Score : 1.016

List of scientific papers published in BDI journals in phD thesis domain

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