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The philosophical basis of the
Arrangement Field Theory (AFT)

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Abstract

The Theory of the Arrangement Field of the space-time points is briefly exposed and its basic philosophical background is outlined. The Arrangement Field Theory has been proposed in 2012 by Diego Marin and intends to be a theory of everything, capable to describe all particles as different manifestations of a single, unified field. This new conception might represent a remarkable improvement of current Quantum Field Theory. It also includes some features of String Theory and Loop Gravity. In the AFT, distance between points of space-time are regulated by quantum amplitudes, so that concepts as "near", "far" or "between" become limited, and quantum entanglement can find an elegant explanation.

Keywords: Quantum Mechanics, Entanglement, Relativity, Philosophy, Free will.

Table of Contents

1 – How the universe is conceived in classical physics.

According to classical physics, space and time are absolute and fundamental entities. In analyzing the events which take place in the universe, it is assumed that the extension of space and the flowing of time form a preordained structure, within which the interactions between physical objects can take place. Moreover, the physical properties of an object or physical system are supposed to be objective and independent of a possible observation made by a scientist (or any conscious person). In this paradigm, reality exists independently of measurements and is not significantly influenced by them: it is supposed that the observation of a system does not alter its physical characteristics, unless it is particularly "invasive", or implies remarkable operational influences. Even in highly "invasive" cases, however, it is assumed as obvious that the observed object possessed preexisting characteristics, certainly not predetermined by the process of observation occurred later.

The facts that space and time are absolute, and that the observation of a physical system does not significantly alter its properties, appear as natural and implicit tenets of classical physics and that may be expanded to whole science, in its continuous development towards pure universality and objectivity. Such a purpose appears to have a solid foundation in the structure of space-time, that is implicitly considered unchangeable and perfect, a huge four-dimensional lattice that represents the theater where all the events of the universe occur, compared to which the figure of the observer and the act of measurement are virtually irrelevant.

Living in the objective universe, we can act on nearby objects and possibly modify them, but we can not operate directly against space or time: at most we are allowed to "occupy" some parts of space, during periods of time, but, apart from this, space and time happen to be "unassailable" imposed over us, regardless of our will. These considerations are shared by the majority of human beings and appear as absolutely obvious or even trivial.

However, starting from the second half of the seventeenth century (when modern science had just taken the first steps) until the beginning of the nineteenth century (when science was definitely established), a number of famous philosophers such as Locke, Hume, Leibniz, Kant and Schopenhauer, conceptualized and described space and time not as objective and universal entities, separated and independent by conscious human beings, but (in a strikingly different way from the one conceived from science) as concepts defined by our own intellect and intuition, for the purpose to interpret and understand reality, both as a whole and in its various aspects. On the other hand, the extraordinary results obtained between 1600 and 1900 by classical, mechanistic physics, appeared to be in a irreconcilable conflict with the unusual convictions of those philosophers, and seemed to confirm the "solid materiality" and "objective persistence" of the world. Space and time really seemed to be absolute structures on which "objective" reality was actually based, whereas the considerations by Kant and the other mentioned philosophers appeared unrealistic, unfounded and misleading fantasies.

In the early twentieth century, however, physics began to face certain problems and contradictions, and was forced to accept several radical changes. First of all, Einstein's *theory of special relativity* [1] indicated that time flowed differently in different inertial systems of reference, and the perception of space was also different depending on the system of reference. Time and space lost their absolute characteristics if considered separately (as independent from each other), but, together, remained absolute as a single unified *"space-time"*, a generalized geometrical entity which included, in addition to the three-dimensional space, time as a fourth coordinate, thus forming a structure in four dimensions (also called *"chronotope"*) constituted by points also called "events". Furthermore, the speed of light, symbolized by *c*, showed to remain invariant in all inertial reference systems, since demonstrated not to be subject to composition with the motion of the observer.

It is well-known that the speed of light is very high: in order to accelerate a material object to comparable high speeds (as seen from a given system of reference), more and more energy would be required, until the purpose would prove impractical, since the required energy would be excessive and, to the limit, infinite. The constant *c* thus showed to be an insurmountable speed limit.

2 – The limitations of objectivity according to quantum mechanics.

After Einstein proposed his theory of special relativity in 1905, in the next three decades the concept of "objectivity" of physical events was somehow weakened by the discoveries and the research methods of quantum mechanics (QM). Quantum theory was born in 1900 as a result of the hypothesis proposed by Planck [2] to solve an important problem in thermodynamics of radiation, specifically about *"electromagnetic emission of the black body"*. Planck postulated that the activity of matter at very small scales, ie, the molecular and atomic levels, occurred through "leaps" of energy, so that the radiation was not uniformly emitted, but by discrete amounts, called "quanta" of light or "photons". Einstein, in 1905 (the same year he formulated the theory of relativity) used the concept of Planck in order to solve the so-called *photoelectric effect* [3] in which the light could also be *absorbed* in quanta (besides being *emitted* in quanta as in the Planck's case of the *black body*).

During the following years, the first details about the internal structure of atoms started to emerge: Rutherford in 1911 showed that most of the mass of the atom resides in the small nucleus, around which the electrons, much lighter than the nucleus, somehow "orbited" [4]. Rutherford's experiment represented a major step in the development of atomic physics, i.e. in the gradual process to understand the atom, its structure and behavior, much of which consisted in activity and interaction with light and other electromagnetic radiations.

Each chemical element can emit and absorb light (or electromagnetic radiation) with specific frequencies (which correspond to specific wavelengths) that are characteristics of the chemical substance under consideration, and distinct from those of other elements. Physicists were able to measure these wavelengths with remarkable precision, but did not understand the laws determining them, yet. They knew that these phenomena were produced by the individual atoms of the chemical elements. So, these phenomena involved various different disciplines such as optics, electromagnetism, thermodynamics, general physics and general chemistry, but none of these sciences could provide a proper and complete explanation of the observed results.

In 1913 Bohr proposed a model of atom [5] that eventually could explain a large amount of the experimental data, almost all those collected in spectroscopy during several previous decades, especially regarding hydrogen and other light gases: in such cases accuracy between the new Bohr's theory and experimental data were extraordinary, although in the cases of heavier atoms the situation was not as good, and certain corrections were necessary.

Bohr was inspired by the discovery made by Rutherford two years before, and, even more important, had used the new concept of "quantum", the one that Planck in 1900 (*black body*'s radiation) and Einstein in 1905 (*photoelectric effect*) had already successfully applied. In this case, however, Bohr did not impose the quantization on the energy of photons (either emitted or absorbed) as in the two previous cases (of Planck and Einstein) but proposed to quantize the angular momentum of the electrons in their (alleged) orbits around the nucleus. As a consequence, energy also were quantized. It was specifically a consequence of quantization of the angular momentum, rather than an "a priori" and direct quantization of energy.

By performing simple calculations upon the simplest atom in nature, hydrogen, whose nucleus is a single (positively electrically charged) proton around which a (negatively charged) electron somehow "moved" (in a different way than in classical physics), Bohr found that the possible energies of the electrons were also quantized in a series of energy levels whose respective differences excellently matched and explained the spectral lines showed by hydrogen. In the case of more complex and heavy gases, the picture became less precise and mathematically more difficult: the agreement between theory and experimental data turned out to be less precise. However, it was clear that quantum physicists were progressing towards the right direction.

The model of Bohr had shown that quantization was not exclusively related to energy, but was something more general and important, since could be also related to the angular momentum of electrons in the atoms. The "Bohr model" represented a turning point for the development of quantum mechanics (QM), which gradually showed to be able to describe virtually all the phenomena of microscopic systems, such as molecules, atoms and subatomic particles, making QM the foundation of molecular physics, atomic, nuclear and sub-nuclear physics, which cover the whole realm of microscopic reality.

As said, the results provided by the Bohr atom model were very good but nor perfect neither complete yet: in the case of heavier atoms many details could not be explained. The laborious subsequent researches (conducted mainly by the School of Copenhagen in the 1920's) brought the theory to be mathematically more precise, but intuitively more abstruse and incomprehensible. There was not a clear view of the movement of the electrons around the atomic nucleus.

3 – Quantum uncertainty, the role of the observer, entanglement and non-locality.

While developing the quantum theory, it began to emerge that experiments inevitably influenced the observed systems. At one point, Bohr and other physicists of the so-called "Copenhagen school" (from the city of Bohr) began to suspect that physical properties of particles and quantum systems could no longer be assumed to be completely predefined and independent from the observation! In the first version of the so-called "Copenhagen interpretation" they arrived to assume that the will of the conscious observer (i.e. the scientist performing the experiment) played a decisive role in the collapse of a quantum state to a single eigenstate [6].
The natural and reasonable attitude of scientists (and generically human beings) towards interpreting external reality, since Galileo, was to believe that the universe had objective characteristics of its own, so that it followed its course independently of whether we observed it or not. Galileo, Newton and most of the first modern physicists were astronomers too, so

that their natural attitude while looking at distant stars implicitly included the conviction that they had no possibility whatsoever to influence those observed objects by any means. This conviction of a purely objective universe, unconsciously continued to dominate scientists' attitude in viewing reality, not only when familiar, typical objects of daily life were examined and studied, but even when physics began to deal with microscopic objects such as molecules and atoms. In classical physics, the examined bodies are always considered as objectively and exhaustively defined by their own properties. However, we know today that quantum particles and quantum systems are mostly described by states that do not contain all the possible information that may be attributed to a classical, macroscopic system.

A quantum state is essentially defined by a mathematical superimposition of so called "eigenstates". It is a complex state which deterministically evolves but remains deprived of certain characteristics, that can be expressed and "objectivated" only when the state collapses (probabilistically, not deterministically) to one of the possible "eigenstates" associated to a physical quantity. That is the reason why physical quantities in QM are called "observables": because they remain in a virtual, abstract state until they are observed. However, eigenstates are a minority compared to generic states. Moreover, eigenstates are usually different, depending on which physical quantities ("observable") is measured. For example, a fairly accurate measurement of the position of a particle (usually denoted by q) implies an inaccurate measurement of the velocity v, having the small uncertainty Δq a relationship with the uncertainty on the momentum Δp according to the *"uncertainty principle"* of Heisenberg [7], which states:

$$\Delta p \, \Delta q \geq h / 4\pi \ .$$

The uncertainty principle puts an end to absolute determinism that seemed implicit in classical physics. The previously rigid chains of cause-effect now admitted a margin of "uncertainty", in which Nature seemed to reserve a small room for Her own non-predictable "willingness". Not only. The subsequent course of the physical system was inevitably changed by the measurement process that occurred, and therefore its course was no longer completely depending on the rigid determinism of classical physics, since the observations and measurements inevitably imprinted different directions to the events any time a measurement was made.

The message coming from QM was hard to accept: reality was partly "created by the observer". In the simple example above, the scientist decides to accurately measure the position q, and the system adapts to such a choice, even if in a very small amount, but still in a deeper sense than even the physicists could understand at that time. They were aware that QM was quite a strange and unusual theory, but only during the 1930's most of the physicists began to realize the big implications that it could have.

Initially physicists believed that the source of that uncertainty was a simple and obvious "operational disturb" caused by the physical intervention of the measuring instrument, such as Heisenberg himself explained in 1930 with the example known nowadays as the "Heisenberg microscope" [8]. Still today, a few physicists believe that this is as an obvious, sufficient and complete explanation. But the actual influence of observation on the state of a particle or a quantum physical state is far more "subtle" than that, and constitutes a point of crucial importance for physics, a point that has been capable to shake the foundations of the entire science and its supposed pure "objectivity".

In 1932, von Neumann tried to reorder and fix mathematically quantum theory [9], highlighting that there had to be something which "broke" the classical linear evolution. A few years before, Schrödinger, developing an original idea by De Broglie [10], who had attributed also wave-like properties to the subatomic particles, formulated his wave equation [11], offering an extremely valuable alternative formalism, called "undulatory mechanics", which showed to be much more intuitive than the abstruse "matrix mechanics" (then still called “quantum mechanics” in an exclusive sense, as though “undulatory mechanics” was not a part of the same discipline) that had been developed by the "Copenhagen School", and that later was simply called “Heisenberg representation”. Schrödinger equation showed that "wavefunctions" were able to describe the deterministic evolution of microscopic systems, following the usual and "classic" principle of causality, but at the time of a measurement, the wavefunction had to suffer a "collapse" from a linear combination or superimposition of "wave eigenfunctions" (each with its own amplitude) to just a single one of those eigenfunctions.

Von Neumann believed it was worth to reassess the first basic idea of "Copenhagen interpretation" [6] that the "collapse" of a state into an "eigenstate" (or equivalently, in the “Schrödinger representation”, the “collapse” of a "wavefunction" into one of the different possible "wave eigenfunction"), giving a single “eigenvalue” as the result of the physical measurement performed, among the set of possible “eigenvalues”, was due to the act of measurement performed by an observer.

The inevitable criticism that followed against that hypothesis, which seemed to deny or limit the classic concept of "objectivity" of reality, led Bohr and Heisenberg to change their interpretation, making it based on the assumption that the “collapse” was sanctioned by "irreversible thermodynamic reactions" implied in the processes of measurement (such as in the case of an electron which leaves an indelible trace on a detector). With hindsight of nowadays we can see in such an attempt to fix the supposed problem (that did not exist actually, if not in the mind of the many scientists still obsessed by the prejudice of a pure and absolute objectivity of reality), a clear and obvious logical inconsistency, since the thermodynamic phenomena should be interpreted in terms of statistical products of the collective behavior of the particles, in turn explained by the behavior of the individual particles, and not vice versa. This new interpretation would claim that the existence of a single particle can be "objectifiable" into observable reality as a consequence of thermodynamics, that is to say, of collective particles phenomena, which forms a self-referential, circular and inconsistent reasoning standing on nothing.

Furthermore, even if such a new interpretation was valid, however it would relate matter fields interacting with other matter fields, with nothing being there as a distinctive pattern to cause the discontinuity of quantum "collapse", so that it would be reasonable to expect the deterministic wavefunction development to go on with nothing happening, i.e. with no collapse or discontinuity. According to von Neumann, the intervention of something new and different would be necessary to create the collapse, and that new element could be the observer's conscious will.

In this new conception, objective reality cannot be anymore considered as self-referring to itself, but had to be subjected to be observed, tested and measured by scientists, in order to actually show its real existence. This may be surprising initially, but after a deeper analysis, it should be recognized that the fundamental attitude of the Galilean science was based on experiments rather than on pure speculation about a "totally objective reality" independent from the observer! Such alleged and imagined “objective reality”, paradoxically, is definitely more "metaphysical" than the experimental science of Galileo, that was based to real facts and observations, rather than on an abstract mental image of a self-standing, absolutely objective reality. Therefore, the hope that an absolute "objectivation" of reality may really exist sounds nowadays as an illusion to most quantum physicists.

Returning to von Neumann, the mathematician who formally arranged QM into a complete theory, he aligned himself with the belief that the conscious observer had a decisive role in causing the "collapse" of the quantum states into eigenstates: this radically new conjecture was supported primarily by Wigner and Jordan, and more discreetly by Pauli, Bohr, and perhaps Heisenberg, who decided to maintain a cautious and diplomatic position, which, while defending the Copenhagen interpretation, avoided to express strong convictions, and simply declared that it was necessary to follow a "logical positivism", closely and exclusively related to the observed experimental phenomenology.

In the meanwhile Jordan, also from the Copenhagen group, had proposed that "free will", which we believe to have got as humans beings, was due just to quantum uncertainty acting at the subatomic levels of the brain. In a purely deterministic view, man would just be a puppet in the hands of rigidly mechanical laws, and his conviction of possessing a free will and be able to create or modify events, would be just an illusion. Bohr perfectly exposed this concept noticing *“the contrast between the feeling of free will, which governs the psychic life, and the apparently uninterrupted causal chain of the accompanying physiological processes”* [12].

Quantum uncertainty, far from being seen as a problem by many of the quantum physicists, according to Jordan finally provided a window of opportunity within which the human will, through some mechanism operating at atomic or subatomic level in the neurons inside the brain (and in generally in the whole nervous system) could act upon the so-called "objective world" and modify it to a certain extent [13]. The situation instead would not become better by attributing the uncertainty to blind chance, as a few physicists still believe as of today, since man would remain a puppet in the hands, rather than deterministic laws, of irrational random choices at subatomic scales, all which does not match with our experience of conscious beings who know (or believe they know) what they want and – wherever possible – they are actually able to do.

In the following decades such hypothesis of quantum uncertainty as being related to our free will was supported by other physicists such as Wheeler [14] and, more recently, by Stapp, who in 1982 proposed again in detail that conjecture, and called it "creative" the human mental activity, because only partially undergoes the course of causal mechanisms and has got a margin for free choices [15].

Returning back to the Copenhagen School, it is interesting to quote the apparently "neutral" opinion of Bohr, trying to balance and satisfy the convictions of all the different positions of the physicists who were trying to understand the real nature of QM. Even if he was very diplomatic, his belief was probably the same as Wigner's and Jordan's, as it turns out from many of this statements, such as the following:

"In every experiment on living organisms, there must remain an uncertainty as regards the

physical conditions to which they are subjected, and the idea suggests itself that the minimal freedom we must allow the organism in this respect, is just large enough to permit it, so to say, to hide its ultimate secrets from us. On this view, the existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting point in biology, in a similar way as the quantum of action [the Planck constant *h*]*, which appears as an irrational element from the point of view of classical mechanics, taken together with existence of the elementary particles, forms the foundation of atomic physics"* [12].

Bohr also added many other comments on certain apparent similarities between the human mind, which, even though surrounded by various thoughts, images, perceptions and other mental impressions, is able to focus its attention on one at a time: *"The inevitable influence of observation on atomic phenomena* [the collapse to a single eigenstate] *here finds its correspondence in the color change of the psychic experience, which accompanies the act of directing attention on one or another of its parts*" [12]. By the way, the similarity with one of the basic principles of the psychology of Gestalt is noticeable.

Returning to the simple explanation of quantum uncertainty in terms of an "operational disturb" due to the measurement: if the matter was that simple, there would not have been those compelling reasons, between 1900 and 1935, to build such a new theory such as QM. Of course, also in classical physics there are "modifications" due to the observation of an object or a physical system, although these modifications are, in principle, reducible at will and become insignificant, while in QM cannot, since the quantum of action *h* is non null and cannot be divided. The limitations imposed by the operating characteristics of the measurements and by precision of instruments in classical physics had been managed for centuries by the so-called "theory of errors", a sub-discipline of statistics which assesses the limits of precision associated with physical measurements. But the simple theory of errors, of mere operational nature, certainly does not include fundamental principles or universal physical constants - such as the Planck quantum of action *h*.

QM is not a secondary branch of measurement theory or statistics, but is a "real" physical theory, new and different, not dealing with the limitations of our measuring instruments and our methods, but about the limitations implied in observability of the quantum systems, which we must admit to be coincident with their “reality”, that can no longer be "imagined" as independent and preexisting. The laws of QM describe observational aspects that are, at the same time, also ontological qualities characterizing and governing the microscopic levels, where inevitably observer and observed are merged with each other, just as observation and event are, and, ultimately, as perception of reality with reality itself are either.

These unusual and unexpected limitations on the knowledge of the "objective" reality were obviously uncomfortable for those scientists with a more "objective" vision than others, i.e. those who more than the others believed that the objectification of reality was an “a priori” feature of Nature. Among these scientists, Einstein emerged, while in the opposite side, old and sage Bohr, with great diplomacy, became the most respected figure.

In 1935 Einstein, Podolsky and Rosen proposed a "thought-experiment” known today as the "EPR paradox" [16]. The purpose of E., P. and R., was to show that, assuming that quantum theory is valid, it would lead to consequences that (according to them) are absurd, including the violation of the "principle of locality", which could result in instant communications (therefore faster than the speed of light *c*) between particles far away form one another, if previously had been connected by a quantum "superposition" or "entanglement". EPR intended to propose a “reduction to absurdity” reasoning, assuming that violation of the principle of locality is impossible. But they did not take into serious consideration that Nature might actually behave just in that manner that they “a priori” defined as "absurd".

In 1951 Bohm reformulated the EPR paradox into a more understandable physical example, where the “entanglement” is based on a superimposition of spins [17]. It was implicit in the EPR paradox that certain "hidden variables" must exist, not yet discovered and provided by the quantum theory, but that could make reality completely "objective" and solve the alleged paradox. According to EPR and even Bohm himself, the fact of not having yet found those "hidden variables" was just a limit of quantum physics and physicists, rather than a demonstration that Nature behaved in a (supposed) absurd way. Although QM gave excellent scientific results, they did not believe that it was a complete theory capable to consistently explain the physical phenomena of reality and give an exhaustive view of the universe, that they still conceived in the classical, purely "objective" terms.

In 1964 Bell formulated a theorem that allowed to establish, through really feasible experiments, whether the "hidden variables" invoked by EPR actually existed, and then whether the universe had to be considered fully "objective" [18]. In such case, a certain statistic value, calculated from actual measurements in a quantum mechanic experiment, should be smaller or equal to 2 ("Bell’s inequality"). The standard QM theory instead admitted values greater than 2, up to a maximum (in the case of a certain limit configuration) of 2 times the square root of 2, which is about 2.83 in decimal terms.

The first experiments, conducted since 1972, showed an actual violation of the inequality, with the resulting values randomly oscillating just over 2, suggesting that Nature actually behaved in the "absurd" way that EPR had excluded “a priori”. These early experiments, however, were not very precise and presented non-negligible experimental errors, close to the limits of acceptance for the validity of the experiments themselves.

The "decisive" experiment was conducted by Aspect, Grangier and Roger at the end of 1981 and described in a paper [19] published in 1982: the result obtained was 2.70 with a 0.05 experimental error. These numbers ensured that the searched value was definitely greater than 2. Later several other experiments confirmed the violation of Bell's inequality. In a nutshell, EPR were wrong: there was no paradox, the principle of locality was indeed violated somehow by entangled particles (which was not absurd), there were no "hidden variables", and the universe could not be considered fully objective according to the canons of classical physics.

4 - Space and time in the theory of relativity.

In the perfect objectivity of classical physics, bodies are inside the three-dimensional space, conceived as a huge container in which objects can move and interact with each other according to exact laws and mechanisms in function of time, which in turn is marked by an ordered sequence which flows in the same way everywhere, uniformly, and independently of the objects.

The Galilean transformations [20] are simple linear equations which allow to convert the space coordinates (*x, y, z*) of an object measured in some inertial reference frame *S*, into the coordinates (*x', y', z'*) of the same object a different system *S'*. The formulas include the relative velocity *v* between the two systems, the spatial coordinates *x, y, z*, and time *t*, a common parameter that flows in the same way in both reference systems (and in all the other possible ones): in other words, time *t* is absolute. The three spatial coordinates can be transformed separately from each other, but calculating the length of any object in the new coordinates (or the distance between any two points), the result remains the same. So the also three-dimensional space as a whole, i.e. including all its three dimensions, is considered as absolute.

Galileo also enunciated the "principle of relativity" [21], according to which the laws of physics remain the same in all possible inertial systems. Nearly three centuries later, Einstein's theory of relativity took this principle and perfectly adjusted and adapted it to the optical and electrodynamic discoveries occurred in the meantime. So, in 1905, Einstein defined as absolute the speed of light *c*, which plays a special role compared to other velocities in physics. But for Galileo, who lived long before philosophers like Locke, Hume and Kant, and did not know electromagnetism or other new branches of physics, his assumptions were reasonable and natural: in fact, even Newton, building the large conceptual building of classical mechanics and the theory of gravitation, continued on the same way, assuming that space and time were absolute, or (so to say) "Galilean".

At the end of the nineteenth century, however, the finding of an underlying physical problem in classical electrodynamics arose and remained unsolved for years. Einstein in 1905 described such a problem in a masterly way in an historical article, which even provided the solution of the problem, and which created the foundations of the theory of relativity [1]:

"It is known that Maxwell's electrodynamics [...] when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighborhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighborhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise [...] to electric currents of the same path and intensity as those produced by the electric forces in the former case".

More formally, Maxwell's equations include the current density *J*, which is not invariant in different inertial reference systems. Einstein also explained the experiment of Michelson and Morley [22], which had shown that the speed of light did not follow the classical laws of addition of velocities (also due to Galileo [21]), since it does not vectorially sum to the speed of Earth in its annual orbit [1]:

"Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the 'light medium', suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that [...] the same laws of electrodynamics and optics will be valid for all

frames of reference for which the equations of mechanics hold good. We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate [...] that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies".

In this way there is no privileged frame of reference, and all inertial systems became equivalent, as was already realized by Galileo (who did not know electromagnetism, of course). To solve the problem, it must be assumed that there is a universal physical constant that is independent of the reference system: the speed of light c. Before Einstein, no physicist had found such solution, which implied that the time t had to flow differently in different reference systems, and further on (as a consequence), that mass and energy were two aspects of a single entity.

In special relativity the classical Galilean transformations are substituted by the Lorentz transformations [23] which convert the coordinates (x, y, z, t) of the reference system S into the coordinates (x', y', z', t') of S'. Unlike the Galilean case, the time t does not remain the same but is transformed into t' (actually, for dimensional consistency, and because the time contributes with a negative term in the four-vector length, the product ict is used as the fourth coordinate). What is "invariant" in all systems is the "length" of four-vector (which includes time and is hence a generalized length), while the equations describing the laws of physics are "covariant", that is, maintain the same form in all inertial systems. By contrast, space and time are no longer absolute separately, but can transform into one another, in order to leave unchanged the "length" of the four-vector.

With the *theory of general relativity* [24] Einstein then expanded the principle of relativity to non-inertial (accelerated) systems, leading to a description of the universe in terms of a four-dimensional geometry curved by the presence of the masses. In this new perspective, the so-called "gravitational force" finds a natural explanation in purely geometrical terms.

5 – Is really space-time ordered in advance ("a priori")?

The concepts of space and time, as we have seen, have been radically altered by the two relativistic theories of Einstein, though common events in classical physics (where speeds are much lower than c) the relativistic corrections remain negligible.

It is necessary to make a clarification on the concept of "relativity", a term which today is often abused. When a physical quantity or concept is "relativized", it is possible that other ones are (so to say) made "absolute". In the theory of relativity space and time become relative, and in different reference systems combine to take different values. In all systems, however, the four-vector remains invariant, the velocity of light c remain the same as well (which therefore is a universal physical constant) and the laws of physics remain the same (covariant), too.

Certain counter-intuitive and paradoxical features of relativity, such as for example that two events can be contemporary in a system of reference but not in another, show how the concept of time of its own becomes relative. Obviously, these time differences can be detected by comparing the events as they occur in at least two different systems of reference.

However, staying in the same reference system, space and time remain unchanged, or "absolute" as Galileo and Newton had understood. Within a single system it appears as though there are actually absolute points of space-time: we do not expect that they will “move” or "exchange" their respective positions! This observation may appear trivial and self-evident, but might suggest a further step in the "relativization" of space and time, capable to account for the quantum paradoxes related to the entanglement between two distant particles with the violation of the principle of locality [16, 17, 18, 19], and also explain other fundamental properties of elementary particles. Here is where the concept of the Arrangement Field of space-time points proposed by Diego Marin can come to help [25].

The paradoxical results suggest that in the current conception there is “something missing". According to the theory proposed by Marin, in the EPR paradox there would not be a real violation of locality or communications faster than light, but there would just be a different, shorter path followed by information [26]. This path may appear as discontinuous in a system of reference (the information "disappears" on a dot to "emerge" into a separate one), but may appear as continuous in a different system (the point of "disappearance" coincides with that of "reemerging"). This should become more clear in the next paragraph.

While some physicists saw the issue of entanglement as a "problem" to solve, which might point out the incompleteness and even the inconsistency of QM, from our point of view non-locality would be a clue towards the new theory, based on an "arrangement field". The arrangement field does not depend on the structure of space-time, but it is the field itself that defines such a structure. Its values determine the mutual distances between points (or events) in different ways, depending on the physical field (bosonic or fermionic) that is acting.

Events that in a reference system are separated, may be superimposed on another system, and vice versa. Entangled particles can become coincident by changing the system, so that they can instantly communicate by virtue of a null separation distance [26]. The arrangement field unexpectedly might explain both the gravitational field (metric) and the phenomenon of entanglement as different expressions of a single entity.

QM, from a scientific point of view, and as a technical and pragmatic approach, has achieved spectacular success and brought a large number of hugely important applications (semiconductors, lasers, and much of the current technology). Nevertheless, the intuitive framework in which QM operates still appears as partly inconsistent and contradictory So far several physicists have gone on just closing an eye, if not both, proceeding as if the problem did not exist, in the tacit hope to reach a compromise the sooner or later. Now this new conception might even give us the whole solution.

QM has shown to be mathematically robust and consistent. Instead, is it possible that the concept of space-time introduced by Einstein and now universally accepted by physicists, is an approximation of a deeper and more general theory? Is it possible that that space and time are even more "relative" than we have hardly accepted so far? This is the question we ask, following the intuition of Diego Marin. The reader should not misunderstand: the new theory is not an arbitrary attempt to add further doubts about the nature of space-time. On the contrary, a brilliant explanation of some phenomena (that are not yet fully understood) could emerge from this theory. The next paragraph tries to explain how, even though a deeper and more technical descriptions is needed for a complete explanation, as it can be found in the cited paper [25]: consider this just as an introduction.

6 - The new theory applied to contemporary physics.

Assuming that the points of space-time can be arranged depending on the field acting on them, the paradox of non-locality can be resolved, existence of gravity can find an explanation that the theories of total unification seem not to be able to find, and at the same time an elegant explanation of the basic characteristics of elementary particles as their mass, their spin and their different behavior (bosonic or fermionic), can be given [27].

The point from which the basic idea springs out, is the following. After the complicated evolution of quantum mechanics since the 1920's, and the results achieved in the 1930's and 1940's in building a relativistic version of the theory, it came out in the 1940's that the quantum relativistic calculations became extremely difficult or impassable, so that Feynman [28] proposed his relatively simple method to solve physical problems (at sub-nuclear levels), based on calculation of action, i.e. the integral of (the density of) Lagrangian (which in the relativistic case reveals invariant properties that make it preferable to Hamiltonian) on all possible "paths" that a particle could potentially travel.

We know that an integral is substantially a sum (although expressed in the proper forms of infinitesimal calculus). In a simplified view, the Feynman integral is an addition of the values that a field assumes locally, and since addition is commutative, the order of points in space-time is no longer a necessary constraint. Each field may establish its own arrangement and redistribute, so to say, the various points in different ways, and the final result would not change [29].

It is not just a matter of sums, though. Besides simple additions of local terms, we know that the Lagrangian can contain other operations, specifically, derivatives, which have to be properly taken into account somehow. To understand how, it is useful to temporarily simplify our framework from the four-dimensional space-time to a one-dimensional discrete space curved on itself (i.e. a circle).

The whole set of all the point of this simplified universe can be simply enumerated by natural numbers, and the values of a physical field in these points can be rendered as an array. After doing that, it can be shown that the operation of derivative can be performed by a simple antisymmetric matrix with all zeros in the diagonal, with +1 in all the entries just at the right of the diagonal, with -1 in all the boxes at the left, and zero again in all the other entries of the matrix. Applying this matrix to our array, which represents all the points of our one-dimensional discrete universe, it easy to realize that this operation approximates the effect of a derivative [29]. In fact, at point i the matrix produces the difference between the value of the field "at the right" and "at the left" of the point i itself:

$$f(i+1) - f(i-1)$$

Applying the matrix to the array produces no other terms (since all the other entries contain zeros). This difference just needs to be divided for twice the step from a point to the next one, to make a "difference quotient" giving an excellent estimation of the derivative, better and better as the step get closer to zero.

So, we have a huge antisymmetric matrix mostly composed of zeros, apart from the +1's and –1's close to the diagonal. As we have described it so far, this is a static situation, in which the matrix is fixed and only capable to make derivatives. Now we can imagine that certain forms of activity or perturbation occur: hence, some entries of the matrix we have introduced (or of a matrix strictly related to that, as explained in the cited paper) can be different from zero. If those non-null entries happen to be on the diagonal, which includes the trace terms, they contribute to mass-energy in that point i, that is to say, the existence of a particle [27]. If the non-null terms happen to be far away from the diagonal, they represent some kind of interaction or communication occurring between point i and j [26].

Even if the details cannot be exposed in this short article (they are widely described in the cited paper) we can intuitively accept that such interactions, depending on values contained in the entries, can either explain the action at a distance that we perceive as gravitation (and we know that no other theory so far has been able to consistently unify gravity with the other 3 fundamental forces), or account for another, different, unexpected interaction between the point i and j, that is entanglement. There is no real violation of locality, since in the metric that is created by the rearrangement of points, it can happen that the supposedly distant points i and j actually come to be temporarily adjacent to each other [26]. Ordering of points is no more fixed and preordained, but can vary in probabilistic terms. After all, probability shows to be a basic characteristic of the quantum realm, ruling the acts of measurement and the outcomes of the various eigenvalues of the observable (so, why should not be the same for space-time?).

After having understood this basic concepts, a larger model of universe can now imagined in four dimensions, with the step between the different points tending to zero, in order to return to our standard, continuous universe, not necessarily circular anymore, provided the radius of curvature tends to infinite. Further on, the theory can explain the differences between fermions and bosons by postulating two different ways of interaction for the trace terms [27] (interaction of each space-time point with itself), as explained in the cited paper.

7 – Philosophical details.

We mentioned that between the seventeenth and nineteenth centuries important philosophers like Locke, Hume, Leibniz, Kant and Schopenhauer had the courage to question the concepts of space and time as absolute and objectively existing entities on their own. Nevertheless, they were philosophers who tended to be inclined more to philosophical "realism" rather than to "idealism" (except perhaps Leibniz). We have not cited idealist philosophers such as Plato, Plotinus, Berkeley, Fichte, Schelling, Hegel or Croce, for whom it was natural to assume that space and time, just as all the other basic manifestations of reality, were expressions of a primordial mental (or spiritual) principle, from which everything originate. We are dealing with "realist" and "empiricist" philosophers, instead. And yet, they did not fully accept that space and time were absolute, objective entities. Let's analyze a little more their thought.

Locke dwells on the fact that we can perceive matter only because it is projected into our minds. Thus he discuss extensively the concept of "idea", distinguishing between "simple ideas" from "complex ideas". The simple ideas are sensations, images, or "impressions" from elementary and limited experience, which reach our consciousness through the senses, while the complex ideas are composed and constructed by combining simple ideas in our mind.

Locke meets with a difficulty, almost a contradiction in admitting that the real foundation of the universe is matter and that our mind is a product (an "epiphenomenon"), since we can perceive matter only through conscious perceptions that are projected in our mind in the form of ideas. This means that our perception of matter is inevitably filtered, modified and "degraded" from our perception, becoming itself an impression, or a simple idea!

Locke is aware of this limitation, but this does not make him become an idealist (as will happen instead to another empiricist, Berkeley). Locke admits that the objective qualities can be perceived by the (albeit approximate and inaccurate) subjective qualities, and then looks for compromises. He concludes that at least three things must exist for sure: the "self", without which we could not see, hear or think anything, not even objective matter; "God" (just due to his personal belief); and "things", i.e., material objects, of which, however, he says that we can not say much, just because we perceive of them only the impressions (ideas of things). It should be noted that space and time are not included in these three basic elements. Hence, for Locke, space and time are just ideas.

By combining “simple ideas”, our mind creates and builds “complex ideas”, i.e. ideas of ideas, which acquire more generality, but as they become more complex, lose the natural contact with particularities of daily life and objective reality. Locke arrived to consider “complex ideas” even the generic material substances such as water, wood, iron, etc. (because they are more abstract than the particular things). And, more important for this paper, he considered space and time as “complex ideas” as well. So, from essential and absolute containers of all the universe as was believed by most scientists, space and time are reduced by Locke not just to simple things, or ideas of things, but even to ideas of ideas.

At this point a strong basis has been created for the skepticism of Hume, which places additional emphasis in rejecting the concepts of space and time as objective entities. Hume starts from the concepts of space and time as "complex ideas" that our minds shape by extrapolating them from "simple ideas". But complex ideas can not be composed of an infinite number of parts, or go beyond the perceptual abilities of the human mind. Likewise the complex ideas of space and time must be reduced to a limited number of elements, namely those associated with the ideas we had and real perceptions, unified into one big unified framework, with a certain extent and duration. In conclusion, space cannot be infinite and boundless, and cannot even be defined as the "natural place" of objects, as Aristotle had called it. Space, like time, is only useful extrapolation constructed by our mind.

Kant collects the previous contributes in that sense and provides a detailed, consistent description of space and time, which he placed in a special position between the subjective forms of our intellect and objective forms of external reality, but which are ultimately produced by the subject [34]. Kant defines space and time as "synthetic a priori forms", which in his terminology is almost a contradiction. In fact our sensory experiences of the outside world are perceived in space and time (this is the meaning of "synthetic forms") and yet, according to Kant, space and time do not come from the outside world but are created by our intellect, before the objective experiences (this is the meaning of "a priori"). The purpose of these "synthetic a priori forms", innate in the human, is to order and understand the surrounding universe, but they have no actual existence in the objective reality: it is our understanding that creates and projects of them the feeling of the outside world.

As a conclusion, we don't want certainly deny the existence and consistency of space and time, but our purpose is to show that they are not necessarily so fundamental as it was believed in classical physics, while unexpected aspects may arise. For example, Marin notes that (unexpectedly) the arrangement field created by (or coincident with) the matrix described in the previous section, orders space-time and simulates (or actually performs) physical measurements [27] as if it was conscious – this might be the effect of consciousness of the observer, as have been shown for decades by other quantum paradoxes –.

Marin even states that the metric in the objective universe, that is related to gravity [32], appears in the objective reality as a consequence of the will of conscious beings to see an ordered universe. Apart from these conjectures, anyway, the theory of the arrangement field shows to be a promising attempt to explain physical phenomena not yet fully understood, and thus concur to a certain extent to development of physics, science, and general culture and knowledge.

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