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Birth, development and applications of quantum physics: a transdisciplinary approach

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ABSTRACT

The last century has been a period of extreme interest for scientific research, marked by the overcoming of the classical frontiers of scientific knowledge. Research oriented towards the infinitely small and infinitely big, in both cases beyond the borders of the visible. Quantum physics brought to a new Copernican revolution, opening the way to new questions that led to a new view of reality. At the same time, advanced theories have developed, involving every field of science, philosophy and art, rediscovering the link between unity and totality and the importance of the human potential. In a transdisciplinary approach, we consider the birth, development and important applications of quantum physics, the world of nanotechnology, pointing out on new ideas about the concepts of vacuum and entanglement, metaphysical aspects, so as the introduction of different interpretative approaches to the concept of "whole".

***Keywords*:** Modern Physics, Unification, Vacuum, Entanglement, Education, Transdisciplinarity, Human Being, Metaphysics, Nanotechnology

1. INTRODUCTION

The last century has been an extremely interesting period for scientific research; the feeling was that science had reached the frontiers of classical knowledge. Scientists focused

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more attention both on the microscopic world, i.e. the infinitely small, and on the infinitely large, i.e. the universe. It aroses the need to look beyond the frontiers of the visible, beyond the natural classical field of action, to probe what until then had remained unprobed.

In particular, the *new physics*, that is *quantum physics*, placed the unknowable at the center of any possible speculation about this new path of knowledge. Over the next few years, this led to a revolution in the development of human thought, with the arrival of questions that would have led to a new vision of the universe.

Along with research into the depths of the infinitely small and large, theories involving every field of science, philosophy and art were also developed. The birth and development of psychoanalysis directed interest towards the depths of the human soul, with connections to various other human sciences. All this global research led to the rediscovery of unity, with everything linked to the whole, and to the enhancement of man's intuitive and creative abilities, as well as his unexplored potential [1, 2].

2. THE SURPRISES OF QUANTUM PHYSICS

Thanks to quantum theory, radical changes have taken place regarding the concept of reality; in its final form, this theory has concentrated the new ideas of modern physics. One of the greatest crises of classical physics started in 1900 with German physicist Max Planck (1858-1947), although as young man he was advised not to undertake studies in physics, as at that time it seemed that almost everything had been discovered in the physical field. This vision of physics was fueled by the triumphs of Newton's laws on mechanics and Maxwell's laws on electromagnetism [3].

The experiments of his group on black body radiation did not lead to the expected results. Planck had an original intuition that led him to elaborate an idea destined to write a memorable page in the history of physics. In December 1900 Planck presented his report, arguing that the exchanges of energy in the phenomena of emission and absorption of electromagnetic radiation occur in a *discrete form*, and *not in a continuous form* as claimed by the classical electromagnetic theory, according to the relation:

$$E = h\nu \quad (1)$$

where E is the energy, ν is the frequency of the radiation and h a constant, then called Planck's constant, also called *quantum of action*, with value given by: $h = 6.626\times10^{-34}$ J s.

This paved the way for quantization, i.e. to the fact that the fundamental physical quantities did not evolve continuously, but could only assume multiple discrete values of this constant. Planck's constant is one of the universal constants of Nature [4].

Planck's theory, later reworked by Albert Einstein and Niels Bohr, began a new path related to subatomic particles. In followed years it was learned that the basis of the solidity of the real world is given by tiny particles that represent essentially *empty space*, with positions distributed in clouds of probability.

In 1905 the German naturalized Swiss and American physicist Albert Einstein (1879-1955) resumed Planck's theory highlighting the quantum nature of light; he demonstrated how electromagnetic radiation was not just a *wave*, but a set of *discrete particles*, the *photons*. This is the *photoelectric effect*.

Following Einstein's discoveries, in 1924 the French physicist and mathematician Louis De Broglie (1892-1987) postulated the *wave-particle dualism* of matter, a central part of the theory of quantum mechanics: each moving particle is associated with a wave and the link between wave variables and those of a particle depend on Planck's constant. To a particle of energy E is associated a wave of wavelength:

$$\lambda = \frac{h}{mv} \Leftrightarrow p = \frac{h}{\lambda} \quad (2)$$

These wave-like aspects of matter received experimental confirmation in 1927. Each particle is therefore endowed with a double descriptive modality:

- *energetic mode* (wave representation);

- *material mode* (particle representation).

However, it is not possible to simultaneously reveal all the characteristics of a particle or a system; this fact was studied in particular by the German physicist Werner Heisenberg (1901-1976). He reasoned on the idea that in microscopic physics the uncertainties in the measurements of position and momentum could not be reduced to zero at the same time, due to the inevitable interaction between the object to be measured and the instruments needed to observe it; the more we know about the particle's position, the less we know about its momentum, and vice versa. This indeterminacy also exists between energy and time variables. These arguments have remained in history as *Heinsenberg's uncertainty principle*, enunciated in 1927; it is a principle that plays a fundamental role in the interpretation of microscopic reality and is connected to the Planck's constant:

$$\Delta x \cdot \Delta p_x \geq \frac{\hbar}{2}; \quad \Delta E \cdot \Delta t \geq \frac{\hbar}{2} \quad (3)$$

According to this principle, it is not possible to force a particle into a certain position. Following the De Broglie's idea, the Austrian physicist Erwin Schrödinger (1887-1961) elaborated an equation relating to the nascent theory, which marks an analogy with respect to Newton's equations of the macroscopic world. This is the Schrödinger equation:

$$i\hbar \frac{\partial \Psi}{\partial t}(\bar{r},t) = H\,\Psi(\bar{r},t) \quad (4)$$

with i imaginary units, $r = (x, y, z)$ generic point of the space, Ψ wave function and H Hamiltonian operator.

This equation studies, in a deterministic way, the temporal evolution of a quantity called *wave function*, a central concept of quantum physics and whose interpretation is still today subject of debate. This function would represent a sort of electron diffusion around the atomic nucleus [5].

The wave function does not propagate in the ordinary three-dimensional space, but lives in a space called *configurations space*, of which we can give a mathematical representation; it is a complex Hilbert space. The values that the function assumes in this space are related to the probability of finding the particle represented by the wave function at that point.

This leads to think on science as a reality that cannot describe Nature in its entirety and totality, but gives us a partial knowledge of it; in this case it answers questions about the *possible results* of the measurements. Before the measurement, the state of the system is in a state of *superposition* of all possible states; after taking the measurement, the system *collapses* into a certain state.

This also leads to two different interpretations:

- of *ontological type*: the wave function represents the reality as it is, and its collapse is the natural evolution of the system following the interaction with the surrounding environment;

- of *epistemological type*: the wave function represents at the maximum degree our limited knowledge of the state of the system and its collapse is not a real physical process, but the updating of our knowledge on the state of the system.

Elementary particles are not just *particles*, which can be visualized as tiny balls of matter (possibly electrically charged), but they are *waves and particles at the same time*. They cannot therefore be located in a specific point in space, but they are *everywhere* in relation to the delocalization of their wave function. Therefore, the electrons do not *literally* orbit around the nucleus; their wave functions form three-dimensional structures called *orbitals* in the space surrounding the nucleus, linked to the probability of finding the electron in a specific spatial region around the nucleus.

With quantum physics we passed from the Democritus hypothesis of an indivisible atom as a building block of primary substance to a set of particles in continuous motion with a *double reality*, a corpuscular and wave reality, governed by the laws of probability and by the uncertainty [6,7].

3. EMPTINESS, MICROCOSM AND MACROCOSM

The atom is a substantially an empty structure. About its size, the atomic nucleus (consisting of protons and neutrons, made up of quarks held together by gluons) has an average size of the order of 10^{-15} meters; electrons move at an average distance of about 10^{-11} meters from it. Therefore, more than 99% of the space occupied by an atom is empty.

Despite this vacuum situation, matter is solid thanks to the electromagnetic forces that hold its fundamental elements together. Electrons do not respond to the laws of classical physics, but to those of quantum physics; in normal conditions they can only occupy discrete energy states starting from a minimum level. The uncertainty principle prevents the electronic cloud from falling on the nucleus, which would happen following the classical laws.

It is this emptiness that we must refer to when thinking to forms and substance, a vacuum that structures the universe; the multitude of events is realized by particles through different rules of ordering and movement [8].

Almost all particles have mass (at rest); being mass and energy linked by the Einstein's relation:

$$E = mc^2 \quad (5)$$

we can say that all elementary particles are made up of energy. We could therefore consider energy as the *first substance* of the cosmos; it has the essential property of being conserved.

In the modern particle accelerators of the world, we are witnessing collisions between particles that give rise to new others; they are experiments providing evidence that all particles are composed of the same substance, i.e. energy.

According to quantum field theory, the physical vacuum does not appear to be nothing, but a potentially active reality, related to the continuous process of creation and destruction of matter. What happens in the infinitely small, at subatomic level, is revolutionizing the human knowledge about the surrounding reality, which appears so different from that described by quantum physics.

In the macroscopic world everything seems to be:

- *deterministic*: it is always possible to know position and speed of an object at the same time;

- *linear*: a movement from a point P_1 to a point P_2 is performed continuously, passing over each point that separates them;

- *causal*: between two correlated phenomena there is always a cause-effect link;

- *local*: distant objects cannot be influenced instantly.

Classical reality rests on these foundations, which have determined and influenced the deductive scientific thinking. In quantum reality, however, what has been indicated above is contradicted. In relation to the four main indicated properties, we can say:

- *uncertainty*: the Heisenberg principle establishes precise limits in the measurement of the values of conjugate or incompatible physical quantities. Following the interference of a quantum system with a measurement system, a precise prediction is not possible;

- *non-linearity*: in the case of a transition from an energy potential to another, a particle such as the electron does not travel through all the points that separate the two extreme points, but performs a sort of instantaneous *quantum leap* between the two levels (and in the operation it absorbs or gives a photon) without assuming intermediate energy values;

- *non-causality*: the values of an observable quantity are obtained in a non-deterministic way through a probability distribution uniquely identified by the state of the system;

- *non-locality*: new phenomena, such as the *quantum entanglement*, show that two entangled particles can instantly influence each other even if they are at very great distances between them, overcoming the barrier of the finite speed of light as means of communication.

Elementary particles constitute the real world and yet the laws that govern their dynamics appear in stark contrast with the laws that govern the behavior of the material bodies they make up. This seems to lead to the renunciation of the hope of a *sure knowledge* of the world based on the so-called *exact sciences*. In the light of quantum physics, the universe appears as an indeterminate and indeterminable reality.

This leads to ask whether we are not using an improper language to describe a reality that goes beyond our current understanding, also in view of a unifying theory that can describe in its totality the physical behavior of the subatomic and macroscopic world.

Quantum physics has introduced the scientific world to the fundamental question of the *observation-observer relation* and of the related level of reality; it often happens that what seems impossible and inconsistent, turns out to be admitted and not contradictory if viewed by a different perspective [9-11].

4. QUANTUM PHYSICS AND TRANSDISCIPLINARITY

The focal theme of the objective or subjective reality of the wave function has involved and is still involving physicists, epistemologists, philosophers, thinkers, neuropsychologists. The Hungarian naturalized American physicist and mathematician Eugene Wigner (1902-1995) proposed the observer's consciousness as a dividing line that triggers the collapse of the wave function; this approach has been resumed and developed over the last few years [12].

The British mathematician and physicist Roger Penrose has developed a model called Orch-OR (Orchestrated Objective Reduction) according to which consciousness originates from processes within neurons, related to microtubules, rather than by the connections between neurons, i.e. the conventional vision. It is a quantum physics mechanism called *objective reduction* and directed by the molecular structures of the microtubules of brain cells, which make up the cytoskeleton of cells. In collaboration with the American anesthetist Stuart Hameroff, he has suggested a relation between the quantum vibrations of microtubules and the formation of consciousness.

Over time, physics and mathematics have studied and presented reality from three distinct points of view:

- the *microscopic view* of subatomic-elementary particles;

- the visible *macroscopic view*, in which we live;

- the *cosmological view* of great intergalactic distances, that is related to infinity.

For each of the indicated sectors, formulas and theories describing the fundamental laws have been studied and elaborated. However, despite the efforts, a unified theory has not yet been found and tested, expressing its validity in the transition from a dimension that tends to zero to one that tends to infinity [13, 14].

Therefore, it is important and constructive an approach that takes into account other human disciplines which can integrate the models presented by physics, coming to consider different levels of reality. It is a transdisciplinary research capable of integrating the human being within it, with due connections with reality.

There are different paths of knowledge, each with its own particular modalities, but which pertain to the same global reality; the *levels of reality*, with their respective different levels of perception, are constitutive of transdisciplinarity.

According to the common scientific approach, the physical laws are valid only within their area of competence; however, the various levels exist simultaneously and those which appear as contradictions in one of them, are no longer so in the others.

This complexity of reality cannot be described by mathematical language alone; it addresses the analytical mind, while the symbolic language addresses the totality of the human being, in relation to his thoughts, feelings and body. The classical Aristotelian logic of *tertium non datur* must be critically reviewed, in the light of a transdisciplinary approach, especially following the discoveries of quantum physics.

Quantum physics brings with it consequences of epistemological, methodological, ontological nature; it highlights two different aspects of reality that are usually indicated with the two concepts of *objective* and *subjective*. Quantum physics has shown that various key points of classical science need to be rethought, such as:

- the *total separation* between the *subject* and the *object*;

- the hypothesis that sees the *material world* as the only *real world*;

- the idea that science can develop *totally independently* by other sources of knowledge such as theology, philosophy, art, neuropsychology [15].

The discovery of the laws of quantum world has led to an integral review of what was previously considered as contradictory in the exclusive sense (A and non-A), in relation to pairs of concepts such as:

- *wave* and *corpuscle*;

- *continuous* and *discontinuous*;

- *local* and *global*;

- *separable* and *inseparable*;

- *reversible* and *irreversible*;

- *symmetrical* and *non-symmetrical*.

This has led to rethinking these pairs of contradictors no longer through the interpretative filter of classical logic, but using new logics.

Physics, prior to the quantum period, was founded on the rigid axiom of *cause and effect*; the study of new phenomena, such as the *synchronicity* studied by the Swiss psychiatrist, psychoanalyst and philosopher Carl Gustav Jung (1875-1961) with the Austrian physicist Wolfgang Pauli (1900-1958), made inconceivable any presumption of a causal link between synchronic events. Non-causality, which seems to have no reason to exist at macrocosmic level, is instead one of the basic principles of entanglement in quantum reality [16].

5. QUANTUM FIELD THEORY AND ENTANGLEMENT

Quantum mechanics is able to describe the behavior of particles and subatomic systems with a high degree of experimental consistency, without taking into account the equally valid conclusions of general relativity. Among the attempts to unify the two levels of reality (macrocosm and microcosm) through a theory of unification, a fundamental step concerns the formulation in terms of *quantum field theory* (QFT). This theory has been developed over several decades through the studies of famous scientists like Paul Dirac, Richard Feynman and Freeman Dyson.

One of the starting points was the observation of the process of emission and absorption of photons by atoms, which is not fully understandable within the quantum mechanical model based on particle mechanics.

In the case of particle emission by other particles, such as the emission of a photon by an atomic electron that loses energy, in the initial state of the system we have only the electron, while in the final state we have an electron and a photon. In the classical formalism of quantum mechanics the number of particles is fixed and the Schrödinger wave function establishes that the particle is always somewhere [17].

Such a situation does not allow to treat the photon as a particle that can appear and disappear; atomic transitions are also possible in which multiple photons can be emitted or absorbed at the same time. The quantum mechanical models developed until then were unable to describe such processes.

It is possible to describe these dynamic processes using the axioms of quantum theory in a different way; it is the so-called *quantum field theory*. The concept of *field* in physics is related to the characteristics and properties that a region of space, even empty, can have, in the absence of matter. The fields are revealed through their *action*, i.e. the production of forces that act on the material objects in the space *filled* by the field.

Among the most classic and simplest examples, we remember the electric and magnetic fields, which fill a region of space and attract or repel electrically charged objects and magnetized objects respectively.

Quantum field theory describes the behavior of elementary particles and its visualization and statement is more complex than with a classical field. Considering the validity of the uncertainty principle, the smaller is the region being examined, the larger and faster are the fluctuations; classical models are unable to correctly describe the properties of the quantum field. The quantities we can talk about are in fact the averages of the velocities over regions of space and in time intervals.

It is not easy, if not through qualitative analogies that often do not convey the idea, to explain in non-technical language how particles emerge by the fluctuations of a field, yet this is what really happens [18].

The image of the world described by the QFT can be summarized as follows: there are a certain number of different quantum fields, related to the various types of elementary particles. Each of them fills all the space and has its own particular properties; there is nothing else, only these fields, which make up the entire material universe. There are different types of interaction between the various fields; the number of particles of a given type is not fixed, as new particles are constantly being created or destroyed or transformed into others.

The classical electromagnetic field can be accurately described by QFT, with *photons* as its reference particles. The elementary particle corresponding to the gravitational field is the *graviton*, even if its detection is proving problematic at experimental level. This is also due to the extreme weakness of the gravitational interaction, which requires big masses to produce observable gravitational effects, with a huge number of involved gravitons. Consequently, observing a single graviton is a very hard circumstance.

QFT needs the strong support of mathematical theory at its foundations; on a qualitative and approximate level, we can think of a quantum field as a *tissue*, composed of very small vibrating springs correlated with each other, which extends into known space. The fabric is rippled and these ripples represent what we call *particles*.

It happens that a large number of ripples come together and jointly move along the fabric; this gives rise to a macroscopic object. A single particle, on the other hand, is a lonely and quantized excitation of the tissue; when the fabric is subjected to a strong shock, the particles can be created or annihilated. The quantum mechanical interactions among the various particles are described as terms of interaction between the corresponding underlying quantum fields; therefore, the fundamental constituents of matter and their interactions are not particles or waves in the classical sense, but a *quantum field*. Each type of elementary particle is described by a quantum field; particles represent elementary excitations of the quantum field, and matter manifests itself in response to the interactions of the field.

QFT made possible to describe the behavior of a great variety of atomic and subatomic phenomena very well. This is not only a theoretical success, but also an experimental one, especially in the field of interactions between light and matter. The field exists everywhere and is the vehicle of all material phenomena, a vacuum filled with energy that allows the creation and dissolution of particles.

This vision offered by QFT therefore requires to leave the classic distinction between material particles and vacuum; they must be considered as condensations of the field that is present in all space and therefore cannot be seen as isolated entities. Empty space is therefore not empty; it appears in this way because the incessant creation and destruction of particles occurs in extremely short time intervals that no material time is left for their detection.

In consideration of the uncertainty principle between energy and time, in very small time intervals, matter-antimatter pairs can be created, such as an electron and a positron; the effects of these spontaneous behaviors were measured in laboratory in accordance with the uncertainty principle. The vacuum contains therefore an unlimited number of particles that are continuously created and annihilated.

We can make an intuitive connection between the quantum field, understood as the underlying *fabric* of the universe, and the creator deity Prajapati of Vedic culture, who sustains every event. New models are being developed that describe the reality in its totality, i.e. understood as composed of dense energies, together with subtle energies related to the non-material aspects of reality, such as consciousness [19, 20].

Of all phenomena appeared during the development of quantum physics, the *entanglement* represents the most amazing reality; it has generated since its discovery an incredible enigma that collides not only with classical physics, but also with relativistic physics.

Two particles are in a state of entanglement (they are *entangled*) when the properties of one are totally correlated with the properties of the other; two entangled particles do not represent two separate entities, but the manifestation of a single entity.

If two particles, which have interacted with each other at least once, are separated and moved away even at a very great distance, when a measurement is made on one of them, the collapse of the wave function that describes its state is determined, making manifests one of its properties. At the same instant, even if the distance between them is enormous, the measurement operation on the first particle *instantly* influences the other, whose wave function will collapse anyway.

The phenomenon of entanglement was described on a theoretical level in the early decades of the twentieth century, but was highlighted in laboratory starting from the mid-sixties of the last century; it was fully demonstrated in 1982 by physicist Alain Aspect. Already in 1935 Schrödinger had glimpsed it [21].

The instantaneous reaction that the entangled particle undergoes following an action on the other particle seems to violate and exceed the limit imposed by the finite speed of light. In fact, this violation is not to be considered wrong, as there is no *propagation of signals* between the two particles as there is no cause-effect mechanism in the phenomenon; there is nothing that physically travels from one particle to another. It is not a propagation of signals, but is the intrinsic deep structure of the universe, where there is an intimate link beyond space and time.

At the beginning of studies on entanglement, it was thought that entanglement was confined only to the region of very low temperatures (near absolute zero Kelvin) and only for extremely short time intervals, since only in these particular situations it seemed possible to reproduce the phenomenon in laboratory. Surprising findings were then analyzed that overruled the previously mentioned restrictions. A striking example of *biological entanglement* has been studied by Penrose and Hameroff in relation to the quantum behavior of consciousness.

According to their Orch-Or theory, the microtubules present in the brain, which constitute the cytoskeleton together with the microfilaments and intermediate filaments, and whose main function is organization and intracellular transport, would be in perfect state of entanglement.

According to this theory, the *conscious moment* corresponds to the *collapse of the wave function* which collects in itself, in a single quantum state, the global entanglement that unites the microtubules of the brain. This phase was referred by them as *orchestrated objective reduction* (Orch-OR). The presence of quantum vibrations in the microtubules of brain neurons seems to be experimentally confirmed [22, 23].

6. QUANTUM PHYSICS AND NANOTECHNOLOGIES

Nanotechnologies allow the realization of functional materials, devices and complex systems through the control of matter on atomic or molecular scale. Historically, the birth of nanotechnologies is fixed in 1959, the year in which Richard Feynman, in a famous speech at Caltech, showed that, with the knowledge of physics at that time, there seemed to be no obstacles to miniaturization [24].

Nanotechnologies are *based* on *quantum mechanics*. These are objects made up of a few tens or hundreds of atoms/molecules that have different or intermediate properties from those observed in molecules and solids.

Starting by Rutherford's conclusions on the atomic structure, i.e. a small nucleus of great mass in the center with electrons moving around, Bohr introduced with his model the quantization of energy states starting by a hydrogen-like atom. Using the equations of classical physics, he obtained the allowed orbits and the binding energy of the electron in these orbits.

Quantum mechanics confirmed the presence of the energy quantization and the cause of the emission of electromagnetic waves from an excited atom, introducing the concept of *wave function* and *probability*, allowing the calculation of energies and states of many electrons atoms, as well as the probability that an electron passes from one state to another. To calculate the energy and wave function of an electron in an atom we use the Schrödinger equation.

When we go from single atoms to molecules, the atomic states combine to give rise to *molecular orbitals*. In the case of a heteronuclear molecule, the energy levels of the states in individual atoms are generally different, but the effect is similar, i.e. the formation of binding and anti-binding states whose energies are, respectively, lower and greater than those of the atomic states combine.

When we move from molecules to solids, the effect on energy levels is similar to that observed in the transition from single atoms to molecules, with the addition that in this case we have to consider a much larger number of levels. Considering that the average distance between 2 atoms in a solid is about 0.1 nm, in a cube with side L = 1 cm we have about $(10^8)^3 = 10^{24}$ atoms (in fact it is about 10^{22} cm^{-3}) [25]. If the number of atoms becomes very large, the levels become so numerous that they form a continuum, called *band*. The energetic distance in the band between one level and another is such that it is possible to treat them just as continuous levels.

These bands are formed by the more external electronic states of the atoms making up the solid.

Between one band and another there is an area in which there are no permitted electronic states; these are the so-called *forbidden areas*. The distance between these bands varies by fractions of eV (of the order of tenths or less) up to some eV (1 eV = $1.602176634 \times 10^{-19}$ J).

The transition, i.e. the passage of an electron from one band to another, occurs in general due to the thermal effect or to absorption of a photon. The bands in a solid, which concern the more external electronic states, are divided into *valence* and *conduction bands*.

The development of nanotechnologies is mainly due to the possibility of *seeing* the created nanotechnological objects. Among the main techniques to do this, we remember the scanning electron microscope (SEM), transmission electron microscope (TEM), scanning tunnel microscope (STM) and atomic force microscope (AFM).

The limit resolution of optical microscopy is about 500 nm (diffraction limit); with the microscopy indicated above, on the other hand, using fast electrons (high energy electrons), images with a resolution lower than 0.1 nm can be obtained [26].

The possible applications of nanotechnologies are constantly growing, in the fields of:

- *materials science* (powders, coatings, carbon-based nano-materials, carbon-based nano fabrication);
- *energy* (solar and photovoltaic, hydrogen for fuel cells, white light LEDs);
- *medicine* and *biotechnology* (genomics, proteomics, lab on a chip, nanotubes, nanofibers);
- *electronics* (MRAM, NRAM, Q-dots, Q-bits);
- *devices* (lithography, dip pen lithography, AFM, MEMS).

It is in *no way* possible to explain the charge transport (current) properties from the microscopic point of view *using classical physics*. The operation, for example, of the MOSFET semiconductor transistor is based on the theory of solids that derives by quantum mechanics, through the use of the concepts of energy bands, Fermi level, density of states, Fermi-Dirac distribution, etc.

Through chemical synthesis it is possible to build nanoparticles (NPs) of various nature and with different sizes, which have intermediate properties between single atoms/molecules and solids [27].

For materials science, the priority is the discovery and design of new materials, in particular special materials with high innovation potential (smart and self repairing materials), biomaterials, nanomaterials and materials for alternative energy sources. In the near future, it is expected the control of phenomena affecting materials at the nanometer and femtosecond scales and under extreme operating conditions.

To achieve this goal, nanotechnologies contribute for obtaining new properties by acting on the dimensionality, exploiting the extreme reactivity of the surfaces and the surprising quantum effects that regulate the behavior of atoms [28-31].

7. CONCLUSIONS

The extraordinary discoveries related to the most intimate structure of matter have not limited to upsetting the scientific world of physics from its very foundations, but have introduced a *metaphysical revolution*. Physics has always been linked to philosophy, therefore every discovery in the physical field always carries a philosophical character.

It can basically be:

- of *ontological nature*, i.e. relating to the being of specific scientific knowledge regardless of its relation with the observer;

- of *epistemological nature*, when it refers in particular to the relation of the scientist as experimenter with the object under examination, therefore relating to the conditions under which scientific knowledge can be obtained and about the methods to achieve it.

Quantum physics had a great importance regarding the modification made to the epistemological theory on the relation of existence between subject and object. The probability wave is inserted between the *idea of an event* and the *event itself*, a strange physical situation between *possibility* and *reality* [1, 5, 7, 10, 23].

The new and strange behavior of particles is in strong contradiction with schemes and rules of classical physics, and brings to mind analogies with ancient sapiential cultures. Modern physics, which has quantum physics as its basis, is progressively attenuating the divergences and harshness of the debate between science and religion.

Science and religion are two windows through which it is possible to look at for understanding the mysteries of universe; they offer different points of view, but they can complement each other. The problem arises when they claim the right to be infallible.

With quantum physics, the world of subatomic particles appears as a network of relations between the various parts of a *single whole*. The classic concept of *isolated particle* becomes an idealization; it can be defined only in relation to its connections with the whole, and these connections are of a statistical, probabilistic nature. Uncertainty becomes crucial in the world of modern physics, overcoming a classical approach governed by precise, univocal, indispensable laws.

By observing a system, we interfere with it, we make interact our macroscopic level of reality with the microscopic one; the macroscopic world determines the microscopic reality from which it in turn is formed. Quantum measurement leads to this strange situation.

Yet without quantum physics, the human being would not have discovered and invented a whole series of things that we use everyday in our life today. However, despite all these novelties and successes, quantum physics as a whole can explain *how* the systems interact with each other, but not the *why* of this continuous interaction of energy.

This interactions generate an incessant exchange of particles in a process of continuous creation and destruction, and this leads to the stable structures of the material world that surrounds us and of which we are made.

So, even in the context of a science that defines itself as *exact*, energy seems to have a transcendent quality. In the human being does not seem to be a marked distinction between a body and a soul; the so-called body can be considered as a manifestation of the soul. Energy is life, and proceeds from the body.

Biography

Paolo Di Sia is currently adjunct professor by the University of Padova (Italy). He obtained a bachelor in metaphysics, a master in theoretical physics, a PhD in theoretical physics applied to nanobiotechnology, a PhD in Mathematics, a PhD in Philosophy (of Science). Scientific interests: classical-quantum-relativistic nanophysics, theoretical physics, theories of unification, metaphysics, mind-brain science, history and philosophy of science, science education. He is author of more than 300 publications to date (papers on national and international journals,

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