CURRICULUM VITAE

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Academic degrees: Ph. D. in Physics and Aggregation in Physics

Education: Licence in Physics in1973 by Faculty of Sciences of the University of Lisbon

PhD in Theoretical Physics in 1985 by University of Lisbon

Aggregation in the Field of Physics in 1998 by University of Lisbon

Academic Title: Professor Doutor

Positions:

1973-1976 Auxiliar Assistant in Physics.
1976-1986 Assistant in Physics.
1985-1990 Auxiliar Professor.
1990-1998 Definitive nomination
1998-2006 Aggregado Professor
2003- Researcher at the Philosophy of Sciences of the University of Lisbon Center

(All posts held at Faculty of Sciences of the University of Lisbon)

Prizes:

2008 Gold Medal of the Santilli-Galilei Association, for The Crusading Work Towards the Demise of the Prevailing Scientifc Obscurantism.

Prize FIR 2008, for his Work in promoting REASON, from the International Rationalis Federation.

Teaching:

Many Courses related with theoretical Physics, Quantum Physics, and others, also Experimental Physics at graduate level.

Many students at post graduate level.

Research

I was initiated in the foundations of Quantum Physics by Professor J. Andrade e Silva one of the most direct collaborators of the great French physicist Louis de Broglie.

So, my research activity follows, naturally, along this line, and therefore has been focused mainly on the study of the foundations of quantum mechanics and its extension to all physics, explicitly in the following aspects:

a) Foundations of Quantum Mechanics

The aim of this research is related to the problem of the rejection of causality and locality introduced in the first quarter of the twentieth century by Niels Bohr. Is it possible that, at the quantum level, physical systems are not susceptible of causal description in terms of space and time? Are these concepts, which have proved very fruitful in the past, be now mere obsolete instruments completely outdated? It is also true that important physicists of twentieth century, like Einstein, de Broglie and many others, always felt that this proposal was very unsatisfactory. Space and time should remain the cornerstones to help us to understand and unravel the secrets of Nature.

The fighting in defense of causality began early. Just at the beginning the formation of quantum mechanics. An important group of physical, from which we can point out, some of the very founding fathers of Quantum Mechanics, such as Einstein, de Broglie, Schrödinger and Max Planck, always were opposed to the indeterminist borhean paradigm. From this grand effort, the best succeeded was indeed the one of Louis de Broglie which was able to establish the basis for the development of a consistent causal theory. His work lies, indeed, at the very roots of the present nonlinear causal approach. Still, all these earlier efforts were done under the nonlocal and nontemporal Fourier ontology. Precisely because of this all this work was, in a certain way, condemned, since the very beginning, only to a partial success.

As long as one accepts, as basic starting point, that only an infinite wave has a frequency and therefore a well-defined energy, there can not be finite signs, in time and space, with a well-defined energy. This happens because a finite signal, in Bohr indeterminist paradigm, which establishes Fourier ontology, is always a superposition of "perfect" harmonic plane waves, each one with its well-defined frequency. Consequently, for this very reason, it is not possible to have real objective systems with local properties and possessing, at the same time, individuality.

Claiming that any finite physical system is, ultimately, made by the sum of endless harmonic plane waves is simply equivalent [as I shown in the Invited talk, *Local Wavelet Analysis Versus Nonlocal Fourier Analysis*, at *International Workshop ad memoriam of Carlo NOVERO*, *Advances in Foundations of Quantum Mechanics and Quantum Information with ATOMS and Photons*, Turin, May 2006] to the rejection of the locality and individuality.

The “pure” frequencies, and consequently, the “pure” energies, of the Fourier ontology correspond to the monochromatic harmonic plane waves produced by a perfect uniform infinite motion of a point in a circle. Since these waves are infinite both in time and space it means that the piano, or the organ, started playing the notes from the infinite beginning of times and will be playing them forever. The fact that the any real physical musical instrument was built at a certain time and will eventually disappear sometime later has no importance. Their finitude, in this ontology, is a kind of fantasy of our senses. The “perfect” sounds, the monochromatic harmonic plane waves, should exist even before the piano was built, and will last forever, even when the material musical instrument no longer exists. These assumptions, we must be aware, are basic for the Fourier ontology. They imply, in reality, a return to old Plato circular paradigm, which led directly to the Ptolemaic model for the heavens. In this cosmologic model the heavenly bodies existed forever playing endlessly the eternal and ethereal harmonic music of the spheres.

Fourier ontology maintains the impossibility of producing finite pulses with a well-defined frequency. Only the infinite harmonic plane waves do have a well-defined frequency. A finite signal is always is, in this ontology, composed of many frequencies, each corresponding to a single harmonic plane wave. So, any fairly finite localized particle is a sum of many harmonic plane waves. Since each of these infinite “pure” waves has a well-defined energy or frequency, it means that, before measurement, the quantum particle does not have a well-defined energy. Since any real particle has only one single energy, it follows, necessarily, that single quantum particles before measurement do not have real existence.

Some, less familiar with the conceptual frame work of the orthodox theory and using a causal thinking, would say that the waves constituting the wave train correspond to a kind of statistical distribution for an ensemble of particles each with its own energy. In such circumstances there would be no problems. This statement could indeed be true for an ensemble of particles! Still one must be aware that we are dealing with a linear theory. Therefore which is valid for one ensemble of particles is also for one single particle. So, in this theory, the same wave packet, made of a large sum of harmonic plane waves each with its own “pure” energy, can describe either a single particle or many particles. For the case of a single quantum particle we have a problem when we ask: What is the energy of the particle before measurement? Since we are dealing with a single particle, to be consistent we have to say that, before the act of measurement, the particle had as many energies as the number of harmonic plane waves necessary to make the wave packet. Giving other answer, like for instance: the particle, before measurement, had the energy we actually saw, even if we do not have the possibility of knowing it. Such a statement would imply the denial of the duality wave-particle and consequently the possibility of interferences. We ought to say that, before measurement, the single quantum particle had a multiplicity of energies. How can a concrete real particle have a multiplicity of energies? It is not possible! The only reasonable conclusion to draw, in this paradigm, is that before measurement the particle did not exist really. All what existed was a bunch of potentialities, or possibilities each corresponding to its own energy. When the act of measurement is performed all these potentialities collapse into a single one. That is, the large number of potential particles, without physical reality, by the act of measurement, materialize, collapse, into the single particle.

To get rid of those consequences, leading to the denial of the objective reality, it is necessary to reject Fourier ontology. We have accept that the infinite, in space and time, harmonic plane waves are only mathematical abstract entities devoid of any intrinsic physical meaning. After taking that step it is then logically possible to assume that a finite sign, a finite wave, may have a well-defined frequency.

These facts lead us to believe that Niels Bohr proceeded with great subtlety to promote the mathematical tool, developed by Fourier, from simple rule of composition of functions to the status of a true ontology. With this step he achieved once and for all, the non intrinsic localization, that is, the omnipresence for the physical systems, leading directly to the rejection of objective reality.

Now, that we are more distanced in time, we can better understand and be aware of the real difficulties faced by all those who tried to recover causality, separability and individuality in physics. Being, just from the very beginning, restricted by the implicit acceptation of a nonlocal ontology, whose deep implications were not, at those times, very clearly understood, they could not develop a true causal local quantum theory. The development of a truly causal local theory is, in this conceptual frame work, a very hard for not saying even impossible task.

In order to break the vicious circle it is necessary to refute, once and for all, Fourier ontology. We have to accept, as natural, that a finite sign, a pulse, a finite piece of a cosine function, for instance, can indeed possess a frequency and consequently a perfectly well definite energy.

When the hammer strikes a diapason, a wave of a fairly well-defined frequency is produced. Therefore it seems quite reasonable to represent this sound by a finite wave of a well-defined frequency. For what physical reason has one to say that this finite wave, of a well-defined frequency, is composed of an infinitude of harmonic plane waves that have no real physical existence? We are so immersed in the Fourier ontology that when one has a finite pulse one tries immediately to decompose it into the so-called pure frequencies of the harmonic plane waves to obtain the power spectrum. We forget the fact that in Nature no one has ever seen a device able to produce the infinite harmonic plane waves.

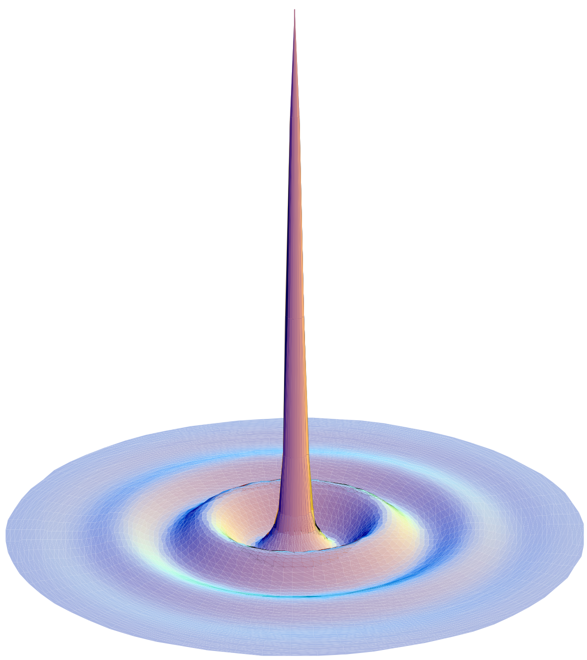
The recent development of wavelet analysis allows us to represent mathematically the diapason sound by a finite wave of a well-defined frequency. It is true that prior to wavelet local analysis, we had to describe mathematically these finite physical waves, as a sum of infinite waves whether we give them a basic epistemological status or not. Now, since we have a mathematical tool that allows us to avoid the physical nonsense of Fourier analysis one is free to reject the old nonlocal and nontemporal ontology.

The denial of the Fourier ontology is equivalent to the abandon of the old Plato-Ptolemy cosmology for a more general one. This, as we know, was the work of Kepler in astronomy.

Even if it may appear strange the first steps along this route were made, not in the so called, by some, high spheres of the theoretical physics, but in the “simple” domains of the physical applications where the researchers are permanently facing the practical problems of everyday reality. Precisely because of it they need to have there feet well placed on Earth. It was just in the field of the Earth sciences that this adventure began. The geophysicist Jean Morlet, in the eighties of the XX century, was trying to develop a better process for predicting with more efficacy the localization of the oil deposits. Since

Fourier analysis proved not good enough for the task he developed a new process, later named, local analysis by wavelets or finite waves. This analysis by wavelets is presently a mathematical field of research in explosive development mainly due to its great usefulness in the treatment of the information.

The application of gaussian wavelets allows us to develop a causal mathematical model for the quantum particle. This model contains both the local and extended properties of the quantum particles ascribing to it a perfectly well-definite energy.



Model for the quantum particle

Furthermore, the analysis by Gaussian wavelets allows us to derive [as shown for the first time by me as Invited speaker at the *International Symposium on Basic Problems in Quantum Physics*, 29 August - September 1993, Oviedo Spain, where I presented the communication *On the Uncertainty Relations* and in the following year in the *UK Third Conference On the Foundations of Quantum Theory and Relativity* at Cambridge, September 1994 which presented the communication *On the Meaning of the Uncertainty Relations*] a more general set of mathematical expressions for the uncertainty relations. These more general new uncertainty relations contain, in formal terms, Heisenberg orthodox indetermination relation as a particular case.

With the help of these conceptual tools it is now relatively easy to develop [see, JR Croca, *Towards a Nonlinear Quantum Physics*, World Scientific, London, 2003] a global synthesis, coherent and objective, of classical physics and quantum physics. In this synthesis we assume, as stated before, the existence of a Reality independent of the observer. Naturally, we acknowledge that the observer interacts and may, eventually, modify, in a more or less degree, this very reality of which he is a part.

In such situation classical physics and quantum physics are no more than distinct levels of description, different scales of observation, of the same very reality.

At the level of description of classical physics the local systems, the corpuscles, and the extend systems, the waves, for instance, are assumed as different realities. In such conditions, they, naturally, are described by different set of equations. The Hamilton-Jacobi equation, for the corpuscles, and the continuity equation for the extended systems.

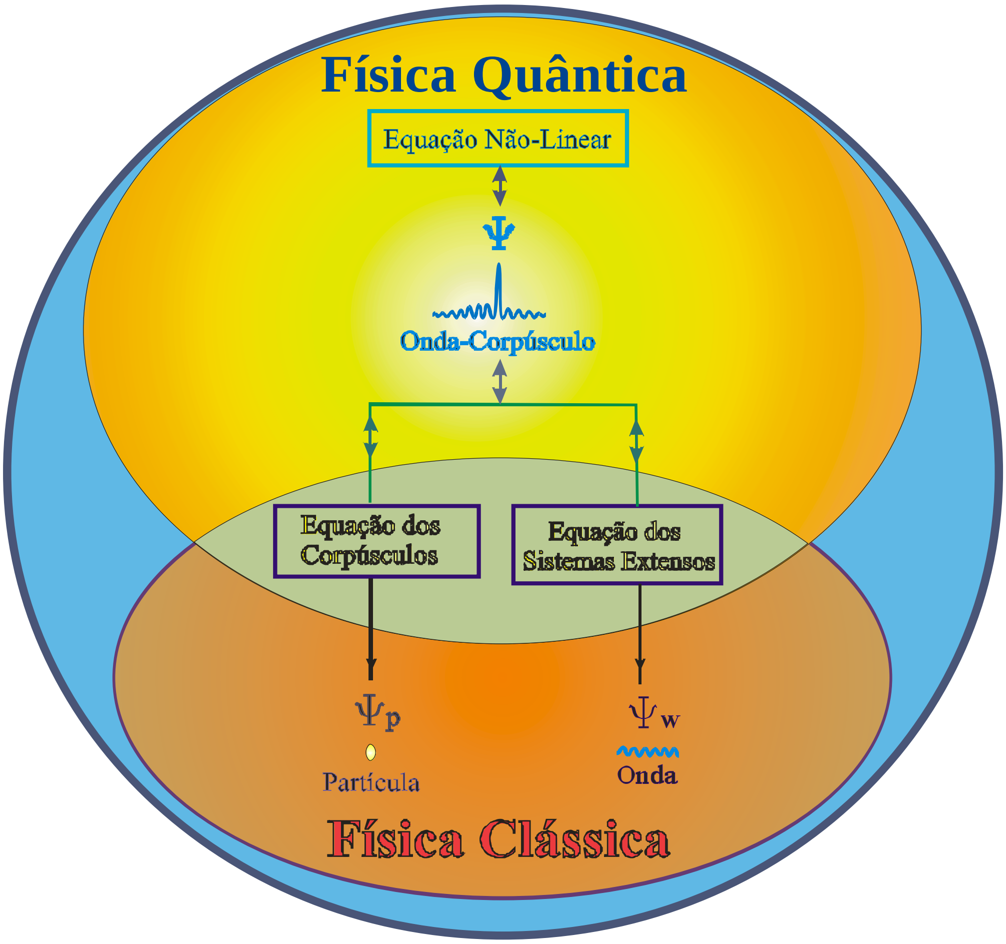
At the quantum level this dichotomy, local and extended is no more meaningful. Localization and extension are gathered into a single whole. This unique entity corpuscle-wave needs now to be described by a nonlinear master equation.

$$-\frac{\hbar^2}{2m}\nabla^2\psi + \frac{\hbar^2}{2m}\frac{\nabla^2(\psi\psi^*)^{\frac{1}{2}}}{(\psi\psi^*)^{\frac{1}{2}}}\psi + V\psi = i\hbar\frac{\partial\psi}{\partial t}$$

Therefore, we are allowed to say that classical physics derives, is a particular case, of the quantum description when the unity corpuscle-wave is broken and these two properties of the systems are then treated as separated entities.

Symmetrically, we may say that quantum physics is no more than an extension, a generalization, of classical physics where local and extended properties are taken as a whole. Thus, by simple fusion of the two fundamental equations of classical physics it is possible to obtain the nonlinear master equation for describing quantum phenomena.

The global synthesis between the two levels of description of reality is shown in next figure.



Física Quântica
Equação Não-Linear
Ψ
Onda-Corpúsculo
Equação dos Corpúsculos
Equação dos Sistemas Extensos
Ψp
Partícula
Ψw
Onda
Física Clássica

Reality is objective and one. What changes is only the way how we describe the same very reality.

At quantum level, at the quantum scale, it is not possible to separate local and extended properties.

At classical level of description is much more useful to treat these two properties of the systems as completely independent.

The problem we have now before us is to decide of the validity of the more general causal and local theory when compared with the orthodox Copenhagen interpretation.

Happily, it is a dispute between physical theories. So, and in line of principle, we know how to work out the question. Any physical theory, worthy of that name, can only be validated, or invalidated, by the experimental evidence. In such a situation, what we need to do is submit the two theories to the verdict of experiments.

A most promising field for this testing is related with the uncertainty relations. In last instance we must know if the indetermination Heisenberg relations

$$\Delta x \, \Delta p_x \geq \hbar$$

are, in fact, the ultimate expression for our capacity of measurement, and therefore of knowing Nature. Or, on the contrary, Nature need to be described by the more general set of uncertainty relations derived from the causal nonlinear theory.

$$\Delta x^2 \geq \frac{\hbar^2}{\Delta p_x^2 + \hbar^2 / \sigma_0^2}$$

or

$$\Delta x \, \Delta p_x \geq \frac{1}{\sqrt{1 + \hbar^2 / \sigma_0^2 \Delta p_x^2}} \hbar$$

As can be seen, the new uncertainty relations contain formally the old Heisenberg relations as a particular case, when $\sigma_{0,}$ the size of the mother wavelet, is much large than Planck's constant.

Our question can now be formulated in this way: Is it true that orthodox Heisenberg indetermination relations do indeed describe all experimental known universe? Or, on the contrary, there are domains where these relations do not apply. If so, are these new experimental fields described by the more general set of causal uncertainty relations?

Indeed there are, [as shown by me, for the first time, in the plenary session, at Merton College, before closing the *UK 5th Conference on the Conceptual and Philosophical Problems in Physics*, at Oxford, September 1996 where I presented the communication *Experimental Violation of Heisenberg Uncertainty Relations*] very particular concrete physical situations which falsify the common Heisenberg relations. These observations, made with the apertureless scanning optical microscope, are not, in reality, described by the common uncertainty relations.

The super resolution microscope belongs to a family of microscopes recently developed by IBM researchers. The concrete practical resolution of these super microscopes goes far beyond the maximal theoretical limit of the common microscopes, also named by Fourier microscopes.

The measurements done everyday with some of these super microscopes are not described by the common uncertainty relations. These facts clearly show that the common Heisenberg relations are not, after all, so general as the followers of the orthodox quantum mechanics claim.

Naturally, these measurements, done with super microscopes, are nicely described by the more general causal uncertainty relations.

For better clarify this issue, and at the same time for confirmation of previous results, there were developed several proposals for concrete experiences. Diverse experimental groups, national and foreign, have expressed interest in carrying out the experiments.

Apart from experiments connected with the study of the general validity of the common Heisenberg relations there were also developed other proposals of experiments. These experiments are related with the problem of knowing whether the quantum de Broglie waves are real or merely mathematical abstractions. That is, merely probability waves devoid of any physical meaning. Some of these experiments [(*Optical quantum predictions for an experiment on de Broglie waves detection*, JR Croca, A. Garuccio, V. Lepore and R. N. Moreira, Found. Phys. Lett. 3 (1990) 557), (J.R. Croca, *Some basic differences between the de Broglie and Copenhagen interpretation of quantum mechanics leading to practical experiments*, in *The Concept of Probability*, eds. E. Bitsakis and C. Nicolaides (Kluwer Academic Publishing, 1989))] proposed by myself and other researchers have already been made in important international laboratories, particularly in the Laboratory of Quantum Optics at the University of Rochester (New York). The results achieved so far can not yet be considered conclusive. To overcome this impasse new proposals of experiments have been developed.

b) Tunneling effect

Recently many experiments have shown without any shadow of doubt that the pulses going through a potential barrier arrive first than those that go by the air. The whole scientific community is in agreement with the experimental results. The question is to know whether such pulses travel indeed with a superluminal velocity. That is if their velocity is greater than the speed of light in a vacuum, or not? Since all calculations are made within the Fourier ontology, it becomes very difficult if not even impossible to define the speed of a finite wave. As we have seen, only in the case of harmonic plane waves, infinite in space and time, the problem offers no difficulties. In this nonlocal and nontemporal paradigm, as we have seen, only the harmonic plane waves do have a "real" frequency, all other finite waves are a merely combinations of the infinite waves. Thus, each of these finite waves has, in principle, as many velocities as the number of harmonic plane waves composing it. Since these harmonic plane waves occupy all the space and time, it becomes very difficult, if not even impossible, to know in this ontology, which is the velocity of finite wave. Since the components that make up the finite pulse occupy all the space and time, almost anything is possible. The most extravagant situations can occur, such as retrodictions in time. For instance, a pulse can arrive at the destination before being emitted by the source!

The aim of this line of research is to study the transmission of both quantum and non quantum systems in tunneling conditions. We whish to understand the physical nature of the tunnel barriers and furthermore to determine the conditions and transit time within it.

c) Principle of eurhythmy

Recently I started studying the extension of the nonlinear principle of guidage of Louis de Broglie, generalizing it from quantum physics to the whole physics, including gravitation. To this basic principle, unifying the whole physics, was given the name of principle of eurhythmy [JR Croca, *The Principle of Eurhythmy Key To The Unity Of Physics*, in the *First Lisbon Colloquium for the Philosophy of Science - Unity of Science, Non Traditional Approaches*, Lisbon, October, 25-28, 2006].

d) Foundations of relativity

This line of reseach, in some ways marginal, and resulted from the collaboration with Professor Franco Selleri of the University of Bari. Its aim is to develop proposals of high precision experiments, designed to test the invariance of speed of light in one direction, one-way experiments. In this sense there were already developed some proposals for experiments. One aimed to test the invariance of C with the speed of the source (JR Croca, *Experiment on the Independence of C*, in *Open Questions in Relativistic Physics*, Franco Selleri ed, Apeiron, Montreal, 1998). The experiment is based on second and fourth order interferometry and has a time precision of the order of hundredth of femtosecond, leading to the detection of hypothetical changes in C on the order of meters per second or less.

In this proposal the light travels in one single direction, unlike the experiments done so far, round-trip, where the light comes and goes by the same route. Another proposed experiment is a one-way variant of the classic experiment of Michelson (*Is the One-way Velocity of Light Measurable?* J. R. Croca and F. Selleri, Nuovo Cimento, 114 B, 447-457 (1999)).

Later, it was possible to develop an experiment [JR Croca, *Experimental Proposal for Determination of One-Way Velocity of Light with One Single Clock*, to be published] that allows the determination of the speed of light, in one journey, using a single detector, thus breaking the so-called Poincaré's curse that claimed its impossibility.

Research projects

I have been involved in many research projects namely:

Foundations of quantum physics:

In collaboration with researchers of the University of Bari (Italy) Prof. Franco Selleri, Prof. Augusto Garuccio, Dr. Gino Lepore, Prof. N. Cufaro Petroni, and also with Prof. L. Pappallardo the University of Catania (Italy) participated in a project supported by INIC (Portugal) and the CNR (Italy). This project was intended mainly to study the foundations of Quantum Mechanics. One of the objectives of the project consisted in the study and analysis of experimental situations, either concrete or ideals, which could clarify the meaning of the psi wave function. In the final analysis we wanted to know whether the quantum waves had physical reality, as assumed by de Broglie and others, or by the contrary, are no more than simple abstract representation of mathematical probabilities devoid of any physical meaning.

This project had a remarkable success since it led to enormous progress in this area. From it a whole mathematical and physical treatment of the problem was developed that led to a series of proposals of concrete feasible experiments able, in principle, to clarify the problem.

The project led to a first experimental realization by the Group of Quantum Optics of Professor L. Mandel, University of Rochester, New York, USA. The experiment conducted by this team was proposed by the members of the reseach team (JR Croca, A. Garuccio, V.L. Lepore and R. N. Moreira, Found. Phys. Letts. 3 (1990) 557) was based on the interference with pairs of photons produced by parametric down conversion in nonlinear crystals.

Later in 1994, Professor S. Jeffers, Department of Physics at the University of Toronto, Canada, has carried out another experiment, proposed earlier (JR Croca, in The Concept of Probability, Eds. EI Bitsakis and CA Nicolaides, (Kluwer Academic Publishers, 1989)) to test the reality of de Broglie waves. This experiment was based on another effect named auto-reduction of the wave trains.

This line of research has had the collaboration of Professor M. Ferrero the University of Oviedo (Spain). On the other hand, we have had a project of cooperation for the effective implementation of a series of experiments on the quantum waves of de Broglie, with the Laboratory of Quantum Optics at the University of Minas Gerais in Brazil, under the direction of Professor G. Barbosa.

Another line of research, also on the basis of Quantum Mechanics, in which I have worked and continue to work is related with Heisenberg relations and the problem of non-locality. The aim of this project is to know if these relations, as they are formulated, are indeed our last possibility for measurement. These relations, as demonstrated by Niels Bohr, are a direct consequence of non-local Fourier ontology. However, the recent development of mathematical analysis by wavelets allowed the deduction (JR Croca, *The Limits of Heisenberg Uncertainty Relations*, in *Causality and Locality in Modern Physics*, Jeffers et al. eds. (Kluwer, 1997)) of a more general set of uncertainty relations that contain the common Heisenberg relations as a particular case.

From the theoretical point of view this project has had the cooperation of researchers from the Departments of Physics (Professor A. Rica da Silva) and Mathematics (Professor J. Sousa Ramos) of the Technical Superior Institute of Lisbon.

From an experimental side this project had the collaboration, for a time (1989-91), of Professor Scheer of the University of Bremen and his group composed by Dr. M. Schimdt and T. Kock.

This project has had remarkable success because it was possible to carry out many of its objectives. Indeed, resulting from it a cycle of proposals of experiments (JR Croca, *On the Uncertainty Relations*, in *Fundamental Problems in Quantum Ph*ysics, M. Ferrero and A. van der Merwe (eds.), (Kluwer, 1995)) feasible, with the available technology, were developed. The purpose of such experiments is to test the validity of the general of the common Heisenberg relations, against the new causal more general uncertainty relations.

Moreover, related to the previous project, I am working on the nonlinear Quantum Physics analysis and wavelet local analysis. This research has relied on the collaboration of Professor R. N. Moreira, the Department of Physics of the Faculty of sciences of the university of Lisbon and of the Group of the Technical Superior Institute of Lisbon formed by researchers from the Departments of Physics (Professor A. Rica da Silva) and Mathematics (Professor J. Sousa Ramos). One of the objectives of the project is the study of master nonlinear equation and its solutions, including non dispersive solutions, wavelike type solitons that include both the locality and extension. This causal theory, in direct line of de Broglie's, shows that the quantum particles, localizes and extended, are described in the first approximation, by wavelets, finite in space and time. As a direct consequence of such assumptions it was possible to deduce the expression that relates the true length of the particle, the region where it can cause effects interferometric, with the de Broglie wavelength, (JR Croca, *The Uncertainty Relations*, Apeiron, vol. 6, No. 3-4 pp 151-165, 1999).

This project on the foundations of quantum physics, culminated with the publication of a book commissioned by Professor Evans, then Scientific Editor of World Scientific, (JR Croca, *Towards a Nonlinear Quantum Physics*, World Scientific, London, 2003). In this work it is developped a causal synthesis including classical and quantum physics.

Project on the Principle of eurhythmy:

It is related with the principle of eurhythmy and its application on the unification of physics. This project has the collaboration of Professor RN Moreira, Professor M. Gatta of the University of the Azores and also with Professor Pedro Celestino of Department Chemistry of Faculty of Sciences of Lisbon.

Project for the tunneling effect:

Includes the study of the transmission of quantum systems in tunneling conditions. The aim of this line of research is to determine the conditions and tunneling transit times.

Project on the foundations of relativity:

This project has the collaboration of Professor Franco Selleri of the University of Bari, and of Professor Rica da Silva, of the Technical Superior Institute of Lisbon. Its aim was the development of concrete proposals of experiments for studying the one-way velocity of light.

Other interests:

Philosophy of Science

Art
Sculpture (in different materials, wood, stone, etc.)
Painting
Architecture