αTOM

A Transdisciplinary & Transcultural Insight

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FOREWORD

We have before us a unique book, a true celebration of intellect, culture and spirituality. The four authors of this unexpected history of the atom and of the void put before us a fascinating incursion into an issue that has caused human thought to remain trapped between Unity and diversity. The views expressed in the book, with perfect rigour and coherence, approach multiple fields of knowledge and reach a surprising conclusion. What connection could there be between the Upanishads, the Triune God of Christianity, the Indian scholar Kashyap Acharaya Kanad (7$^{\text{th}}$ century BCE), the physics of elementary particles, quantum mechanics, Democritus, Leucippus, Zeno, alchemy, Carl Gustav Jung, Nikola Tesla's ether, the theory of sets in mathematics, fractals, information theory, Niels Bohr's atomic model, the structure of language, architecture, the movie *Matrix*, Dante's God and Jorge Luis Borges? One spectacular example is the symbolic presence of an atom on the northern wall of the narthex at Voroneţ. The authors prove, in a pertinent manner, that one invariant can be found in all the considerations made throughout time about the atom and about the void, and this invariant can be translated through the cross-disciplinary notion of the Hidden Third, the source of all Reality.

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FROM THE AUTHORS

This book was born out of a challenge.

The fabled three musketeers were in fact four, and the authors of this book are like them: four good friends, three "scientifics" and one "literatus", splitting ideas and sometimes skirmishing amongst themselves, with gleeful but at the same time sober restlessness. One day, during an animated debate, Alina threw down the gauntlet: "Let us write together about the atom, the smallest particle, as we know it and as we imagine it, tackling it from as many different directions as possible." We were overcome by a whole host of feelings: we were at first bewildered, then reluctant as we measured, with lucidity, the risks of such a venture and the insanity of the attempt to encompass infinity, but we became increasingly more curious, as our inquisitiveness was piqued by so many diverse associations and new meanings that were parading before us in vertiginous succession. The issue is so complex and so vast, that the gap between the gates we have barely pried open is about as great as the size of the nucleus when compared to that of the entire atom! Countless other connections and novel interpretations await their turn. Nevertheless, for us, the enthusiasm of discovery and the profound joy of sharing possible pluri- and cross-disciplinary pathways for interpretation and reflection have materialised in this volume, borderless, unexhausted and without closure, because the atom is truly a never-ending story.

The Authors

Contents

Chapter 1

The turbulent sea of virtual particles...

Stolzius (...) was a searchlight in the void, and we were the void.

(I.P. Culianu)

1.1 Brief historical overview

Having fallen from Paradise into time, man seems to carry two essential nostalgias that are, in effect complementary: the nostalgia for being reintegrated in the One, and that, more humanly unsettling, for identifying the smallest seed of creation. It is between searching the bigger infinity and the smaller infinity that out entire destiny as creatures runs its course, at once dramatic in the acknowledgment of our ontological and gnoseological limitations, and exalting in the richness and diversity of forms of existence and comprehension. The breaking of the original oneness pulverised our relation to reality into fragments of elements, teachings, experiences, but our yearning for the ultimate meaning drives us towards the global, holistic comprehension. Therefore, one formula that summarizes such a totalising intellectual endeavour would be:

cognition - knowledge - (re) cognition

Since Paradise was not satisfactory, and he decided to shake the forbidden tree, man went on to sharpen his curiosity and restlessness on every threshold he encountered, on every obstacle that would not allow him to look "beyond". Upwards, we hit the issue of the universe's finitude or infinitude; meanwhile we found out that the most remote object (theoretically) observable emitted its light in the first moments of the transparent universe, approximately 13.7 billion years ago, thus defining what we call the "visible horizon"; we cannot see and implicitly know anything beyond this distance. We do not know whether the universe stretches any further or not. We do not even know whether this question makes sense.

Downwards, the issue of the smaller universe also concerns the identification of the truly indivisible particle. Experimentally, however, things are so complicated and costly (as was the case of the discovery of the Higgs boson), that many physicists, mainly quantum mechanics specialists, have abandoned the search for the fundamental particle after reaching the conclusion that there are no independent entities, as they are all interconnected. Others have taken novel directions that are no less plausible, especially when they tend to confirm the second Hermetic principle, that of correspondence - "As above so below: as below, so above." - in other words, the principle of the holographic universe, in which every part contains the whole and is contained within it. For instance, professor Andy Parker from Cambridge University has shown (and his opinion is shared widely by NASA physicists) that the singularity at the core of a black hole could easily run for the title of the smallest part of the universe, since, according to some of the current formulation of the laws of physics, black holes form when matter is condensed in a space so small that it becomes and infinitesimal point. In Eminescu's words: "Suddenly, a dot starts moving - the primeval, lonely Other..." (Levitchi). The search for the infinitesimal "dot" of space is also in the realm of the smaller infinity. But as the issue of space continuity or discontinuity has not been resolved yet, we may wonder whether the minuscule "Planck length" truly is the spatial *quantum*, or whether it is merely a length beyond which none of the current physics theories apply. No-one knows...

1.1.1 From the Indian to the Greek atom

A very brief, inevitably incomplete and subjective diachronic excursion will take us back to *atomism* as a thought pattern, not just as a particular philosophical and scientific vision of the ancient Greeks, but also as a perspective that constantly questions the transition from discontinuity to continuity, from small to large, from multiple to unit, issues that stand as landmarks across the entire history and philosophy of sciences.

Let us return for a moment to the Indian *Vedas*, and particularly to the *Rigveda*, the oldest of the Vedic texts (dating, probably, from the 15$^{\text{th}}$ century BC), which is viewed as the source of the source of the Indian outlook on reality, and order in nature, the generally accepted origin of the Indian thought in physics and mathematics. The Vedic scholars started from the recognition of an indissoluble unity between all the constituents of this universe. This model of the interdependence between entities is also reflected in the approach of the structure of the cosmos, of language, but also on the place and role of the observer and of the object of observation, an issue that has been given a privileged treatment in the classical Indian physics thought. Almost 4000 years later, this has once again become part of the main discourse in physics and psychology when it comes to the dichotomic issues of order and disorder.

But maybe the most fascinating part of the *Vedas* are the *Upanishads*, India's Brahman philosophical and spiritual texts. "The world proceeds from the void space"; "The void space was produced by the Supreme Being", states the *Chandogya Upanishad*. And it seems that the entire discussion about parts and whole, about fractals and holism, about subject and object, about creation and destruction, about One and multiplicity, about void and so much more is contained by these few lines of the *Svetasvatara Upanishad* regarding the Brahman and the Purusha (the latter designating the Universal Being, the awakened Brahman, the Cosmic Principle, as well as Man, the self, the consciousness). Without going into nuances that are difficult to express in any language that inevitably distinguishes, separates, freezes as it were, let us say, for the sake of simplification, that the Brahman is the unimaginable creator, while Purusha is the imaginable creation. Only that the unimaginable God enters creation, enters a human being ("the Son of God"), who is merely a part of creation. This part of creation, filled with God, is called Purusha. However, as part of creation, Purusha is also creation itself. A *fractal* of Brahman, if we may call it that:

> 1.8. The Lord, Isa, supports all this which is a combination of the perishable and the imperishable, the manifest, [...] and the unmanifest [...]. The same Lord, the Supreme Self, devoid of Lordship, becomes bound because of assuming the attitude of the enjoyer. The jiva by realizing the Supreme Self is freed from all fetters.
>
> 1.9. The Supreme Lord appears as Isvara, omniscient and omnipotent and as the jiva, of limited knowledge and power, both unborn. But this does not deny the phenomenal universe; for there exists further the unborn prakriti, which creates the ideas of the enjoyer, enjoyment and the object. Atman is infinite and all - pervading and therefore devoid of agency. When the seeker knows all these three to be Brahman, he is freed from his fetters.
>
> 1.12. The enjoyer (jiva), the objects of enjoyment and the Ruler (Isvara) - the triad described by the knowers of Brahman – all this is nothing but Brahman. This Brahman alone, which abides eternally within the self, should be known. Beyond It, truly, there is nothing else to be known.

Before leaving this fascinating mediatation, here is a fortunate comment made by Swami Tejomayananda to one of the sections of the same *Svetasvatara Upanishad*, to help us better understand the complexity of Indian thought, so succinctly formulated:

> III.9. The whole universe is filled by the Purusha, to whom there is nothing superior, from whom there is nothing different, than whom there is nothing either smaller or greater; who stands alone, motionless as a tree, established in His own glory.
>
> God/Truth has no cause or effect. The cause always exists before the effect. It means that nothing exists before the effect. In means that nothing exists before God. This is accepted by all the religions of world. However Vedanta also says that God/Truth is not the cause of anything. He s not the Creator! Nothing really comes from him, since nothing is different from him. God/Truth is neither a cause of anything nor an effect from anything. Nothing exists before Him or after Him, He is one without a second. The non-dual God/Truth alone exists. From the absolute standpoint God/Truth is not the Creator of the world.
>
> There is nothing greater or smaller than God/Truth. [...] God/Truth is beyond all concepts of small or great, all is Him alone. Even at the relative plane, God/Truth is subtler than space which exists in the smallest atom and also engulfs the whole universe.
>
> (Tejomayananda: 122-124)

This is food for thought and for many books in the above, but we shall not dwell, but instead continue this dynamic overview, leaping over a few centuries, although we shall inevitably return to this point.

In modern times, John Dalton, an English chemist and physicist in the late 18^{th} century, was credited with the development of atomic theory. Mankind seems to have a short attention span and be possessed of presumptuous ignorance. In fact, a first (?) theory regarding atoms was formulated approximately 2500 years before Dalton by an Indian scholar, Kashyap, also known as Acharaya Kanad, born in 600 BCE. Legend has it that Kashyap was on a pilgrimage to Prayag when he saw thousands of people filling the streets with flowers and grains of rice as offerings to the temple. Fascinated by the tiny particles, he started picking up the grains. When the curious crowd asked him why he was collecting grain that even a beggar would reject, he replied by saying that individual grains may appear to lack value in themselves, but that together, a few hundred grains could provide a meal to one person, and many more than that could feed the entire world. Therefore, a single grain of rice is the same as important as all the wealth in the world. People called the rice grain *kan*, which in Sanskrit means "the smallest article", and Kashyap became known as Kanad, that is "the master of the smallest things".

In fact, Kanad began taking an interest in the invisible and conceptualised the principle of the smallest particle, which he called indivisible matter, *parmanu*, or *anu*. Etymology comes, as always, to the rescue: In Sanskrit, a*nu* means "minuscule", "atom", "subtle", "minute unit of time or space". As for the word *atom*, used universally, it comes from Greek and it consists of a privative prefix, *a-*, and the verb *a-temnein* "to cut", designating thus a thing that cannot be cut, separated into fragments. Acharya Kanad stated that this indivisible matter cannot be perceived by any human sensory organ, it cannot be seen with the naked eye, and that an inherent force has determined one *anu* to combine with another, resulting in a combined substance, a *dwinuka* (binary molecule), the various combinations of *anu* producing various types of substances; he also stated that breaking *anu* apart would result in *maha-anu* (nucleus). Kanad also said that *anu* may have two different states: absolute stillness and movement, postulating thus the existence of 108 particles - 108 being the divine number for the Hindus, since Vedic science asserts that our universe consists of 108 elements. 108 is also the number of Upanishads.

This is particularly interesting, given that the founder of the Periodic Table of the Elements, Dmitry Mendeleev, openly expressed his gratitude to Indian scholars, especially to the famous Panini, who gave him the rules for organizing the grammar of his elements, 63 at the time Mendeleev designed the table, but 108 in most of the tables used today, where the elements listed after hassium, the 108^{th} and the heaviest element in the periodic table, have only a laboratory existence, where they live for about a thousandth of a second. To make the connection even more striking, Mendeleev had also anticipated the atomic mass of this element, hassium, which he called *eka-osmium*, *eka* meaning "one", "the first", "the only", "the sole", in Sanskrit, but used by Mendeleev with the very transdisciplinary meaning of "beyond". In other words, One beyond the apparent multiplicity.

Returning to Kanad, let us add that he founded Vaiśeşika (a Sanskrit word meaning "special", "excellent"), one of the six "orthodox" Hindu philosophical schools, where he taught the comprehension of the atom and of the nature of the universe, and where he wrote the *Vaiśeşika Sutras*, becoming known as "the father of atomic theory." Surprisingly, he also considered the mind to be an eternal and indivisible atom, the fifth, after the four fundamental constituents, the atoms of air, fire, earth and water. Very close to Vaiśeşika was the Nyaya school (the name meaning "rules", "method", "model", "axiom", "judgment"), led by the philosopher

Praşastapada, known especially for the development of the theory of logic in her epistemology works. Nyaya-Vaiśeşika goes far beyond a mere presentation of atomism, it evokes the properties of matter and offers an entire metaphysics, associated with logic, arguing, for example, that the imperceptibility of the atom is explained metaphysically: atoms are eternal substances and prime causes. Therefore, in brief, the two schools have given us two possible directions for approaching the atom:

1. physics (the atom being considered a material constituent / a constituent of matter)

2. metaphysics (through the eternal atom *nitya*)

In Indian physics, matter is reduced to an abstract *anu* that emerges as four fundamental types of matter due to the four types of fundamental movements of this atom /*anu*. The atom is an energy point with zero mass and dimensions. This view is comparable to the point of view of modern physics, for which elementary particles such as electrons, protons, bosons, etc. are mere clouds of energy that enter into various combinations to form the whole of known matter. The beginning of the creation process is characterized by the motion acquired by the atom together with certain inherent properties, and that is the point where time begins. Kanad reduces all matter, space, and time to certain functions of "motion". In the absence of movement, even time falls to zero. The observer represented by the mind is also a function of movement. The whole universe is only matter and observant mind that are capable of motion. Indian physics is an observer-centred system, with space-time as the fundamental matrix through which the entire universe is observed by the observer. It considers that time collapses in the period of stillness between creation and cosmic disintegration, time being a function of the "state of motion" of the cosmos, which "rests" in this period between creations and dissolutions. Matter is preserved in the atomic state.

Space is also eternal and continues to remain a it is. The *anu* of Indian physics is an atom insofar as it is still indivisible and a-causal or indestructible. But the difference is that the Kanad the philosopher does not attempt to describe only visible matter, but instead proposes a complete system of space, time, matter, in order to describe the entire cosmos that begins with the visible matter and extends to categories and potentials that are not similar to matter. His atom does not exist in real time. In its fundamental form, it possesses no motion, as motion is by definition visible.

It is not without interest to mention that neither Kanad nor Praşastapada explicitly raises the issue of the indivisibility of atoms, which results naturally from the other characteristics of atoms, especially from their eternity. And this is because, in Indian thought, eternity is synonymous with *causa prima*, the supreme principle, One, the indivisible substance.

Nyayasutra speaks of the presence of the whole in each of the parts (2.1.32), opposing the Buddhist conception, considering that the whole is different from the sum of the parts. Therefore, a problem that logicians and scientists still face today also kept the ancient Indians on their toes. However, they appeared to be sure of the answer. They had identified two categories of properties: properties of the whole that are not also properties of any of its parts, and properties of the whole those that are of the whole only because they are also properties of each of the parts. In other words, the contemporary discussion about *emergency* and *reduction*. What cannot be reduced to the properties of the component parts represents the emergence, the property of the whole. Nevertheless, there are controversies on this topic, the classical Indian philosophy is not homogeneous: according to Buddhists and Vedantists, for example, it is natural for us to think that the atom must also have parts, because it is penetrated outside and inside by the *akasha*. This notion, which has undergone many translations and interpretations over time, is fundamental and inescapable. Here are just a few defining elements of it in *Vaiśeşika Sūtra*:

> Akasa (ether), time and space have no lower constituents. (VS 2.1.27, 29-31) Of akasa the qualities are - sound, number, dimension, separate-ness, conjunction and disjunction. (VS 7.1.22) Thus, then, being endowed with qualities, and not being located in anything else, it is regarded as a substance. And in as much as it has no cause, either homogeneous or heterogeneous, it is eternal. (VS 2.1.18)

And here we meet again with contemporary physics. Today, it is considered that vacuum is a cosmic medium that carries waves of photons and waves of density and pressure and that it is this vacuum that endows the particles with "mass". This medium is not an abstract, theoretical entity, but instead has a full physical reality. The vacuum is "the holographic mechanism of information that records the historical experience of matter," writes Ervin Laszlo, taking on the assertion of Edgar Mitchell (whose experience as an astronaut confirmed some of his theoretical assumptions, especially the idea that information and energy are parts of the same dyad, active information and effective being present everywhere in the universe, since the beginning of time) and bringing it closer to the Vedic *akasha*, this all-encompassing environment that underlies everything that exists and becomes everything. It is real, but it is so subtle that it cannot be perceived until it becomes all the things that populate the manifested world. Like an eternal library, the *akasha* (which means “cosmic sky, space” in Sanskrit) appears in the Upanishads as what sustains and carries creation from pure consciousness to physical form. *Akasha* shapes all manifestations, names them, contains them, reveals them, preserves their informational imprint. It is the original field from which emerge the elementary particles, the atoms, a dynamic environment, full of constantly fluctuating energy.

And visions meet and complement each other again, thousands of years apart, because, as Fritjiof Capra points out, both modern physics and ancient Chinese philosophy consider change and transformation to be the primary aspect of nature, and regard the structures and symmetries generated by change as something secondary. In both systems, the focus is on the process rather than on things. The main coordinates of this Eastern conception, as a whole, are the unity and intercorrelation of phenomena, as well as the essentially dynamic nature of the Universe.

Buddhism came with a slightly different view from the Vedic one, closer to Taoism, through the concept of *vacuity*, which establishes the fundamental principle of interdependence. Nothing intrinsic exists, things, phenomena are empty in themselves and derive their nature from mutual dependence, the chain of connections being thus endless. Eastern spiritualities in general had an understanding of the vacuum that was very different from the Western one. For Buddhists and Taoists, *the vacuum is full.* Two thousand and five hundred years ago, Lao Tzu had already intuited that the vacuum had been the origin of all things. Similarly, the Buddhist teachers of the School of Mind, developed in 7th century China, would put their mind through the vacuum in order to purify it.

> Master Yangshan asked Master Weishan, “What is the abode of the true Buddha?” Weishan answered, “by practicing reflective illumination on the boundlessness of the divine spark, through the profundity by which the absence of thought is arrived at through thought itself, conceptions are exhausted and one returns to the source. Eternally abiding in the essential nature, action and practice are not two, and this is the genuine ’thusness’ of the true Buddha.”
>
> (http://www.koreanbuddhism.net/bbs/board.php?bo_table=0020&wr_id=57&page=4)
>
> Yang-shan’s question was about the abiding place of the true Buddha. In reply, Kuei-shan said. “By the ineffable subtlety of thinking without thinking, turn your attention inwards to reflect on the infinite power of the divine spark. When your thinking can go no farther, it returns to its source, where nature and form eternally abide, where phenomenon and noumenon are not dual but one. It is there that abides the Suchness of the true Buddha.”
>
> (https://terebess.hu/zen/guishan.html)

The "Suchness/Thatness", that is *Tat Tvam asi*, is the famous formula of Vedantic Hinduism – "You are that", the summarisation of the essential identity between One and the multiple forms of the real world.

The meditation of the Vaiśeşika-Nyaya schools of thought continued with a natural question: how do we know that atoms exist, if they are imperceptible? Kanad and Praşastapada say, however, that we have several types of proofs in this respect:

1. logical and physical evidence (common practice): the decomposition of larger things exists in everyday life, and decomposition involves the atom;

2. ontological proof: in order to stop the regression *ad infinitum*, the decomposition process must have a limit.

*

Leaving aside the Hindu space for the moment, let us turn our attention to the West, where *atomism* emerged in the 5th century BCE, its main representatives being the Greeks Leucippus, Democritus, Epicurus and Lucretius. It is difficult to say precisely whether and to what extent Indian culture influenced the Greeks, or vice versa, or whether these directions developed independently, being organically part of the expectation horizon of the era, which was one of the most prolific in the history of mankind, given that in the 6th and 5th centuries BCE millions of lives and perspectives were influenced, among others, by Heraclitus, Pythagoras, Socrates, Buddha, Lao-Tzi, Sun Tzu, Confucius, Zoroaster... Truly, a golden age!

But even Democritus does not seem to have been considered a pioneer in terms of ideas about the atom, this honour being given, in the ancient world of the West and the Near East, to a Phoenician named Mochus of Sidon, about whom who, unfortunately, we do not know a great deal; some researchers place him in the 13th century BCE, before the Trojan Wars. It is certain however that this proto-philosopher is mentioned in the writings of many ancient authors, such as Diogenes Laertius, Strabo, Flavius Josephus, Eusebius of Caesarea, and seems to have enjoyed a great reputation among scholars in the ancient world for his theory. He is believed to have established a school in Beirut, which operated until the 6th century BCE. Isaac Newton himself credited him as the author of the first atomic theory. But before Newton, Pythagoras was initiated into the ancient mysteries of the Phoenicians and studied for about three years in the temples of present-day Lebanon, specifically in Tire, Sidon, and Byblos. Unfortunately, nothing of Mochus' original writings has been preserved, only their influence on his descendants.

All Atomists agree with the basic theory: the world is made up of atoms and *vacuum* (another major concept, which had to cross millennia before it managed to explain many of today's perplexities!). Of the themes and concepts developed by Indian philosophers, atoms, the infinity of worlds, atheism, *ataxia* (peace of mind), the microcosm and the multiplicity of existences can be found in Democritus. According to some testimonies, Democritus met Indian philosophers during his travels. But on closer inspection, we see that the Indian philosopher Kanad proposed an atomic conception of matter based on nine types of atoms, while Democritus asserts an infinite number of categories exists. Therefore it is not at all certain that Greek atomism has its origin in Indian atomism, it may have been developed independently to answer the paradoxes of the Eleatics and the problems posed by Anaxagoras' theory of the infinite divisibility of matter (see Lucretius, *Book I*). In fact, there were different schools in Greece as well, the vision of the composition of the world and the cosmos varying from one thinker to another, some struggling to avoid the thorny issue of vacuum, of nothingness.

Thus, Thales, around 600 BCE, strongly denied its existence, because nothing can arise out of nothing and cannot turn into nothing. But Thales wondered what was left if we took everything out of a given volume. His answer was in line with his own beliefs about the structure of the world: in that volume will remain a primordial element, namely water. Later, in the fifth century BCE, another great Greek thinker, Empedocles, sought to see whether air could be the substance that fills that empty space, and he broadened the notion of primordial matter to four elements: air, water, fire and earth. But something else is more interesting to note in Thales' theory, from the perspective we have adopted here. He considered that matter has a granular structure, being made up by "packing" tiny spheres. Obviously, there is a free space between them that needs to be filled with something. That something was not, even for him, the vacuum, but a subtle form of matter, the *ether*, which was lighter than air.

Other philosophers insist on other aspects: Heraclitus, for instance, insists on the perpetual change in nature (as in classical Chinese thought); Parmenides argues that the whole Being is complete, continuous and permanent (as in the Vedic tradition). However, they all claim the existence of a hidden law that ensures the order of the world beyond appearances. And in fact, precisely the search for a more adequate description of the world is the one that underlies the atomistic models.

As a result of the numerous reflections developed by the predecessors of those mentioned above, Greek atomism was born in Abdera around the year 430, with the teachings of Leucip. We know almost nothing about this philosopher from north-eastern Greece, but he remains forever famous for his idea of describing the universe in terms of vacuum and small microscopic, indivisible and unalterable Parmenidian worlds - *atoms*.

Leucippus was certainly familiar with the reasoning of Zeno and Melissos, and especially with the contradictions imposed by the continuous / discontinuous duality. The atomistic theory he founded was intended to solve the problems of emergence (form) and becoming. He also had to find compelling arguments in order to connect the concepts of time and space. For this purpose, Leucippus introduced a surprisingly modern symmetry of logical type to one of the qualities of Being: non-Being, their respective attributes being the Full and the Void. One remains unique, but, due to the existence of the Void, it can divide into a multitude of fragments with infinitely varied forms. Time is introduced by placing these "atoms", invisible and indivisible due to their small size, into a perpetual motion.

Also at that time, another thinker, Diogenes of Apollonia, was trying to return to the monism of his predecessors and thus came to develop a central idea for atomistic thinking, namely that all things are variations on the same theme:

> 2. (B2) In my opinion, to sum it all up, all things that are are differentiated forms of the same thing and *are* the same thing. And this is manifest. For if the things that are now in this kosmos - earth, water, air, fire, and all the rest that are seen to exist in this kosmos - if any one of these were different from another, being different in its own nature, [...] they could not mix with each other in any way nor could help or harm come to one from another [...]. But all these things, being differentiated out of the same thing, come to be different things at different times and return into the same thing.

Here is the whole unfolding of universal creation, with *Noûs* generating movement, life, multiplication, before becoming *Noûs* again. By using the notion of vacuum, atomists came to explain both identity and difference. Unfortunately, the traditions that took over and perpetuated their thinking often focused on minor, or even erroneous, issues. The reputation of the Greek atomists, untarnished for centuries, was based on the materialist models transmitted by Lucretius' text, *De Rerum Natura*. All things in nature have a cause and a necessity, Democritus believed, and therefore accident, randomness, chance are foreign to the Greek spirit, which considers them to be essentially anti-scientific. Both Leucippus and Democritus claim that there is a Law ($\lambda\acute{o}\gamma o\varsigma$) that governs the embodiment of material forms, but that this law can only be the result of a "principle of construction" rather than the revelation of a pre-existing form that would have intrinsic autonomy and a life of its own.

Probably a student of Leucippus, Democritus was undoubtedly familiar with the philosophies of his contemporaries and, in particular, with the reasoning of the Eleatic school. Therefore, he developed a system of nature in which he tried to resolve the duality of opposition between permanence and change, between continuous and discontinuous, and explained the progressive appearance of forms through infinite combinations of elementary atoms (of the four elements), moving by virtue of the principle of inertia. But necessity requires certain paths, certain interactions, which means that, despite the infinite variety of forms, they are never accidental.

Cognition of the world comes from the fact that we ourselves are composed of atoms and therefore able to interact with atoms moving in a vacuum. The image proposed by Democritus is particularly vivid and strong, although far from specialized scientific terminology: he says that light is made up of smooth atoms that, entering our eyes, hit those who constitute us, thus provoking reactions and determining our intimate knowledge of the world. Consequently, the role of the senses is essential in the organization of knowledge. This uniqueness of the nature of things allows us to have access to reality.

From the perspective of atomists, the world has not had a beginning and will not have an end, and on the other hand there is no indication that just one world exists. Movement is a primordial principle of the Universe, it appears automatically, out of pure "necessity". Of course, vacuum is a necessary condition for movement to occur. According to Diogenes Laertius, Leucippus imagined the creation of the world thus:

> Leucippus' opinion is this: All things are unlimited and they all turn around one another; the all [the universe] is both the empty [void] and the full. The worlds come to be when the atoms fall into the void and are entangled with one another. The nature of the stars comes to be from their motion, and from their increase [in entanglements]. The sun is carried around in a larger circle around the moon; and whirled around the center, the earth rides steady; its shape is drumlike. He was the first to make the atoms first principles.
>
> (Diogenes Laertius, Lives of the Philosophers 9.30; tpc)
>
> (67A1) He declares the universe to be infinite... Of this, some is full and some is empty [void], and he declares these [full and void] to be elements. An infinite number of kosmoi arise out of these and perish into these. The kosmoi come into being in the following way. Many bodies of all sorts of

> shapes, being cut off from the infinite, move into a great void. They collect together and form a single vortex. In it they strike against one another and move around in all different ways, and they separate apart, like to like. When they are no longer able to rotate in equilibrium, the fine ones depart into the void outside as if sifted. The rest remain together, become entangled, move together in unison, and form a first spherical complex.

A cosmic fresco of extraordinary force, in which the constancy of the themes that have preoccupied the human mind of all times is striking, because we find them in almost identical form in today's physics and cosmology. Would we be able - even as science fiction writers - to sketch such an adequate projection of the world over 2500 years? But atomists not only have a rich and structured imagination at the same time, they are also the initiators of a consideration of causality, and the introduction of motion as a primordial given is a prelude to the reflection that Newton will make much later in *Principia Mathematica.*

This first idea, associated with that of vacuum, allows the shaping of a generative materialism in which the essential cause is the "necessity" of a motion that would cause the encounter of innumerable atoms and, through innumerable trials and errors, constitute forms, of which only the most stable will survive. We note the absence of the famous problem of "potentialities" that haunted Aristotle and permeated the entire Middle Ages. For atomists, forms are created by encounters, and their potentiality results from the plausibility of the encounter. Everything that has been achieved was possible, but what has not yet been achieved is a potential only insofar as the meeting *will occur* in a *predictable* time and place. It is important to remember that the world is traversed only once: no cause, no force was needed in order to impose the initial motion on the atoms, because their motion is eternal, past and future. Thus, the atomists rediscovered the ionic principle of the unlimited as an initial element, and this determined them to accept movement as a primordial principle.

Last but not least, atomists are also known for their advanced theory of animal or human sensations, which proposes a very modern view, unifying the description of the nature of things by including the particular properties associated with the human knowledge of the world. Atoms are the relays between objects and humans. For Democritus, seeing means receiving a reflection of what is being viewed. The underlying idea is that sight requires physical contact between the viewer and something emanating from the object being viewed. The same thing happens with other senses: certain atoms of the object are emitted, which enter through "pores", whose shape is adapted to the nature of the object for the perceiver. Therefore our sensation and adequacy to the object are produced through the selection, mediated by said pores, of the specific components of the nature of the object.

Unfortunately, very few traces remain from the writings of that period, but even so, it is enough to realize that, through the fruitfulness and soundness of their thinking, the atomists of ancient Greece allowed the development of debates and research on topics that are still at the heart of our knowledge and queries today. The despotic omnipotence of finalist dualistic thinking has long denied them any justification, and has certainly delayed many conceptual revolutions. By hundreds or maybe thousands of years. But some landmarks are there to show us how their thinking has been transmitted and enriched.

No need for microscopes or particle accelerators. Zeno's aporia was enough: dividing any amount of matter (or space, or time) into increasingly smaller quantities, if it knows no limits, can only lead to nothing. But matter is obviously not nothing. It is visible, it is heavy, it takes up space. QED: ultimately, it is made up of tiny entities that cannot be broken, connected to each other by "hooks" that are more or less strong... and separated by a vacuum. Today, we say that every particle of matter is actually condensed energy. But the ancient atoms of Democritus are in perfect agreement with the convincing definitions and experiences of modern science. However, before their timid reappearance, in the physics and chemistry of the nineteenth century, they were in a shadow cone for two millennia. Thus, from the seventeenth century to the end of the nineteenth century, successive editions of academic dictionaries demoted the atom to the rank of an archaic fantasy of Democritus and Epicurus, who argued that bodies are formed by the chance encounter of atoms. Academies granted them at most a metaphorical significance, but their fate was still better than that of Indian atomism, completely ignored by Europeans until the nineteenth century and, in fact, almost as ignored today.

Nevertheless, it is very difficult, without a deep and long meditation, to penetrate this rigor of atomistic thinking, this mysterious third included, about which transdisciplinarity speaks, this third path between chance (which, moreover, is not a notion suitable to the Greek spirit) and purpose, to admit that there can be a constant and purposeless force that directs the construction or development of the world. It is what atomists have called Necessity. But here Aristotle stumbled. The Stagyrite could accept things only in the light of their purposes. He did not conceive of the blind necessity of the vortex motion of atoms, without cause and without origin. Therefore, he cannot conceive of the existence of a vacuum, in which motion would not relate to any landmark, and atoms, without meeting the resistance of the environment, would reach infinite speeds. Since this is not possible, Aristotle concludes that no movement can take place in the *vacuum*. A concept he dismisses as useless, depriving the West, for nearly 2500 years, of the integration into science of this "turbulent sea of virtual particles", as Leonard Susskind calls it (2006:74).

It is true, however, that Aristotle also introduces, in addition to the four existing elements - insufficient for the description of the cosmos -, a fifth, the noblest, the element heavens are made of, a special element (quintessence - the fifth essence, the fifth being), weightless and unchanging, called *ether*, an element that, having gone through countless avatars throughout history (we have already met him as *akasha*), came to be - in a delayed ironical twist - to be identified with the vacuum!

Vacuum is related to *zero*, whose invention was a huge revolution in mathematics. Zero was born in India and not in the West, because it had very special properties that made the Greeks nervous. When you add zero to a number, that number remains the same. In addition, zero is related to infinity. When you divide a number by zero, you get infinity. When you divide a number by infinity, you get zero. The Greeks hated infinity! Not all of them, as we have seen, but as it happens, only those who had an overwhelming influence on the development of the Western world. They feared that these two dangerous and difficult-to-define notions - vacuum and zero - could result social chaos and panic among the population! Each era with its fears. For almost the same reason, for example, most records of the existence of extraterrestrial life and its interaction with our world are silenced. The foundation is the same: confronting the unknown, something that seems to elude the intellectual routine and existential patterns can lead us astray. Despite the dominant theories and ideology, we are too little equipped to accept otherness, difference, exception.

What is certain is that both Plato and Aristotle rejected the idea of discontinuous matter. For them, matter was, on the contrary, continuous and made up of different combinations of the four elements - water, air, earth and fire. In the West, the Church embraced this conception and did not let it go until the end of the second millennium. Like nature, the Church abhorred a vacuum, but also the "inferiority" implied by the atomistic hypothesis: if God had created matter out of nothing, that matter could no longer contain nothingness. But the Church did not just miss out on the vacuum. Above all, it hated to offend Aristotle and his finalism, which had provided such a convenient ready-made hierarchy of living beings that the Church only had to place under the tutelage of the Creator. So it took it all, wholesale.

Finally, the atomist theory had to contend with the dogma of the Eucharist: how can one say that the Christic bread and wine are made up of atoms and vacuum? What then happens to their transubstantiation, as a result of which they become the true body and true blood of Christ, without changing their appearance? Based on unpublished documents, Pietro Redondi, an Italian historian, states that Galileo's heresy was not the one we know from the history books and that the real reason for his condemnation lies in his declared adherence to the atomist theory and, not coincidentally, in his rejection of Aristotle's theory of falling bodies. The Jesuits did not necessarily reject his assertion that the Earth is the one that revolves around the Sun, but instead his conviction that it is made up of "substantial atoms". This was a much more... modern sin. Doubting the structure of matter was tantamount to attacking dogmas, especially that of transubstantiation. Faced with the Reformation, the Catholic Church had just uncompromisingly reaffirmed this dogma, one of the main sources of discord with the Protestants. It was not at all the right time for the situation to be complicated by those ridiculous stories about the atoms. Or by debating them publicly during a trial. Consequently, Galileo was discredited under another pretext - the theory of the Earth revolving around the Sun, an idea which, incidentally, the defendant had not even invented, but instead borrowed from Copernicus. Despite all these obstacles, atomic theory ended up triumphing and providing resounding proof of its reality. Today, listed and classified, atoms are no longer all considered indivisible, but no one doubts that they constitute the totality of observable matter.

1.1.2 About vacuum and ether in the Middle Ages and beyond

The legacy of ancient Greece and the influence of Aristotle were the protégés of the Church, practically unshakable during the Middle Ages, the relationship between part and whole, between transformation and immutability being arguments to the liking of the clergy. Here is how they are formulated, in his *Confessions*, by Saint Augustine:

> [...] being assured "That Thou wert, and wert infinite, and yet not diffused in space, finite or infinite; and that Thou truly art Who art the same ever, in no part nor motion varying. [...]"
>
> (Book VII)

Thomas Aquinas and other theologians and philosophers would argue, until the dawn of Renaissance, that "God is whole in all beings and in each."

(1997: 117) And the vein of alchemy did not seek to prove otherwise. The transmutation of metals, the elixir of eternal life, or the restoration of the original purity of soul sought only the same restoration of lost unity, of the resettlement of matter and spirit in their primordial matrix. The unifying principle in the *athanor* is the salt between oppositions: cold and hot; male and female; fixed and volatile. Carl Gustav Jung, the famous Swiss scientist, spoke about the essential duality that characterizes alchemy. From its inception, it combined the *Gnostic spirit* of Greek natural philosophy with the highly developed *techno-magic*, so to speak, of ancient Egypt. His examples refer to old metallurgy and to the embalming process associated with the regeneration of Osiris. Jung's fundamental idea is that Western alchemy developed as a kind of underground current complementary or compensatory to the Christian conflict of body/soul, good/evil opposites. Alchemy would thus be a search for God's divine spark in the darkness of the world below. In the solution/dissolution stage of the Black Work, the external and internal impurities are dissolved, in the congelation step of the White Work, the dichotomies disappear as antagonisms and turn into the energy of a dynamic system of contradictions (about which Ştefan Lupaşcu spoke) that makes possible the leap to the level of the Red Work, that of melting into one, a moment where the alchemist can no longer tell whether he is the subject or the object of the process, becoming himself the Work, the philosopher's stone. A transrational reality that shatters the principle of identity and Aristotelian logic.

After the Renaissance, the modern world and science began to be built on different foundations, meaning that science no longer depended on metaphysical considerations and dogmatic interests, but instead on experiments such as those of Torricelli, a student of Galileo, the first to create a vacuum in a tube, or on those of Pascal. Coming from such a comprehensive and flexible ancient view of the universe, especially in Indian philosophy, one cannot help but be astonished by the truncations and fragmentation imposed on freedom of thought by an increasingly reductionist and despotic control of the Church, which was, unfortunately, one of the historical instigators of the separation between science and religion, of the fracture of integrative knowledge. It is enough to watch the struggle of a genius like Pascal, who tried his best to reconcile his authentic faith (the famous "Pascal's wager" is, in fact, the expression of a profound confusion) with the spirit of the experimental scientist, which pushed him to take Toricelli's research further, thus contributing enormously to the development of geometry and mathematical analysis, and of the probability theory. He also spoke at length about the small infinity and the great infinity, equally inaccessible to direct sight and knowledge, which must be supplanted by the dimension of the imaginary, and returned to the ancient visual metaphor of the infinite sphere, which many erroneously attribute to him:

> But if our view be arrested there, let our imagination pass beyond; it will sooner exhaust the power of conception than nature that of supplying material for conception. The whole visible world is only an imperceptible atom in the ample bosom of nature. No idea approaches it. We may enlarge our conceptions beyond all imaginable space; we only produce atoms in comparison with the reality of things.
>
> (...) It is an infinite sphere, the centre of which is everywhere, the circumference nowhere.[30] In short it is the greatest sensible mark of the almighty power of God, that imagination loses itself in that thought.
>
> (...) I will let him see therein a new abyss. I will paint for him not only the visible universe, but all that he can conceive of nature's immensity in the womb of this abridged atom. Let him see therein an infinity of universes, each of which has its firmament, its planets, its earth, in the same proportion as in the visible world.
>
> (For all the English quotes from Pascal:
> https://www.gutenberg.org/files/18269/18269-h/18269-h.htm)

Still, under the religious mark and influence of the era, but also of the rationalism and anthropocentrism that were beginning to take root in the collective mind, Pascal could not overcome the fracture between the two already established fundamental types of knowledge, he could not, spiritually, to admit the fertility of the idea of vacuum, assimilating it with the sterile nothingness ("Infinite - nothing - Our soul is cast into a body, where it finds number, time, dimension."), although, in order to accept its experimental existence, he stood up to Descartes. The inability to "weld" together the two horizons caused Pascal to struggle in this ontological ambiguity, as in his view man was a being that belongs to an interval - nothing in relation to infinity and everything in relation to nothingness - but infinitely distant from both poles. Unfortunately, the median position is not made positive either, it is not an *aurea mediocritas* in the vein of the ancient Chinese thought, or of Aristotle or Horace, namely an area of reconciliation of opposites through their wise fusion, but one of fragile and unstable balance:

> 70. [Nature has set us so well in the centre, that if we change one side of the balance, we change the other also. I act. Τά *ζῶα τρέχει* This makes me believe that the springs in our brain are so adjusted that he who touches one touches also its contrary.]

Around the same time, Sir Isaac Newton, the creator of classical mechanics, published his work *Philosophiae Naturalis Principia Mathematica*, which would become a revolution in physics, and not only. Let us note that although Newton and Leibniz are credited with discovering the most powerful mathematical tool - differential and integral calculus with infinite series, virtually all of Newton's work on physics and infinitesimal analysis has borrowed the theory and results of the mathematicians and astronomers of the Kerala school in south-western India, who had been familiar with them since the 1400's (such as the Gregory series, or the sine and cosine functions). These discoveries seem to be come from a single genius scientist, Madhava, as gifted as his compatriot Ramanujan, the excellence of the Indians in mathematics and computer science being well-known. Moreover, it appears that the law of gravity was also known to Indian scholars since ancient times. In *Surya Siddhanta*, a traditional treatise on astronomy dating from 400-500, Bhaskaracharya notes:

> The Earth has an attractive power by which it draws itself and heavy objects in the air... This attractive power of the Earth shows why things located at a lower part, or at the sides, do not fall from its surface... Objects fall on earth due to a force of attraction by the earth. Therefore, the earth, planets, constellations, moon, and sun are held in orbit due to this attraction.

About 1200 years later, Sir Isaac Newton (re) discovered this phenomenon and stepped through the main door of physics with the law of gravity tied to his name. The information was probably brought to the West by Jesuit missionaries. However, Newton remains one of the very few people who has managed to fundamentally change his peers' way of thinking, sparking a revolution that expanded far beyond the boundaries of physics. But the theory that dominated physics for more than two centuries had a flaw. In his exciting *Book of Nothing*, John Barrow writes:

> Despite the power and simplicity of Newton's ideas, there was an awkward assumption at their heart. Newton had to suppose that there existed something that he called 'absolute space', a sort of fixed background stage in the Universe upon which all the observed motions that his laws governed were played out.

The movement of all the bodies in the Universe had to relate to this "absolute space" which, in turn, is in a state of absolute rest. It could not be observed directly or acted upon, so "it began to sound as mysterious and elusive as the vacuum itself" "begins to sound as mysterious and elusive as the vacuum itself" (Ibid.). We know, however, that in the wake of Aristotle, the idea of empty space was difficult to accept, and then an idea gradually gained ground: that the space between objects in this world was not empty, but instead filled with a kind of immobile fluid, which came to be called *ether* (Chapter 3 will resume and develop the topic from the perspective of physics). Newton, John Barrow tells us, was not overly enthusiastic about this substance, he would have liked something more rigorous for his theory, although he acknowledged that this ether could be a convenient vehicle for understanding some of the properties of light and its propagation through space. Newton was a follower of the corpuscular theory of light, he saw it as a sum of very small particles (photons, as we call them today), problems arising when light behaved like a wave. But let us take another leap over time.

For the light wave, it is precisely this ether that should be the propagation medium. An ether with special features, which scientists tried to explain and verify experimentally in the centuries that followed. It is a fascinating search, concluded with the experiments of Michelson and Morley (1881 and 1887), who wanted to directly prove the existence of the ether. Both experiments failed. The ether, widely accepted by the physicists of the time, showed little sign of existence. Nevertheless, all this led to Albert Einstein's 1905 great revolution.

So, in modern times, ether is dead, gone from the scientific lexicon. The voice of Greek Antiquity seems to resound defiantly again: emptiness is nothing, zero does not exist... All good until Paul Dirac, the English physicist, stated (in 1928) that the vacuum is full, with infinite negative energy even. In his equations (as in everything quantum physics), energy is always associated with time, but the minus sign appears in front of positrons. It took the nonconformist scientist Richard Feynman for the idea that positive energy can be associated with negative time to emerge. In other words, in what he called *reversed time*, the positrons move back in time, carrying with them the information of the present. For now, time travel is only possible at this subatomic level...

1.1.3 Quantum physics and - again - the Vedas

Quantum physics, as we know, explains the nature and behaviour of matter and energy at atomic and subatomic level. The term *quantum mechanics* itself was coined in the early 1920's by a group of physicists at the University of Göttingen, three giant minds, all three Nobel Prize winners: Werner Heisenberg, Niels Bohr and Erwin Schrödinger, who were also united by one, perhaps surprising, passion. All three were avid readers of the *Vedas*; moreover, we could say that they elaborated upon these ancient books of wisdom in their own language, with modern mathematical formulas, in an attempt to understand those complex concepts that ancient Sanskrit called "Brahman", "Paramatma", "Akasha", "Atman", "Anu". In 1925, the worldview of physics materialized in a model of the universe as a large machine made up of particles of matter that can interact separately. Over the next few years, Schrödinger, Bohr, Heisenberg and their followers outlined a universe based on inseparable waves with superimposed amplitudes of probability.

Of the three, Schrödinger was probably me most imbued by this perception of the universe, which he considered "some blood transfusion from the East to the West to save Western science from spiritual anaemia" (My View of the World). His understanding went so far that when Heisenberg argued that quantum mechanics broke down the barrier between Cartesian notions of *Res cogitans* and *Res extensa*, Schrödinger replied that the wording of the problem must be completely overturned, because talking about the collapse of the separation between the subject and object is absurd, since there has never been such a separation. The subject and the object are one in the primordial experience, and the Vedic doctrine of identity expresses this unity very well. In fact, he says, quantum mechanics did not break down a pre-existing barrier between subject and object, but restored an initial state of fact, in which the mechanisms of objectivation do not work.

"This life of yours which you are living is not merely a piece of this entire existence, but in a certain sense the whole," Schrödinger concludes from in the texts of the Vedic tradition, fascinated by the amazing summarising force of the Brahmins sacred formula, so simple and so clear: *tat tvam asi*, you are that. No less comprehensive appears to him the formula "I am in the east and the west, I am above and below, I am this entire world", better known later on in its Hermetic version, the foundation of alchemy and the essence of the fractal universe, "As above, so below", the whole is in the part and the part is in the whole. This also explains the "butterfly effect" theorised by Lorenz, because, since the universe is a whole, information is intrinsically non-local and will be instantaneously transmitted across arbitrarily long distances, which means that an action occurring in a single place can instantaneously influence an action at the other end of the universe.

Talking about a universe in which particles are represented by wave functions, Schrödinger opined that "The unity and continuity of Vedanta are reflected in the unity and continuity of wave mechanics. [...] This new view would be entirely consistent with the Vedantic concept of All in One". It is also in the *Upanishads* that the physicist finds the confirmation of the idea that multiplicity is only apparent. And not just there, in fact. All the mystical experiences of union with God lead to this idea. Ancestral Indian wisdom was as clear as it could be about determinism and free will, stating that there is no framework in which to find *consciousness* in the plural; we construct this inflection because of the temporal plurality of individuals, but it is a false construction - a truth that we often forget ... All events occur in the universal, unique consciousness, and there is no plurality of self; the self or its separation from the absolute Self is an illusion (how well Fabre d'Olivet understood this, he who translated "Elohim" by the extraordinary singular-plural phrase "He-the-gods", in the *Cosmogony of Moses*, too little known, because... non-canonical!).

The unity of consciousness was unequivocally expressed by the Austrian physicist at the end of one of his lectures, when he stated that "Atman is equal to Brahman", adding that this is "Schrödinger's second equation". Recognizing this identity is not considered blasphemous in Indian thought, on the contrary, it is the ultimate goal of our earthly destiny, the sudden comprehension and assimilation of the boldest possible thought. Imagine how most Christian prelates today would react if you went to confession and said, "I am God."! Only the mystical, esoteric vein has kept alive this ultimate truth which, paradoxically, took quantum physics to have us reminded of it. The most subtle science as a revealer of spiritual and material unity – this is the lesson of the search for the ultimate particle!

There are many traces and influences of Vedic philosophy in Schrödinger's physics, but let us just say that, from the above, another notion arises that interests us here, namely *holism*. In his early reflection on quantum physics, Schrödinger takes a view that particles and atoms should not be perceived as small bodies isolated from each other, but as modes of vibration of a single background, which he will later equate with the universe as a whole.

Niels Bohr was himself an avid reader of the *Vedas*: "I go into the *Upanishads* to ask questions", he used to say each time he hit a roadblock with some theory or experiment, after having found, like Schrödinger before him, that their experiments in quantum physics concurred with what they had read in the ancient Indian sacred books.

In the 1920's, Werner Heisenberg formulated his famous uncertainty principle, which states that when one tries to observe a subatomic particle, the experimental device inevitably changes its trajectory. This is because it attempts to observe something that has the same scale as the photons used to observe it. In other words, to observe something of subatomic dimensions, it is necessary to use a device that projects photons on the observed particle, and the reception of photons by our retina is what we call sight. The problem is that photons disrupt subatomic particles because they are the same size. Consequently, there is no way to observe subatomic particles without changing their trajectories. But the interaction between subject and object is discussed at length in the texts of ancient Indian philosophy. In fact, Heisenberg was convinced that "Quantum theory will not look ridiculous to people who have read Vedanta."

In his turn, Fritjof Capra, interviewed by Renée Weber for the volume *The Holographic Paradigm*, spoke thus about Schrödinger's account of Heisenberg:

> I had several discussions with Heisenberg. I lived in England then [circa 1972], and I visited him several times in Munich and showed him the whole manuscript chapter by chapter.
>
> He was very interested. [...] He said that he was well aware of these parallels. While he was working on quantum theory he went to India to lecture and was a guest of Tagore. He talked a lot with Tagore about Indian philosophy. Heisenberg told me that these talks had helped him a lot with his work in physics, because they showed him that all these new ideas in quantum physics were in fact not all that crazy. He realized there was, in fact, a whole culture that subscribed to very similar ideas. Heisenberg said that this was a great help for him. Niels Bohr had a similar experience when he went to China.

But, as expected, this revolution of thought, of vision of the world and the universe, did not win everyone's favour. In 1935, Albert Einstein, Boris Podolsky and Nathan Rosen challenged quantum mechanics and especially what we know as the Copenhagen Interpretation, in other words, the impossibility of determining the state of a system before a measurement that practically forces the system to collapse the wave function, that is to choose to update only one of the multiple virtual possibilities. The mental experiment of "Schrödinger's cat" is a graphic illustration of this theory. But Einstein, a strong follower of quantum determinism, could never accept quantum indeterminacy and the concept of *instantaneous causal influence at a distance*, creating his own paradox (EPR) and challenging Bohr until the end of his life. Even without detailing all these physics theses (this is better left to the specialists), it is interesting to note how the highest expression of classical physics, reached and surpassed in the theory of relativity by Einstein's genius, struggles with a fracture of vision introduced by quantum mechanics, which seriously shakes paradigms and notions that we thought were definitive landmarks in explaining the world, introducing an additional number of metaphysical implications, which modern and contemporary science was not ready to accept. To a large extent, it is not prepared today either, although transdisciplinarity and its major concepts, especially that of "level of reality", greatly facilitate a comprehensive understanding.

It has been said that Albert Einstein also read the *Bhagavad-Gita*, and that after this reading, meditating on how God created the world, everything else appeared superfluous to him. It is, however, unlikely if we look at the constants of his outlook. What is certain is that physicists have not yet finished checking whether Bohr or Einstein were right and, above all, how to reconcile the two visions. But these contradictory debates and perspectives have at least the merit of opening a door to another possible reading of the world, although, no matter how many experiments we do, we can never reach the absolute truth by using inevitably imperfect tools of perception.

Schrödinger had no direct knowledge of Sanskrit, but other important scientists, attracted by this complex thinking, such as Robert Oppenheimer, had learned Sanskrit. He read the *Upanishads* and the *Bhagavad-Gita* in the original, referring to them as some of the most decisive influences in shaping his own philosophy. Significantly, after taking part in the first nuclear test in 1945, he instantly quoted *Bhagavad-gita* chapter 11, text 32: "I am mighty Time, the source of destruction that comes forth to annihilate the worlds"...

In any case, many decisive books written by personalities such as Thoreau, Kant, Schopenhauer, Schrödinger, Heisenberg, Tesla, Einstein, etc., who came into contact with Vedic texts, convey, in one form or another, the idea that reality - first and last - remains timeless and unchanging.

The inventor Nikola Tesla, one of the most spectacular and prolific spirits of all time, is perhaps the most mysterious example of the assimilation of Brahman knowledge, which led him to mathematical formulas of unique subtlety. It is not known how Nikola Tesla came into the area of influence of the *Vedas*, much of his life and work being erased from history, for this brilliant man, with 125 patented inventions, with knowledge of 12 languages (including Sanskrit, whose construction grammar fascinated him) and holder of 14 doctorates in universities around the world, was not able to monetise his ideas and discoveries, going instead - from a financial point of view - from one failure to another. Tesla invented many things that we use every day, although most people have only heard of this name in the form of the American company, run, it is true, by another visionary genius, Elon Musk. But Nikola Tesla understood the great power of the Zero Point (synonymous with *akasha* or *ether*), being the first contemporary scientist to openly express the idea that space vacuum is not empty. Tesla used the old Sanskrit terminology, which was very familiar to him, in order to describe the universe as a kinetic system full of energy, to which man could connect anywhere and at any time. After numerous conversations with the great thinker Swami Vivekananda and after studying in depth study the Vedic texts, the Croatian engineer deciphered the mechanisms that govern the world in Hindu philosophy, assimilating mainly the concepts of *akasha* (ether) and *prana* (the source of universal energy), and adhering to the concept of *luminiferous ether* in order to describe the source, existence and structure of matter (the light effect was demonstrated by Georges Sagnac in 1913), the ether being synonymous with electricity, from his point of view. He explained all observable phenomena through this "infinitesimal world, made up of molecules and their atoms carrying static charges, rotating around their own axis and moving along their orbits, like celestial bodies, engaging the ether in their movement..." (Conference at Columbia College, 1891).

However, in the struggle with Einstein's theory of relativity, Tesla's luminiferous ether lost, being since mentioned at best in discreet, almost embarrassed footnotes. Few victories in modern physics have been so total. Today, relativity gives us the best picture we can have of the macrostructure of the universe. But it cannot be generalized, and the inability to explain the behaviour of the universe at the smallest scales, where only the laws of quantum physics work, clearly indicates that a unitary, integrative, holistic fundamental theory is absolutely necessary.

And, as a culmination of universal irony, the key to the "salvation" of relativity might lie precisely in the much-maligned and ignored ether. Since the early 2000's, a group of researchers have argued that this invisible substance, full of space, could have the power to unite physics, to help build a theory of everything. More and more scientists adhere to this viewpoint. Recently, two independent groups of astrophysicists have suggested that the resemblance between ether and the dark force that populates our cosmos cannot be a mere coincidence. For some, ether is synonymous with dark matter. For others, it could explain dark energy. And the most daring consider that he could designate both...

Courtesy of ESO

It is difficult to touch upon the ether issue without opening up the vacuum issue. This seems to be the key word for understanding the organization of the small and the big infinity. Vacuum possesses its own energy. Nothing, in the sense of absolute void, exists, as long as quantum mechanics postulates - and experiments confirm - the existence of an energy. The vacuum is fluctuating, filled by energy and the movement of billions of particle-antiparticle pairs, which are generated and disappear permanently. On the other hand, particles also contain a quantum vacuum, in a significant proportion. The atom, for example, is much larger than the electrons and nucleus that make it up. Protons in turn contain quantum vacuum, as their mass is largely the movement of quarks rather than the actual sum of the masses of quarks. Almost 90% of the mass of protons comes from the moving energy of quarks, and only 10% from the actual mass of these small constituents (Wilczec, 2003: 32). Even fundamental interactions can be seen as forms of vacuum, argues John Barrow.

Therefore we are entitled to ask: after all, what is an atom made of? We all learned in school that an atom contains a nucleus at its centre and electrons orbiting the nucleus. The nucleus contains nucleons, that is protons and neutrons. However, our knowledge of atoms is very recent, and it was not until the end of the 19th century that scientists began to study it in detail. We now know that, despite the etymology of their name, atoms are not indivisible, that we can “pry” electrons from them, we can break their nucleus, and so on. However, the name remained, designating, in the collective mind, if not in that of the specialists, the smallest possible particle, identifiable as such.

But it is completely daunting to think about the size of an atom. Calculations show that it has a size of the order of 10^{-10}m, that is one tenth of a millionth of a millimetre! And its nucleus is about 10^{-15}m in diameter, that is a hundred thousand times smaller than the atom itself! As for the electron, theoretically, it is a point particle, therefore it does not have a dimension. This means that 99.97% of the mass of an atom is in its nucleus! However, also theoretically, the particles that form protons and neutrons are, like the electron, point particles, that is particles without volume, full of void. Therefore, as the nucleus is very small, the mass of an atom is extremely concentrated. So concentrated that if we removed the vacuum around the atomic nuclei, the Earth could be condensed into a sphere with a radius of only 150 m!

Does that mean, then, that the atom is vacuum?

The above calculations lead to the conclusion that the volume of the atom consists of at least 99.9999999999999999% vacuum! We reach scales of magnitude that are elusive to us, since our minds are equally incapable of conceiving the small infinity as they are the great infinity. *Void, veda* - the same etymology in Sanskrit, the root of the verb *to know*. We return again and again to Vedic knowledge for answers...

But today's scientists have not stopped here with their research. Taking into account the suggestions of string theory, they consider that the quantum vacuum is part of the particles, but also contains them. Hence the deduction, shared by Leonard Susskind (*The Cosmic Landscape*), that vacuum is "a list of all the elementary particles as well as the constants of nature that would be revealed by experiments", being at the same time "an environment in which the Laws of Physics take a particular form" (2006: 279). Therefore, we can say that the entire universe arose from the energy of the vacuum, of the particles that populate it, but which appear and disappear so quickly that they cannot be detected under ordinary conditions, which is why physicists call them virtual.

Is it natural, however, to wonder: where do these virtual particles come from? The answer is given by Heisenberg, in his principle of uncertainty, according to which, if we remove all particles from a small volume of space, it is not *nothingness* that remains in their stead, as pairs of particles and antiparticles appear constantly (it is necessary for the corresponding particle and antiparticle to emerge simultaneously, as the electric charge must remain unchanged), and immediately annihilate each other. Therefore the supposed empty space is, in fact, something very complicated, like a "soup" of particles in constant agitation. On the Plank scale of the world, where dimensions are so small that they no longer mean anything (to us, their Gullivers!), space is nothing like what we can imagine. But this quantum "foam" has immense energy, the sum of the energy of all virtual particles being, according to calculations, greater than that which would be produced by all the stars in the universe, in their entire life, according to the same Susskind. Such energy should simply pulverise the universe. But this is not the case, which means that physicists have still to understand something fundamental. “We made a prediction based on the best theories we have, and it is wrong, woefully wrong”, says Sean Carroll, a physicist at the California Institute of Technology...

Perhaps it is not without interest to present here two comparative tables that can justify the attraction felt by so many great researchers for the rigorous (and poetic) traditional Indian thought. We shall look at the research of the Indian physicist, Rajat Kumar Pradhan (*Particle Physics and the Vaisheshika System: A Comparative Analysis*, 2015), from Uktal University. Here are two figures that compare the physical system of the Vaiśeşika school and that of contemporary physics, from the perspective of indivisibility and eternity of the ultimate particle. We shall not explain them scientifically, this is neither our purpose here nor are we in a position to do so (complete information can be found in the quoted article), but we believe that these schematics are in themselves sufficiently edifying to support a arc over time, the idea of an original community of thought, beyond disparities and historical, cultural and technological peculiarities.

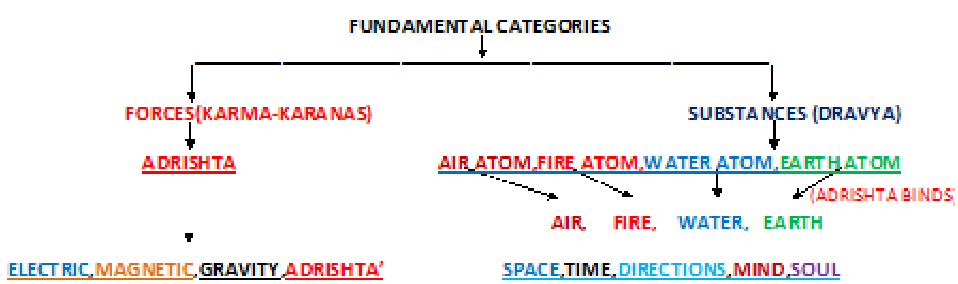


Fig. 1. The Vaiśeşika classification

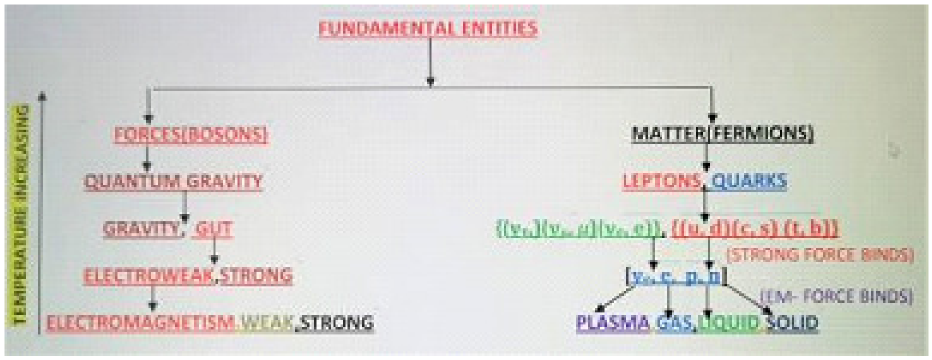


Fig. 2 The quantum physics classification

We only mention that, for the Vaiśeşika school, the mind also appears as an indivisible and eternal atomic particle, and *Adrishta* designates the fundamental or invisible force. In the opinion of the Indian researcher, this is probably the supreme unifying force that can explain all the phenomena involving matter and mind. Traditional Indian philosophy looks holistically at the entirety of our experiences, not just at the physical, quantifiable and subject-to-experience part, as Western science does. Or as it has done until very recently, because these classifications and relationships can not help but lead us to think of the *bootstrap* theory, or of *implicit order*... But we shall return to these issues in more detail in Chapter 5.

*

Finally, let us add that in his 2016 book, suggestively titled *La Plénitude du Vide*, the famous astrophysicist Trinh Xuan Thuan reminds us of the first verse in the *Rig-Veda Creation hymn* (X, 129), which says: *Then was not non-existent nor existent*, therefore, at the origins, before the being, there was nothingness, void, emptiness, not even the non-existent existed, but only the primordial vacuum, full of potentialities waiting for their actualization. For most readers, the above verse certainly evokes resonances from Eminescu, whose work we shall find discussed, along with other similar poetic-philosophical structures, in Chapter 4.

The central problem is that all these exhilarating discoveries awaken in us again the restlessness and ambition of total knowledge. Modern physics tells us that the universe appeared about 13.7 billion years ago, through a grand explosion. We can explain its evolution so far, we can make predictions based on calculations and models, but we are still bothered by an unresolved question: what happened there, at the beginning of the beginning, before the time $t = 10^{-43}$s? In other words, what good is it to be able to describe what happened to the universe *after* time and space began to exist, if we can not know what was *before*? We rummage through the affairs of the gods, forgetting they were angry with Prometheus for much less...

Taking a quick look back, we shall find that all ancient thinkers, be they Indian, Greek, Chinese or Egyptian, as well as philosophers and scientists all the way to the dawn of the modern age have solved this torturous question as simply as possible. By eliminating it. Whatever we call the root cause of the universe, it is the one that generates the creative process. They did not question the possible root cause of the root cause, because our minds cannot conceive of such a thing. In the same *Creation Hymn* we see how the One emanates the whole reality, plurality being only an appearance, and the end of this hymn seems to us really essential (our highlight):

> Who verily knows and who can here declare it, whence it was born and whence comes this creation?
> The Gods are later than this world's production. Who knows then whence it first came into being?
> He, the first origin of this creation, whether he formed it all or did not form it,
> Whose eye controls this world in highest heaven, *he verily knows it, or perhaps he knows not.*

Is there nothing to be learned from this multi-millennial wisdom?

1.2 From holograms and fractals to the informational paradigm

We relearn to live and think under the tutelage of *holos* (in ancient Greek, whole, entirety). Plato left us an important legacy in his series of *Dialogues* that summarize parables learned from his mentor, the philosopher Socrates. And one of the best known myths is that of the cave (*Republic*, Book VII). In this allegory, let us remember, people appear as chained from birth in a cave, so that they can only see the shadows cast by a fire on the cave walls. For these people, shadows represent their entire existence – it is impossible for them to imagine a reality that would consist of anything other than the blurred shadows on the walls. At some point, a prisoner manages to escape from the cave, goes out into the sunlight and sees the reality, but when he returns to the other captives and tries to tell them the truth, he is mocked like a madman. In Plato's time, this story symbolized man's struggle to escape the captivity of the material world and to reach understanding through critical thinking and an open mind. What if, beyond allegory, we read the Platonic myth in its literalness? We are then confronted with the idea that reality could be fully represented by those "shadows" on the walls.

The holographic principle, reminiscent of Plato's allegory, seems to many just as obscure and counterintuitive: how can all complex phenomena, occurring in a three-dimensional space, be equivalent to the shadows dancing on the cave walls? That is, can all the information contained in our body be, in fact, represented by our "shadow"?

One of the starting hypotheses of quantum mechanics was that information can be stored in every volume of space. It has been called the Holographic Principle, and in one form or another we find it in most contemporary thinkers. For example, the physicist and philosopher David Bohm talks about inseparability and *holography*, and the philosopher and sociologist Edgar Morin talks about hologrammaticiy or hologrammatic property, both subsuming them to another fundamental principle – the *relationship*. For Morin, the relationship is at the heart of the notion of complexity, on which his entire system is built. For David Bohm, particles appear when the field folds onto itself, like a cord whose two ends intersect when we want to connect them, thus delimiting a point of contact that is the particle.

Bohm asserted that relativity and quantum theory are in a fundamental contradiction in terms of their essential aspects and that a new concept of order should begin with the one to which both theories point to: *undivided integrity*. The physicist challenged the scientific orthodoxy of reductionism, which has contributed immensely to the success of science over the past four centuries, by breaking up and fragmenting things. But Bohm's point of view is the exact opposite of the reductionist approach. Bohm does not believe that the world can be reduced to a set of indivisible particles in a three-dimensional Cartesian grid, or even in the three-dimensional curvilinear space of the theory of relativity. Instead, the physicist embraces a concept of reality as the dynamic motion of the whole, which he calls *holomotion*: in his 1980 book, *Wholeness and the Implicate Order*, he first presented the hypothesis of the holographic Universe.

The bootstrap theory, developed by American physicist Geoffrey Chew in the 1960s, came with a radical approach to a self-determined and self-sufficient universe. It is another view of elementary particles that puts aside the concept of fundamental entities and states that it is necessary to understand atomic and subatomic reality through the principle of self-consistency, because the structures of matter and those of intelligence or consciousness are reflected and intertwined, and that, after all, nature is what it is because it is the only nature coherent with itself. This novel perspective corresponds to Bohm's idea of implicit order, in which matter and consciousness intertwine, but not in a causal relationship, but in one of mutual containment, referring to a higher reality, which transcends both. But the bootstrap theory was quickly buried, too revolutionary for the inertia of thinking of the time, only to be rediscovered and reactivated today, in geometry and astrophysics, for example contributing fundamentally to the writing of the equations that led to the discovery of the Higgs boson.

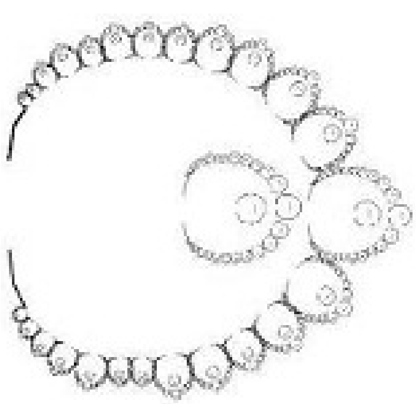
Here we are, having entered the paradigm of the world as a network of relationships, a concept now taken over and developed in many sciences and applied to many disciplines: *reality is a network of relationships* and each part of this network can be understood only in relation to the rest; this means we are no longer talking about fundamental properties independent of the connections with the environment. The concept of relationship has become more important than that of structure or entity or object, and the logical coherence, the self-consistent coherence of these relationships is what determines the structure of the overall network. Some researchers speak of a noetic paradigm (from the Greek word noûs: knowledge, spirit, intelligence), which focuses on the study and development of all forms of knowledge and creation that generate and feed the noosphere, this "layer" of knowledge and information that covers the entire Earth with its networks.

But our universe displays not only the characteristics of holography, but also of *fractality*. As above, so below. Nature is now known for layering and repeating patterns of complexity. Fractality is another way for the multiversal structure to self-organize, optimize, and compress data, but more importantly, it compacts the universal structures *ad infinitum*, into a mathematical representation of infinite fractal propagation.

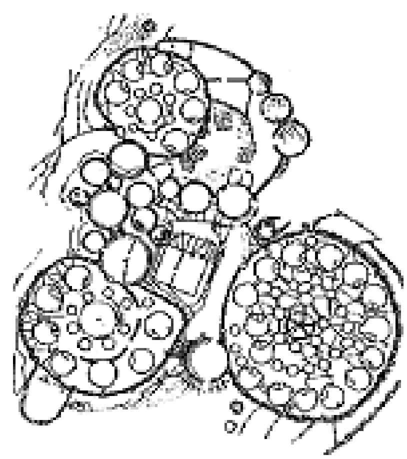
In his well-known book, *Les objets fractals, forme, hasard et dimension / Fractals: Form, Chance and Dimension* (1975), Benoît Mandelbrot laid the foundations of a theory of certain sets of things that can be expressed as infinite sets of precise replicas of them, scaled down and called fractals. The term comes from the Latin word *fractus*, which means broken, fractured. The name is not accidental, because, in addition to the self-resemblance characteristic, it illustrates another essential characteristic of fractals, which distinguishes them from classical mathematical objects: they are not smooth, but have a completely irregular character. Although it was Mandelbrot who formulated the theory of fractals, between 1830 and 1970, many mathematicians (Cantor being perhaps the best known of them) noticed the existence of bizarre, seemingly paradoxical forms, which highlighted the limits of classical analysis, far too restrictive in the face of nature's diversity and irregularities. In fact, fractals appeared in mathematics about 300 years BC, in the treatises of Apollonius of Perga, later rediscovered in 1528 by the research of Albrecht Dürer (who first observed and studied the fractal pentagon ).

Fractals are widely used in modelling the appearance and behaviour of natural systems because they can represent with ease similar shapes that act on multiple levels, while linear geometry cannot. Fractal geometry is practically the missing complement of Euclidean geometry. Also with the help of fractals, biologists and psychologists have managed to diagnose the "dynamic diseases" that occur when fractal rhythms become synchronized.

Obvious and natural examples of fractals are, for example, fern leaves or snowflakes, but scientists such as ethno-mathematician Ron Eglash (*African Fractals: Modern Computing and Indigenous Design*, 1999), following in the footsteps of Mandelbrot, have discovered that fractals are also a very ingenious way of predicting the future in ancient African civilizations, or that the shape of West African villages corresponds to a fractal geometry.



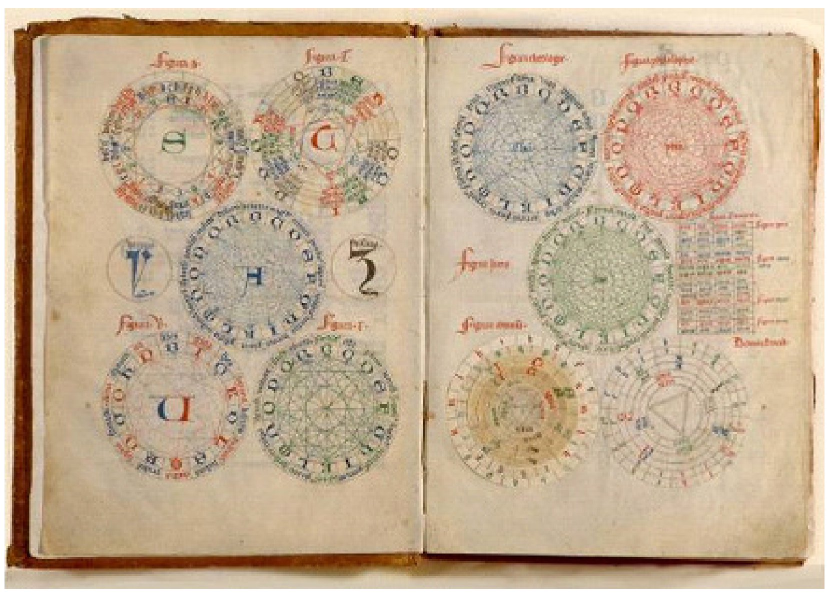
Layout of the Ba-Ila village in South Zambia



Layout of the Mokoulek village in Cameroon

Moreover, although our Eurocentric arrogance, doubled by the cult of technological modernity, leads us to believe that all the great discoveries of mankind come from us and that they are relatively recent, there is clear evidence that Africans invented the "digital computer" as early as the tenth century. In an exciting book, *Histoire de la modernité* (2012), the scholarly professor and economist Jacques Attali talks about the so-called "Bamana code" (the Bamana or Bambara population being, along with the Dogons, in the Mali area, the repository of amazing knowledge, often disguised in myths and rituals), a system for predicting the future, based on simple logic, which is exactly what we call binary code (0 and 1) or Boolean code in modern mathematics, which is the basis of today's digital computer.

In fact, we know very well how things developed. This "Bamana code" started from West Africa in the tenth century, picked up by Arab traders, arriving in Cordoba with Hugo Santalia in the twelfth century, then making its mystical entry and alchemical practice, under the name of geomancy, developed and refined by the brilliant mind of the Catalan Ramon Llull (a fascinating topic for Ioan Petru Culianu), in his *Ars combinatoria*...



Códex written by Ramon Llull (1232-1315). Cod. Cus. 83: Raymundi Lulli Opera, version published in 1428 (St. Nikolaus Hospital-Cusanusstif Bibliothek, Bernkas)

... before reaching the Netherlands and the mathematician and philosopher G.W. Leibniz (17^{th} century), from whom George Boole borrowed the binary code, creating his now-famous Boolean algebra (in the 1850's), based on which John von Neumann created the digital computer (in the 1950's). How simple and coherent appears to be the essentialised history of human thought when we look at it in elliptic leaps! (Ron Eglash, *African Fractals: Modern Computing and Indigenous Design*, Rutgers University Press, 1999)

In this context, the concept of *hologram*, that is a recording of a three-dimensional image on a generally two-dimensional environment, returns to attention. The method was discovered in 1947 by the Hungarian physicist Dennis Gabor, but could not be widely applied until after 1960, with the invention of the laser. The essential difference between a photograph and a hologram is that, in the case of the hologram, the information about each point in the object is not strictly located in a certain area, being instead global, distributed over the entire surface of the hologram. Cutting a person's hologram in half and then illuminating it with a laser beam, we notice that each half contains the entire image of that person. Continuing the experiment recursively, if the two halves are split again, each new part will contain an obviously smaller, but intact, version of the original image. Each part of a hologram thus contains all the information held by the whole.

In collaboration with renowned neurophysiologist Karl Pribram, the already mentioned quantum physicist David Bohm helped develop the *holonomic* brain theory, a model of human cognition that describes the brain as a holographic storage network, in which the universe appears as a huge hologram created by the mind, in accordance with quantum mathematical principles and the characteristics of the corresponding models (a topic developed in Chapter 5). Pribram believes that, in itself, the brain is a hologram. He believes that information is not encoded in neurons or in restricted formations of neurons, but instead in the configurations of the nerve impulses that intersect in the brain. Each unit of information seems to be interconnected with any of the others, which is an intrinsic feature of the hologram. If reality is nothing but a holographic illusion, then the old paradigm according to which the brain produces consciousness can no longer be true. It seems to be the other way around: consciousness creates the appearance of the brain, the physical body and all the things that surround us and that we perceive to be real.

With technical innovations, relationships, networks, complex thinking become essential dimensions, and *information* becomes nested in the core of human life, covering all aspects of existence, from physics and biology to the social sciences. We all acquired, in a short time, an "informational nature", and the main way of modelling, therefore of quantifying information is to use patterns of symbols and the relations between them. No symbol is independent, none can be intelligible and cannot function outside a framework of representation, a "grammar" proper to a given system, within which the symbol creates various associations and networks. And in a scientific approach, information is generally defined in relation to a given symbolic system, which is accepted as a model for a particular situation or environment (especially after visionary researchers such as Alan Turing, John von Neumann, Norbert Wiener and others laid the foundations of this informational paradigm in the first decades of the 20th century). But her, things have separated significantly because, in the "exact" sciences, mathematical language is considered to be the most direct and rigorous, being a convenient tool for translating symbolic systems, while in the "human" sciences, in literature, in art, the ambiguity and polysemy of symbols are privileged. A separation that the new paradigm no longer justifies and which is convincingly, successfully and in a particularly exciting manner cancelled by the epistemology of transdisciplinarity.

1.3 The transdisciplinary vision

The origin of the concept of transdisciplinarity must probably be sought in Niels Bohr's (1955) article on the unity of knowledge. The word does not appear as such, but the concept is clearly expressed: "The issue of the unity of knowledge is closely related to the search for a universal understanding, intended to elevate human culture" (p. 272). This general attitude, characterized as an effort to harmonize increasingly vast and complex issues, was determined by the quantum revolution.

It is not easy to locate in time the word "transdisciplinarity". However, a precise reference is the text written by Jean Piaget in 1970, during a conference on interdisciplinarity: "Finally, in the stage of interdisciplinary relations, we can hope to achieve a higher stage that would be" transdisciplinary, "which would not be content with achieving interactions or reciprocities in specialized research, but instead would situate these links in an overall system, without stable boundaries between disciplines" (1967: 1151). After this date, several authors, especially in France, tried to clarify their view of transdisciplinarity, the first being Basarab Nicolescu (1985, 1993) and Edgar Morin (1994).

> Transdisciplinarity concerns - as the prefix "trans" indicates - what lies at the same time between disciplines, as within various disciplines, as beyond any discipline. Its finality is the understanding of the present world, one of its imperatives being the unity of knowledge.
>
> (Nicolescu, 2007:53)

In other words, within and without disciplines, the search for meaning is established by rediscovering the unity of the universe, life and man, tearing down the walls between forms of knowledge and practicing, according to Basarab Nicolescu's fortunate formula, a "jubilant transgression". Here are the main points of the principles it establishes:

- Transdisciplinarity is incompatible with a reduction of man to a formal structure and with the reduction of reality to a single level and to a single logic.
- Transdisciplinarity offers a new vision of nature, by opening disciplines to what intersects and transcends them. It goes beyond the realm of the exact sciences, which it seeks to reconcile with the human sciences.
- Transdisciplinarity relocates man in the universe.

In short, transdisciplinarity acknowledges that science has reached nowadays the frontiers of metaphysics, and that quantum physics, the evolution of matter after the Big Bang, the standard model of cosmology, etc. cause human beings to ask again the questions that science cannot answer: Where do we come from? Who are we? Where are we going?

Transdisciplinarity comes to meet the needs of this new type of civilization, which is not a natural extension of the past, because the mental mechanisms that have reigned for centuries are about to die out, in order to allow a metamorphosis to occur, a radical regeneration of knowledge, which becomes increasingly compartmentalized, disjointed and hyperspecialized. All these questions, and more, will be also addressed in the last chapters.

For Basarab Nicolescu, the notion of transdisciplinarity is inseparable from the quantum revolution which fundamentally challenged the belief that scientific truth has completely exhausted the field of truth and knowledge, just as it is inseparable from two other fundamental notions: *levels of reality* and *the included third*.

1.3.1 Levels of reality

According to the Romanian physicist and philosopher, the notion of *level of reality* is distinct from that of *level of organization*. The notion of *reality*, which runs through the entire philosophy of Plato in Kant and Auguste Comte, has been challenged by quantum physics, which has led to the recognition of different levels of reality. Basarab Nicolescu states that by *reality* he understands "what resists our representations, descriptions, images. By level I understand a set of natural systems that is invariant under the action of certain laws" (2007: 51). He makes a distinction between *reality* and *the real*, which is "what is" and can never be fully known. Reality therefore designates whatever can be represented or described, whatever we can transpose into language, images or mathematical formulas, that is to say what is rationalizable, as well as what is verified and confirmed through experiment.

The transition from one level of reality to another is far from being explained, because it is both continuous and discontinuous. The microphysical transition is particularly disturbing, because the laws and properties that characterize the quantum level seem irreconcilable with those of the classical physical level, violating all the principles that govern classical thinking, namely the principles of intelligibility, identity, location, causality and separability. Numerous physicists are trying to articulate these two levels of reality, as we know, but so far no perfectly viable theory has been proposed.

But the transition from the physical to the biological level is also a gap that appears to be unexplainable, insofar as, despite some progress, researchers still do not agree with the modalities and stages of this transition. It is true that there is an almost infinite distance between the most complex molecules found in nature and the simplest unicellular being, such as a bacterium. It is not enough to know the structures and functions of a bacterium to understand how it came to be in this world, endowed with certain radically new properties that would remain common to the entire living world.

Regarding the transition from a neuronal activity of an electrochemical nature to a conscious psychic activity consisting of images (representations) and emotions, it remains largely an enigma. Indeed, not only do these images and emotions constitute a different level of reality from the previous ones, but, in addition, they imply that a "subject" perceives and experiences them. Finally, language and reflexive thinking, which represent a psychological reality different from that of perception, are far from revealing the ways and stages of their emergence.

Merely listing the levels of reality proves that each has its specific laws and properties, although they depend on those of the basic levels. Since these laws and properties can be defined – but not explained – without taking into account those of the basic levels, each level gives the impression that it transcends those on which it depends. Thus, psychology is able, within certain limits, to develop into an autonomous discipline, without the need for neurobiology knowledge, but only to the point where only the knowledge of neurobiology makes it possible to explain certain phenomena. If we knew how the transition from one level of reality to another occurs, we would be able to integrate the local into the global.

As far as science is concerned, transdisciplinarity exists only based on disciplines. Scientific knowledge had to reach a certain level of development and all the disciplines had to accumulate significant results for true transdisciplinarity to be possible, although holistic attempts have always existed, as we have seen. Disciplinarity and transdisciplinarity are complementary when it is possible to establish intersections and relationships between all areas of knowledge and all components of the universe, of which man is an integral part, being in constant interaction with them. It is, however, an illusion to think that, one day, this "theory of everything" that scientists dream of could be formulated. Ever since Gödel gave us a subtle and difficult proof of his incompleteness theorem, we have given up complete and closed theories in favour of an open and evolving worldview in which levels of reality are articulated rather than excluded. Transdisciplinarity recognizes the coherence of all levels of reality, but does not forget that it is impossible to observe them all at the same time, that the problem of transitioning from one level to another remains open, as does that of articulation between levels of organization. Man has the intuition of the unity of this whole, but since he is part of it, he cannot explain it.

In the same vein, notions of the level of reality and organization forbid the reduction of the "superior" to the "inferior". Thus, the level of conscious representation, that of sound, visual and other images remains an emergent one and cannot be reduced to that of electrochemical neural phenomena, which are nevertheless the condition of the former.

Whereas each discipline, through in-depth research, reveals more and more of the complexity of structures and processes, transdisciplinarity reveals another aspect of complexity, that of the exchanges and interactions between the constituent elements of the universe, Earth and man. Thus, transdisciplinarity will not eliminate from its field of research the sphere of the sacred, because it is precisely what connects the object and the subject, thought and experience, the effective and the affective, the one that transgresses dualities and operates transmutations. Such an exploration underlines the isomorphisms and analogies that bring these traditions closer together and tend to the "peak" of infinity, where the last convergences sink into Unity, without however seeking false dissolving syncretisms, but on the contrary, fully respecting every tradition related to the primordial, shared background.

1.3.2 The included third

The logic of the included third was developed by Ştefan Lupaşcu, starting from the results, "contradictory" for the classical logic, obtained by quantum mechanics. At the moment it stressed the fact that quantum particles are both particles *and* waves, this contradicted the classical logic that is based on the axioms of identity, non-contradiction and the excluded third.

The clash between classical logic and quantum mechanics gave rise to a new logic, which allowed conciliation with experimental results. The new quantum logics, developed by Birkhoff, van Neumann and others, sought to solve the paradoxes generated by quantum mechanics and, as far as possible, "to reach a greater predictive power than classical logic" (Nicolescu, 2007: 35). These logics have, in fact, modified the axiom of non-contradiction (the second axiom of classical logic) to allow for more truth values (Nicolescu, 2009: 26).

According to classical logic, there can be no particle that is at once both A and non-A, that is, both wave and particle, because this is in contradiction with the third axiom, of the excluded third. This problem raised by quantum physics actually confronts us with our thinking habits, which place us on a single level of reality. "One and the same level of reality can only give rise to antagonistic oppositions" (Nicolescu, 2009: 81).

It was Ştefan Lupaşcu (1960, 2000, 2005) who found the most adequate solution by formulating *the logic of the included third*, based on energy antagonism. Unlike the authors of multivalent logics, Lupaşcu proposes changing the third axiom of classical logic, stating the existence of a term T, which is both A and non-A. It was considered that Lupaşcu's logic contradicted the second axiom of non-contradiction, hence the inappropriate name of "logic of contradiction" (Nicolescu, 2009: 26). The necessary clarification came with at the same time as the idea of multiple levels of reality, advanced by Basarab Nicolescu.

In his vision, there are three types of included third: the logical included third, theorized by Ştefan Lupaşcu, the ontological included third, in which the logical operator is correlated with the leap from one level of reality to another, and the hidden third, which plays a vital role. in the interaction between the transdisciplinary object - "the set of levels of reality and its complementary area of non-resistance" - and the transdisciplinary Subject, represented by "the set of levels of perception and its complementary area of non-resistance", because, through a zone of absolute transparency, it makes possible the communication between the flow of information that passes through the external world and the flow of consciousness that traverses the inner universe.

There are a few other essential operation notions that transdisciplinarity works with.

1.3.3 The system

Everyone is talking about systems today, a concept that has become fashionable once more after a long period during which the sciences were dominated by the idea that it was enough to know the parts or basic elements in order to know the whole, since they were, after all, just DIY pieces, mechanical constructions with parts that science was meant to distinguish and analyze. Indeed, an erstwhile known idea resurfaces: that the whole is something more than the sum of its parts; in other words, an organized whole, a system, produces or favours the appearance of a certain number of new qualities which were not present in its separate parts. Is it not one of the greatest mysteries of the universe that scattered elements, such as macro-molecules, for instance, have come together to give birth to the first living being? And that completely new qualities have emerged from this new type of organization, such as knowledge, memory, movement, self-reproduction?

In biology, the content of intuitions about the irreducibility of living beings has gradually been enriched, from Aristotle to F. Jacob and A. Pichot, by Leibniz, Kant, von Weizsaecker or Buytendijk, for in the living world it is possible to isolate parts of a whole, but you can never reassemble the whole using those parts. Here, more than anywhere, the character of the totality of a structure is not related solely to the visible and measurable forms of organization, because it is in fact a systemic totality.

Reductionism is one of the ways in which modern science promotes the possibility of unifying knowledge through a single language. In this context, the facts belonging to a certain field are explained by models and theories belonging to a lower level. In addition to this epistemological attitude, another explanatory approach tries to privilege the existence of irreducible structures, meaning structures that cannot be broken down into simpler elements without endangering the specificity of the phenomena. G. Canguilhem makes an interesting observation: "(...) an organic element can be called an element only in a state of non-separability. In this sense, let us remember Hegel's formula according to which the whole is the one that realizes the relation between parts as parts, so that there are no parts outside the whole." (G. Canguilhem, *The Whole and the Part in Biological Thinking*, in "Etudes d'histoire et de philosophie des sciences", Vrin, 1968, p. 332.). The parts of the whole constitute a primordial fact, and we find here the notion of emergence, of the properties inherent to the structure as such rather than in the sum of the properties of the constituent elements. In a connectionist network, knowledge is not represented by a set of locable symbols on which sequences of instructions can act, as in the classical cognitivist models. A connection network can thus store a multitude of examples. Given the distributed nature of information storage, one of the remarkable properties of these networks is plasticity.

We can therefore conclude that the notion of system makes it possible to connect and bind the parts into a whole, and to free us from the prison of fragmented knowledge.

1.3.4 The Circular causality

Another important concept is that of circularity or loop. It has been often used without being named. When Pascal said, “It seems impossible to me to know the whole if I do not know the parts, or to know the parts if I do not know the whole”, he stressed that true knowledge is the one that follows the circuit from knowing the parts to the whole and from knowing the whole to knowing the parts. Norbert Wiener explained this idea in his own way, talking about a regulatory loop, in which the return of the effect on the cause cancels the deviance, thus ensuring a relative autonomy of the system. It is obvious that this idea of relative autonomy was all the more important as it had been inconceivable previously, because the determinism of classical science was based on a causality external to objects. And it is not the only type of loop. The most interesting and powerful is the self-generating or recursive loop, the most convenient example being ourselves, who are the products of a cycle of biological reproduction in which we become producers, so the cycle can continue. We are products that produce. Thus, society is the product of interactions between individuals, but, globally, new qualities appear that, through feedback to individuals – through language, culture, etc. - allow them to realize themselves as individuals. Individuals produce the society that produces individuals.

Thus we understand better how interdependencies are constructed. The more autonomous our mind wants to be, the more it has to feed on various cultures and knowledge. Schrödinger had already stated that we carry otherness within our identity, at least the otherness of the environment. In our identity as social individuals, we carry the otherness of society. In our identity as a thinking subject, we carry the otherness of the genetic inheritance which is that of humanity, and the instinctual inheritance, which is that of our animality. And so we come to a number of concepts that should allow us to become closer and connect, instead of becoming separate.

1.3.5 The Complex thought

Because we have discussed it separately before, we shall link the hologrammatic principle to complex thinking. In a system, in a complex world, it is not just the part that is in the whole, but also the whole is in the part. Not only the individual is in a society, but also the society is in him, instilling in him from birth, a language, a culture, prohibitions, customs, mentalities, values; and man carries in him particles that were formed at the beginning of the universe - carbon atoms, the macro-molecules that appeared before life was born. We carry within us the mineral kingdom, and the vegetable kingdom, and the animal kingdom. We are, in a way, the microcosms of the macrocosm, mirrors of the cosmos; in our singularity, we carry within us the whole universe, in the widest and most solid network imaginable.

Kant also develops such a reflection, which has retained all its acuity and relevance, especially in the very complex contemporary debate around artificial intelligence and natural intelligence, or in that around transhumanism:

> Any space intuited within its boundaries is such a whole, whose parts in every decomposition are in turn spaces, and it is, therefore infinitely divisible. (...)
>
> The infinitude of the division of a given appearance in space is grounded solely on the fact that, through this infinitude, only the divisibility (in itself, as regards the number of its parts, absolutely indeterminate) is given - the parts themselves being given and determined only through the subdivision. In a word, the whole is not in itself already divided. The number of parts, therefore, which a division may determine in a whole, will depend on how far we care to advance in the regress of the division.
>
> In the case of an organic body articulated to infinity [...] the whole is represented through this very concept as already divided up, and a multiplicity of parts, determinate in itself but infinite, is encountered prior to every regress in the division - through which one contradicts oneself, since this infinite development is regarded as a series that is never to be completed (as infinite) and yet as one that is completed when it is taken together.

It is the reform of thought that makes possible the integration of these types of connections; a complex thinking that is not afraid to approach with serenity and force at once both separation and connection. Which is not very difficult to do if we understand that "reality is plastic", as Basarab Nicolescu (2009) stated, that we are part of it, that it "changes due to our thoughts, feelings and actions".

In 2005, François Martin presented a theory in which the human psyche is viewed as a field of consciousness of a quantum nature, which would be universal and would extend to the unconscious level. The human psyche would thus have a formal representation analogous to a quantum system, with virtual states and physical states that correspond respectively to the potential and the actualization of the human mind. Free will plays a central role in moving from potentiality to actualisation and vice versa. Before becoming actualized through free will, the human spirit would be in a state of overlap. This overlap would result in particular in the possibility of two human psyches being quantum entangled, similar to quantum systems.

We are experiencing a paradigm shift, as we have said before, we are gradually emerging from the era of reductionism, of segmentation detrimental to knowledge. Any new paradigm, through its mode of operation, modifies, shifts the expectation horizon, directs and conditions the conscious psychic activity. It is convenient, in the sense that it facilitates the reading and interpretation of the world and of our relationship with it, guiding it through already established schemes and models. But, Edgar Morin warns us that "the paradigm is blinding (...) The paradigm is invisible, located in the order of the unconscious and the superconscious, it is the invisible organizer of the visible organizational core of theory" (...) (1991: 216-219). A great paradigm determines, through theories and ideologies, a mentality, a "mindscape", a vision of the world. The possibility of "thinking differently" undoubtedly remains open, but it cannot depend on a simple effect of willpower.

The field of knowledge is increasingly overlapping with the field of communication and information, and if we want to find the meaning of "universality", we must keep in mind that the current evolution is no longer based on the cumulative acquisition schemes previously practiced, but instead on multidimensional processes. Transdisciplinarity manifests itself not only as an evolution of the multi-inter-plural-disciplinary triad, but as a path from sequentiality to the dynamic recovery of integrity. This epistemology raises questions on the stage of an investigation of scientific ways of thinking and, consequently, forces us to ask ourselves questions about their true degree of autonomy, because no science has all the keys necessary to elucidate its own object in the very register in which it claims to own them.

Transdisciplinarity can also be defined as a common system of axioms for a set of disciplines, insofar as notions such as *complexity, hybridity, nonlinearity, reflexivity, heterogeneity, dialogical, circular causality, holistic perspective* are increasingly used and end up producing theoretical structures, research methods and modes of practice that are not "localizable" on a monodisciplinary map. Knowledge is dynamic, it breaks more and more easily the classical societal and cognitive constraints towards a continuous form of network of connections and mutual influences, always generating new configurations, to a coherence, to the detriment of fragmentarism. These transgressions of borders affect all areas, as the erosion of nation states, the globalization of economic activities, the explosive development of information technologies and the new models of cultural diversity and multiple identities have created a new constellation that no longer fits into the old systems and concepts of strict differentiation and classification. Some authors, such as Basarab Nicolescu dare to speak of a new Renaissance, in which the watchword is the permanent movement both ways across thresholds.

But interdependence and cohesion do not mean the cancellation of differences and identities, their melting into an amorphous magma, but rather their placement into a relationship and under a mutually enriching light. The great prize of transdisciplinarity is the replacement of a disjunctive type of thinking with a correlative, open, creative type of thinking.

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Chapter 2

The atom of the mathematical "reality" or the composition and decomposition of the whole

In every atom of the realms of the universe
there exist vast oceans of system-worlds.
The Flower Adornment Sutra
(ancient Buddhist writing)

2.1 Introduction

The idea that matter is made up of discrete units is a very old one, which occurs in many ancient cultures, such as the Greek and Indian ones.

As a cosmological theory, atomism believes that the universe is composed of atoms that were thought to be indivisible and can never be transformed. This notion appeared in the years 500 BCE, its followers being the Greek philosophers Leucippus and Democritus, and the theory was developed later in the fourth century BCE by Epicurus. The Roman philosopher and poet Titus Lucretius Carus, in his *De rerum natura*, uses the synonym relation atomism - epicureanism. A theory from the times of Empedocles and Aristotle considered matter to be the element of origin of the universe, consisting of the four essential primordial elements: earth, fire, air and water. These ideas relied on philosophical and theological reasoning, rather than on concrete evidence and experiments.

Thus, Empedocles wrote:

> The elements predominate, taking turns, throughout a cycle, they disappear by merging with each other or continue to grow depending on the turn that fate assigns to them. Remaining the same, they circulate through each other [...]. So, in so far as one is born of the multiple and, conversely, after the decomposition of one, the multiple is reconstituted, all things appear and do not have a permanent duration. Because this perpetual change never stops, all things subsist through an unchanged cycle.

2.2 Axiomatization, irreducibility and in(non)decomposability in mathematics

In the modern understanding, a set of axioms is any collection of formally stated assertions from which other formally stated assertions follow by the application of certain well-defined rules.

Now, if we take the two sciences dealing with axiom, in logic, it is an indemonstrable first principle, rule, or maxim, that has found general acceptance or is thought worthy of common acceptance, while in mathematics, an axiom, postulate or assumption is a statement that is taken to be true, to serve as a premise or starting point from which other further reasoning, arguments and statements are logically derived. It is self-evidently true without proof.

Today, we take for granted that logic is the basis of intellectual activity. As a formal discipline, it started with Aristotle, who intended to catalog things (causes, events, animals, causes, etc.), identifying valid forms of arguments, and creating symbolic templates for them. This is what we basically considered as the the main content of logic for more than two thousand years.

But what is the support of logic itself?

If, in symbolic logic, we introduce symbols like p to stand for "proposition", then we can derive some basic "laws of thought" which are fundamental axiomatic rules upon which we base our rational discourse. The main logical rules are:

1. The law of identity: p is p;

2. The law of noncontradiction: p is not non-p;

3. The law of the excluded middle: either p or non-p.

But where do these laws of logic come from? Logic is a formal system. And it can be built on axioms, like Euclid's geometry. By the 1400's, algebra had been invented, and spread all over the world, bringing along cleaner symbolic representations of things. But it was only in 1847 that George Boole formulated logic in the same way as algebra, with logical operators like and/or, according to algebra-like rules. Then, in 1910, Whitehead and Russell (Principia Mathematica) generalized the idea that perhaps all of mathematics could be derived from logic.

Mathematicians have often used the words postulate and axiom as synonyms. Some recommend that the term axiom be reserved for the axioms of logic and postulate for those assumptions or first principles beyond the principles of logic by which a particular mathematical discipline is defined.

Mathematicians assume that axioms are true without being able to prove them. If someone starts with different axioms, then he will get a different kind of mathematics, but the logical arguments will be the same. Mathematics is not about choosing the right set of axioms, but about developing a framework from these starting points and every area of mathematics has its own set of basic axioms. In the early 20$^{\text{th}}$ century, David Hilbert set up an extensive program to formalize mathematics and to resolve any inconsistencies in the foundations of mathematics. This included demonstrating all theorems using a set of simple and universal axioms, proving that this set of axioms is consistent, and proving that this set of axioms is complete, i.e. that any mathematical statement can be proved or disproved using the axioms.

Unfortunately, these plans were destroyed in 1931 by Kurt Gödel, who showed that in any (sufficiently complex) mathematical system with a certain set of axioms, one can find some statements which can neither be proved nor disproved using those axioms. When first published, Gëdel's theorems were deeply troubling to many mathematicians. When setting out to prove an observation, you do not know whether a proof exists – the result might be true but unprovable. Today we know that incompleteness is a fundamental part of logic, but also of computer science, which relies on machines performing logical operations. Surprisingly, it is possible to prove that certain statements are unprovable.

Axioms play a key role not only in mathematics but also in other sciences, notably in theoretical physics. In particular, the monumental work of Isaac Newton is essentially based on Euclid's axioms, augmented by a postulate on the non-relation of space-time and the physics taking place in it at any moment.

In 1905, Newton's axioms were replaced by those of Albert Einstein's special relativity, and later on by those of general relativity. Another paper of Albert Einstein and coworkers (see the Einstein-Podolski-Rosen paradox), almost immediately contradicted by Niels Bohr, concerned the interpretation of quantum mechanics. This was in 1935. According to Bohr, this new theory should be probabilistic, whereas according to Einstein it should be deterministic. The underlying quantum mechanical theory, i.e. the set of "theorems" derived by it, seemed to be identical. Einstein even assumed that it would be sufficient to add to quantum mechanics "hidden variables" to enforce determinism. However, thirty years later, in 1964, John Bell found a theorem, involving complicated optical correlations (see Bell inequalities), which yielded measurably different results using Einstein's axioms compared to using Bohr's axioms. And it took roughly another twenty years until an experiment of Alain Aspect got results in favor of Bohr's axioms, not Einstein's.

The role of axioms in mathematics and in the above-mentioned sciences is different. In mathematics one neither "proves" nor "disproves" an axiom for a set of theorems; the point is simply that in the conceptual realm identified by the axioms, the theorems logically follow. In contrast, in physics, a comparison with experiments always makes sense, since a falsified physical theory needs modification. Irreducibility refers to something that is incapable of being reduced or of being diminished or simplified further.

In mathematics, the concept of irreducibility is used in several ways. For instance, an irreducible polynomial is, roughly speaking, a polynomial that cannot be factored into the product of two non-constant polynomials. An irreducible fraction is a fraction in which the numerator and denominator are integers that have no other common divisors than 1 (and -1, when negative numbers are considered), while a fraction is reducible if it can be reduced by dividing both the numerator and denominator by a common factor. In topology, a hyperconnected space or irreducible space (the term irreducible space is preferred in algebraic geometry) is a topological space that cannot be written as the union of two proper closed sets (whether disjoint or non-disjoint). And the examples can go on; the essence remains the same...

Indecomposability (or, nondecomposability) refers to the incapacity of being partitioned, separated into components or basic elements. For instance, in abstract algebra, a module is indecomposable if it is non-zero and cannot be written as a direct sum of two non-zero submodules. In many situations, all modules of interest are completely decomposable; the indecomposable modules can then be thought of as the "basic building blocks", the only objects that need to be studied. In point-set topology, an indecomposable continuum is a continuum that is indecomposable, i.e. that cannot be expressed as the union of any two of its proper subcontinua. In probability theory, an indecomposable distribution is a probability distribution that cannot be represented as the distribution of the sum of two or more non-constant independent random variables. In chemistry and physics, atomic theory is a scientific theory of the nature of matter, which states that matter is composed of indivisible units called atoms.

2.3 Does matter exist?

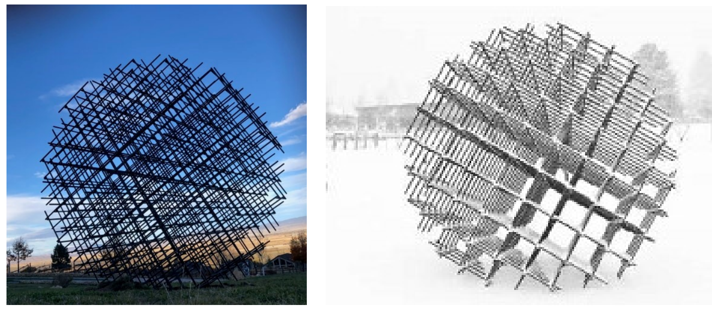
It is easier to disintegrate an atom than a prejudice.
Albert Einstein

In the twentieth century, the term began to be used more and more by chemists in connection with the growing number of irreducible chemical elements. In the early twentieth century, through various experiments with electromagnetism and radioactivity, physicists discovered that the "indivisible" atom was actually a conglomeration of various subatomic particles (mainly electrons, protons and neutrons), which may exist separately; some others, such as Nobel laureate Max Planck, went as far as to state that matter does not exist. Thus, at the Nobel Prize in Physics in 1918, he said:

> As a man who has devoted his whole life to the most clearheaded science, to the study of matter, I can tell you as a result of my research about the atoms this much: There is no matter as such! All matter originates and exists only by virtue of a force which brings the particle of an atom to vibration and holds this most minute solar system of the atom together. We must assume behind this force the existence of a conscious and intelligent mind. This mind is the matrix of all matter.

Einstein supported this idea, namely that "the atom [is] energy rather than matter" and that "atomic energy is essentially mind-stuff".

Since atoms proved to be divisible, physicists later coined the term *elementary particles* in order to describe *the indivisible, though not indestructible, parts of an atom.*



Philip Vaughn, Atom Rebar Sphere

It should be mentioned that the principle of indivisibility and that of irreducibility (indecomposability) are of overwhelming importance in mathematics. On the one hand, the atom, in the mathematical sense, does not model the physical atom, but instead preserves and reflects the idea of the atom in its indecomposable essence. To give just one example, a prime number is a natural number, greater than 1, which has exactly two divisors: the number 1 and the number itself. These divisors are improper. A prime number is therefore non-factorable, impossible to split, indivisible. The opposite of the notion of prime number is that of composite number.

On the other hand, mathematical modelling proves to be not only indispensable, but also in a fertile relationship of intertextuality with atomic physics. An article published in the journal *Notices of the American Mathematical Society* ("Math Unites the Celestial and the Atomic", Sept. 6, 2005) reports research that shows a hidden unity between the motion of objects in space and that of the smallest particles. The mathematics that describes celestial mechanics and that which governs certain aspects of atomic physics seem to correspond. The relationship between atomic dynamics and celestial dynamics seems to be underpinned by the same equations that characterize both the motion of bodies in celestial systems and the energy levels of electrons in simple systems.

Last but not least, in mathematical logic, an atomic formula or an atom designates a formula that does not contain its own sub-formulas. And this principle, of indivisibility, is also found in philosophy. For example, Leibniz's philosophical system is based on the existence of indivisible spiritual elements called *monads*. In Greek, *monas* means "unity", that which is "one". Leibniz believed that everything is, from a metaphysical point of view, reducible to a simple substance. Monads are simple substances that are not born and do not perish, their autonomy being total. They are indestructible, being a mirror of the entire universe. Monads hold a high degree of knowledge of the world, or rather a distinct, unique degree, which is due to the fact that they are eternal, without space, therefore they can be said to be indecomposable. Since "space is an illusion", in Leibniz's view, monads have no spatiality and therefore a distinction must be made between atoms and monads.

Therefore, according to Mandelbrot's principle of fractality (self-similarity), we can say that each monad is in itself a whole world, seen in a certain way. To put it differently, the world is made up of countless worlds.

2.4 Atomism and holism

We have seen, in brief, what atomism is. But as everything in this world exists in opposing pairs, the philosophical concept diametrically opposed to atomism, namely *holism*, was born. While atomism divides things in order to know them better, holism looks at things or systems as a whole and argues that in this manner we can know more about them, and understand better their nature and purpose.

Ian Smuts, who introduced the term *holism* in his 1926 book, *Holism and Evolution*, refers to the dialectic of the part-whole relationship as follows:

In the end it is practically impossible to say where the whole ends and the parts begin, so intimate is their interaction and so profound their mutual influence. In fact so intense is the union that the differentiation into parts and whole becomes in practice impossible, and the whole seems to be in each part, just as the parts are in the whole (1987/1926: 126).

The explanation is that, unlike atomism, which considers that any whole can be broken down by analyzing its separate parts and the relationships between them, holism states that the whole takes precedence and, due to the phenomenon of *emergence*, discussed in the first chapter, and developed in Chapter 5 as part of the theory of complex systems, it is different and more important than the sum of its parts, as Nobel laureate Philip Anderson wrote in an article in the journal Science, to which he gave this very title, "More is different" (*Science* 04 Aug 1972: Vol. 177, Issue 4047, pp. 393-396, DOI: 10.1126/science.177.4047.393).

In fact one can argue that emergence explains the remarkable simplicity of complexity, and that the richness of the world around us emerges from the complex behaviour of many interacting components. As elegantly stated by the German scientist and engineer Jochen Fromm:

- one water molecule is not fluid

- one gold atom is not metallic
- one neuron is not conscious
- one amino acid is not alive.

Emergence therefore represents that property of a complex system, a property that arises from the collective interaction of its components and that cannot be predicted by analyzing only the structure or behaviour of a small number of constituents subject to fundamental laws.

When systems become very complex, it is almost impossible to predict their next states. Therefore, these phenomena require the introduction of new concepts and theories and, as this relates to the way we get to know the world, it has been called *epistemological emergence*, being associated in recent years with the complexity theory and with the nonlinear systems theory. Epistemological emergence does not threaten atomism at a fundamental level; it does not dispute the fact that the world is made, at ultimate level, of infinitesimal parts, but simply argues that the way these elements behave is not perfectly predictable.

In a logical approach, by holism we mean that the world functions in such a way that no part can be known without the whole being known first. Logical atomism is the alternative developed to logical holism, arguing that the world consists of logical facts (or atoms) that can no longer be broken down, and that each can be understood independently of other facts and without prior knowledge of the whole. All truths are thus dependent on a layer of atomic facts, and the world is made up of extremely simple and easy to understand facts.

The debates about the nature of reality, in which mathematics has always been involved, have brought it closer to the realm of quantum mechanics, even to that of psychology, where, with particular relevance and intensity, Nobel Prize-winning physicist Wolfgang Ernst Pauli and psychoanalyst Carl Gustav Jung, debated, over the course of an intense correspondence and a quarter of a century of friendship, about reality, the Self, the structure of the psyche, and the phenomena associated with it (e.g., synchronicity), aspects detailed in Chapter 5.

The analogies between the structure of the psyche and that of the atom allowed Jung to formulate his theory of connection, the (inter) dependence of psychic and physical phenomena, thus structuring the ideas of the Self and the unconscious. While for the atom, the nucleus is the main source of energy, for the conscious Self the energy comes from the depths of the unconscious. This centre or nucleus represents for Jung the symbol of the totality of the psyche, which does not coincide with the Ego, but which has nevertheless always been perceived as external.

In this regard, Pauli admits that the field of physics becomes limited by materialism and considers that, beyond a certain point, it is about the existence of deeper spiritual layers, which cannot be adequately defined in conventional space-time terms.

Jung dwelled for a long time on the analogy that Pauli proposes between the atomic nucleus and the Self, and he wrote in the autumn of 1935:

> Generally speaking, the unconscious is thought of as psychic matter in an individual. However, the self-representation drawn up by the unconscious of its central structure does not accord with this view, for everything points to the fact that the central structure of the collective unconscious cannot be fixed locally but is an ubiquitous existence identical to itself; it must not be seen in spatial terms and consequently, when projected onto space, is to be found everywhere in that space. I even have the feeling that this peculiarity applies to time as well as space... A biological analogy would be the functional structure of a termite colony, possessing only unconscious performing organs, whereas the center, to which all the functions of the parts are related, is invisible and not empirically demonstrable. The radioactive nucleus is an excellent symbol for the source of energy of the collective unconscious, the ultimate external stratum of which appears an individual consciousness. As a symbol, it indicates that consciousness does not grow out of any activity that is inherent to it; rather, it is constantly being produced by an energy that comes from the depths of the unconscious and has thus been depicted in the form of rays since time immemorial [...]
>
> The center, or the nucleus, has always been for me a symbol of the totality of the psychic, as the conscious plus the unconscious, the center of which does not coincide with the ego as the center of consciousness, and consequently has always been perceived as being external.
> (C.G. Jung, *The Pauli/Jung Letters*, 1932-1958, Edited by C.A. Meier Princeton U. Press, Princeton, N.J., 2001).

Therefore, both come to the conclusion that living matter has a psychic aspect, and the psyche, a physical aspect. The quantum domain is the "place" where matter and the mind meet and where the laws of classical physics lead to nonlocal / acausal phenomena.

This is the realm of field theory, which describes how the single mind, *One*, links or connects all things (M.A. Fike, 2014). The suggestive phrase, "*Unus mundus*", used by Jung, reflects his beliefs about the unity of matter, mind, and spirit.

In our reality, we perceive this continuum as divided. The physicist David Bohm explains this in terms of *explicit order* or *unfolded order* (signifying the separation that takes place in the real world), respectively, *implicit* *order* or *enfolded order* (which describes the profound unit from which the physical world arises). The difference occurs between what is separate and local (explicit) and what is unified and nonlocal / acausal (implicit).

Quantum field theory therefore emphasizes the concept of holism, as one cannot consider a part without referring to its relationship to the whole. This theory reflects the concept of *entanglement* (a term introduced by Schrödinger), a phenomenon that explains "spooky action at a distance" (as Albert Einstein says) or nonlocality / acausality.

The division of reality into parts is the product of a convention, because subatomic particles, like all elements in the universe, are, in fact, connected to each other. In the general theory of relativity, Einstein states that space and time are not separate entities, but are instead connected to each other and represent part of a larger whole, which he called *the space-time continuum.* Bohm expanded on this idea, stating that everything in the universe is part of a continuum, and despite the apparent separation of things at the explicit level, the implicit and the explicit order merge into one another.

In their 1997 book on quantum physics, Marshall and Zohar wrote:

> In the quantum universe - and this means the entire universe - each part is "subtly" connected to any of the others, and the very identity - the being, qualities and characteristics - of constituents depends on the relations between them.

The meanings of part and whole, of atomism and holism can in fact coexist, depending on perspective. In his book *The Ghost in the Machine* (a title inspired by the Cartesian mind-brain dualism), Arthur Koestler proposed the term *holon* in order to designate something that is to an equal extent part and whole.

For instance, referring to life sciences, we can describe an atom as a holon - a whole entity made up of smaller parts such as protons, neutrons and electrons. The atom itself can be part of a larger holon, such as a molecule (several atoms chained together to form a new entity). In its turn, the molecule is a holon that can be part of a cell, or part of an organ, or part of a human being. Thus, holons have a dual nature: they are equally complete, autonomous entities, but they are also parts of other wholes. From this perspective, holons exist simultaneously as independent integers in relation to their component parts, but also as subordinate, dependent parts, subsystems of other holon systems.

Regarding the relations between part and whole, between *One* (the principle, the critical substance underlying the world) and *Multiple* (the diversity of phenomena), they have been described by mereology, the branch of logic developed by the Polish logician Stanislaw Lésniewski.

Since the beginnings of philosophy and, more recently, in mereology (Hudson, 2004), profound and difficult questions have arisen regarding the problem of atomism (mereologically, an atom is an entity that does not contain its own parts): Are there such entities? And if they exist, is everything entirely made up of atoms?

The two main options, in the sense that either there are no atoms at all, or that everything is ultimately made up of atoms, are reflected in two postulates that are mutually incompatible (Varzi, 2007).

Starting from an axiomatization, one might hope that a certain axiomatized mereological theory can ensure (decide) the existence of an atomic "space" (or domain), that is, it can guarantee that everything in this domain is composed only of atoms. The results obtained so far at this abstract level of axiomatization deny the existence of such an atomic domain (Tsai, 2017).

2.5 The mathematical "atom"

In the following, we shall see that the mathematical perspective preserves the intimate, defining property of the atom, in its various forms and mathematical meanings of being, in a sense, the essential indestructible, indivisible, irreducible, minimal and self-similar unity.

Using notions, concepts and results, we shall try to answer the question "What is the atom?" from a mathematical perspective, offering at the same time a series of possible interpretations and meanings that exceed its strict limits.

We emphasize that an atom is a mathematical object (an entity) that, in essence, has no other subobjects (subentities) than the object itself or the null subobject. The idea is also found in computer science, for example. Thus, in database systems, an *atomic transaction* is an indivisible and irreducible series of database operations, so that either all of them occur or nothing happens.

2.5.1 Elements of set theory

By a *set* X we mean a collection (an ensemble) of distinct objects (the elements of the set), which is well-determined and considered as an entity.

$\emptyset$ denotes the void set (or the empty set), so it does not contain any elements. In the following, we shall assume that the abstract, arbitrary set

X (the space where we operate) is nonvoid, meaning it contains at least one element.

For instance, $\mathbb{N}$ denotes the set of all naturals $(0, 1, 2, 3, ...)$, $\mathbb{Z}$, the set of all integers $(..., -3, -2, -1, 0, 1, 2, 3...)$, $\mathbb{Q}$, the set of rationals (a rational number is a number that can be expressed as the quotient or fraction p/q of two integers, a numerator p and a non-zero denominator q), $\mathbb{R}\backslash\mathbb{Q}$, the set of all irrationals (which are not rational numbers, that is, they cannot be expressed as the ratio of two integers: $\sqrt{2}$, $\sqrt{3}, e, \pi$ etc.), $\mathbb{R}$, the set of all real numbers, that is, rational and irrational numbers.

All these numbers represent features of the surrounding world, *they reflect reality, but they are not part of it.*

By $\mathbb{R}_+$ we denote the set of all positive real numbers, that is, the subset of those real numbers that are greater than zero: $\mathbb{R}_+ = \{x \in \mathbb{R};\ x \geq 0\}$. By $x > 0$ we mean $x \geq 0$ and $x \neq 0$.

Let A, B be two arbitrary sets from the abstract space X.

We say that *the set A is included in the set B* and we denote it by $A \subseteq B$ (or $B \supseteq A$), if any element x of A (denoted by $x \in A$) also belongs to the set B.

Obviously, if $A \subseteq B$ and $B \subseteq A$, then $A = B$.

If an element x does not belong to a set A, then we denote this by $x \notin A$.

By $A \subsetneq B$ (or $B \supsetneq A$) we mean that $A \subseteq B$ and $A \neq B$.

The symbol "$\forall$" means "for every", "$\exists$", "there exists", "$\nexists$, "it does not exist", "$\exists!$", "there exists and it is unique", and "$\Leftrightarrow$", "if and only if".

By $\mathcal{P}(X)$ we denote the family of all subsets of the set X, and by $\mathcal{P}_0(X)$, we mean the family of all nonvoid subsets of X.

For instance, if $X = \{1, 2, 3\}$, then

$$\mathcal{P}(X) = \{\emptyset, \{1\}, \{2\}, \{3\}, \{1, 2\}, \{1, 3\}, \{2, 3\}, \{1, 2, 3\}\}.$$

The union of the sets A and B is the set $A \cup B = \{x \in X; x \in A$ or $x \in B\}$.

The intersection of the sets A and B is the set $AnB = \{x \in X; x \in A$ and $x \in B\}$.

We say that two sets A, B are *disjoint* if $A \cap B = \emptyset$.

We say that a family $\{A_i\}_{i\in\{1,2,...,p\}}$ of nonvoid sets is a *partition of a set* A if $\cup_{i=1}^{p} A_i = A$ and the sets A_i are pairwise disjoint, that is, $A_i \cap A_j = \emptyset$, $\forall i, j \in \{1, 2, ..., p\}$, $i \neq j$.

The difference of the sets A and B is the set $A\backslash B = \{x \in X; x \in A$ and $x \notin B\}$.

The symmetric difference of the sets A and B is the set $A \triangle B = (A \setminus B) \cup (B \setminus A)$.

The complement of the set A is the set $cA = \{x \in X;\ x \notin A\}$.

The Cartesian product of the sets A and B is the set $A \times B = \{(a, b);\ a \in A, b \in B\}$, where (a, b) signifies the pair of elements $a \in A$ and $b \in B$ (in this order) (called ordered pair).

If $a, b \in \mathbb{R}$, then we introduce the following sets:

$(-\infty, \infty) = \mathbb{R}$,

the open interval $(a, b) = \{x \in \mathbb{R},\ a < x < b\}$,

the closed interval $[a, b] = \{x \in \mathbb{R},\ a \leq x \leq b\}$,

the interval open in a and closed in $b : (a, b] = \{x \in \mathbb{R},\ a < x \leq b\}$,

the interval closed in a and open in $b : [a, b) = \{x \in \mathbb{R},\ a \leq x < b\}$,

the open interval $(a, \infty) = \{x \in \mathbb{R},\ a < x\}$,

the closed interval $[a, \infty) = \{x \in \mathbb{R},\ a \leq x\}$,

the open interval $(-\infty, a) = \{x \in \mathbb{R},\ x < a\}$,

the closed interval $(-\infty, a] = \{x \in \mathbb{R},\ x \leq a\}$.

By *the modulus* of a real number x, denoted by $|x|$, we mean $\max\{x, -x\} \left(= \begin{cases} x, x \geq 0 \\ -x, x < 0 \end{cases} \right)$.

We say that a *set* A is *finite* if it contains a finite number of elements. We denote by $cardA$, the number of elements which constitute the set.

By a *function* $f{:}A \to B$ (defined on A and taking values in B), we mean an application (or, a relation, a law or a correspondence) so that *to any element* of A corresponds a *unique* element of $B : \forall x \in A,\ \exists! y = f(x) \in B$. Sometimes, the function f can be also expressed as $x \to f(x)$.

x is called the *argument of the function*, A is called the *domain of* f and B, the *codomain* of f (*the set of all values of* f).

We say that the *function* f is *increasing* (*decreasing*, respectively) if its y-values increase (decrease, respectively) as the x-value increase: $\forall x_1, x_2 \in A$, with $x_1 \leq x_2$, then $f(x_1) \leq f(x_2)$ $(f(x_1) \leq f(x_2))$, respectively.

A *sequence* $(x_n)_{n \in \mathbb{N}}$ *of elements* of the space X is a function $f : \mathbb{N} \to X$ which associates to any natural $n \in \mathbb{N}$ a unique element $x_n \in X$, called the *general term of the sequence.*

If the following condition is satisfied: $\forall y \in B,\ \exists! x \in A$ so that $y = f(x)$ (any element of B is the image of a unique element from A), then the *function* f is called a *bijection* (or a *biunivocal application*).

We say that:

(i) two *sets* A and B are *equipotent* if there is a bijection between them;

(ii) a set A is said to be *countable* if A and the set $\mathbb{N}$ of all naturals are equipotent (in other words, the elements of the set A can be counted, and this process goes on to infinity);

(iii) a set A is said to be *at most countable* if it is either finite or countable.

We call the *cardinal of the set* A (denoted by $cardA$), the class (or the family) of all sets that are equipotent with a certain given set A. If the set is finite, then its cardinal represent the number of the elements of the set. If two sets are equipotent, then it is said that they have *the same cardinal.*

For instance, the sets $\mathbb{N}, \mathbb{Z}, \mathbb{Q}$, the set of all even numbers and the set of all odd numbers are countable sets.

There are also sets that are not at most countable (called *uncountable*), for instance, $\mathbb{R} \setminus \mathbb{Q}, \mathbb{R}$ etc.

The countable and the uncountable sets are called *infinite sets.*

Cantor denoted card$\mathbb{N}$ by $\aleph_0$ (alef-zero, alef being the first letter in the Hebrew alphabet).

card$\mathbb{R}$, the cardinal of all real numbers, is called *the continuum* and it is denoted by c. Also, $\mathbb{R} \setminus \mathbb{Q}$ and any interval of the form $[a, b]$ have the cardinal c.

Returning to operations with sets, we can consider the union (intersection, respectively), of three sets: $A \cup B \cup C$ ($A \cap B \cap C$, respectively) and then the finite union (intersection, respectively): $A_0 \cup A_1 \cup ... \cup A_n \overset{denoted}{=} \cup_{i=0}^{n} A_i$ ($A_0 \cap A_2 \cap ... \cap A_n \overset{denoted}{=} \cap_{i=0}^{n} A_i$, respectively).

Recurrently, we can introduce countable unions (intersections, respectively) of sets: $A_0 \cup A_2 \cup ... \cup A_n \cup ... \overset{denoted}{=} \cup_{n=0}^{\infty} A_n$ ($A_0 \cap A_2 \cap ... \cap A_n \cap ... \overset{denoted}{=} \cap_{n=0}^{\infty} A_n$, respectively).

$(A_n)_{n \in \mathbb{N}}$ denotes the corresponding sequence of sets (Precupanu, 1998).

2.5.2 Order relations

Let X and Y be two arbitrary, nonvoid sets. A subset R of the Cartesian product $X \times Y$ is called a *relation from* X *to* Y. If, particularly, $X = Y$, we say that R is a *relation on* X.

If X is a nonvoid, abstract set, then a relation on X, denoted by "$\leq$" is called a *partial order relation* if the following axioms are fulfilled:

(i) *reflexivity*: $\forall x \in X$, $x \leq x$ (in other words, any element is in relation with itself or, each element is comparable with itself);

(ii) *antisymmetry*: $\forall x, y \in X$, from $x \leq y$ and $y \leq x$ it results $x = y$ (or, no two different elements precede each other);

(iii) *transitivity*: $\forall x, y, z \in X$, if $x \leq y$ and $y \leq z$, then $x \leq z$ (or, the start of a chain of precedence relations must precede the end of the chain).

In this case, the set X endowed with the partial order relation R (denoted by (X, R)) is called a *(partially) ordered set.*

For instance, the relation "$\leq$" on $\mathbb{R}$ is an order relation. Also, the relation of inclusion of sets is a (partial) order relation.

A partially ordered set A is said to be *totally ordered* if $\forall x, y \in X$, it holds either $x = y$ or $y = x$ (in other words, any two of its elements are comparable).

Let $(X, \leq)$ be an arbitrary partially ordered set and A a nonvoid subset of X.

(i) An element $\alpha \in A$ is called *the greatest element* of A if $x = \alpha$, $\forall x \in A$ (an element of A that is greater than every other element of A);

(ii) An element $\beta \in X$ is called *the least element* of A if $\beta \leq x$, $\forall x \in A$ (an element of S that is smaller than every other element of S);

The greatest element of a partially ordered subset must not be confused with the maximal elements of the set. A set can have several maximal elements without having a greatest element.

(iii) An element $a \in A$ is called a *maximal element* of the set A if from the conditions $x \in A$ and $a = x$ it follows $x = a$ (it is an element of A that is not smaller than any other element in A);

(iv) An element $b \in A$ is called *a minimal element* of the set A if from the conditions $x \in A$ and $x \leq b$ it folllows that $x = b$ (it is an element of A that is not greater than any other element in A);

(v) An *upper bound* (or *majorant*) of A is an element $\beta \in X$ so that $a \leq \beta$, $\forall a \in A$ (is greater than or equal to every element of A).

(Dually, a *lower bound* or *minorant* of A is defined to be an element of X which is less than or equal to every element of A.)

Zorn's lemma. Every partially ordered set $(A, \leq)$ for which every totally ordered subset has an upper bound contains at least one maximal element.

The notion of an atom is found in algebra in the following sense:

An element a of a partially ordered set A possessing the property that there exists $0 \in A$ so that $0 = x$ for every $x \in A$ is called an *atom* if $0 < a$ and it does not exist $x \in A$ so that $0 < x < a$.

In fact, in partially ordered sets, atoms are generalizations of the singletons (that is, sets containing only one element) of the sets theory. Moreover, in this sense, atomicity (the property of a mathematical object of being atomic), provides a generalization in an algebraic context of the possibility of selecting an element from a nonempty set (Davey and Priestley, 2002).

In fact, in mathematical logic, *an atomic formula* is a formula without a deep propositional structure, that is, a formula that does not contain logical connections, or, equivalently, a formula that does not have strict subformulas.

Atoms are thus the simplest well-formed formulas of logic, the compound formulas being formed by combining atomic formulas using logical connections. Also, also in logic, an atomic sentence is a type of declarative sentence that is either true or false and that cannot be broken down into other simpler sentences.

In some models of set theory, an atom is an entity (a mathematical object) that can be an element of a set but does not itself contain elements with similar properties (hence the "ultimate" character of an atom).

As we shall see in the following, in mathematical analysis, a set's property of being an atom is defined in relation to another mathematical object, namely, with respect to a set (multi)function.

2.5.3 Elements of measure theory

Classes of sets

Let us consider an abstract, nonvoid set T and let be the family $\mathcal{P}(T)$ of all parts (subsets) of T.

O nonvoid subfamily $\mathcal{C} \subset \mathcal{P}(T)$ of subsets of T is called a *ring* if the following conditions (axioms) are fulfilled:

(i) $\forall A, B \in \mathcal{C}$ it follows that $A \setminus B \in \mathcal{C}$;

(ii) $\forall A, B \in \mathcal{C}$ it follows that $A \cup B \in \mathcal{C}$.

For instance, $\mathcal{P}(T)$ is obviously a ring of sets (the largest one in the sense of inclusion) of T.

If, additionally to the axioms (i) şi (ii), the following condition is fulfilled:

(iii) $T \in \mathcal{C}$,

then $\mathcal{C}$ is called an *algebra* of subsets of T.

For instance, $\mathcal{P}(T)$ is an algebra of sets (the largest in the sense of inclusion) of T.

A class $\mathcal{A}$ of subsets of T is said to form a $\sigma-$algebra if $\mathcal{A}$ is an algebra which satisfies, additionally, the property:

(iv) $\forall (A_n)_{n\in\mathbb{N}} \subseteq \mathcal{A}$ (for every sequence of sets of $\mathcal{A}$) it holds that $\cup_{n=0}^{\infty} A_n \in \mathcal{A}$ (Precupanu, 2006).

Set functions

Let $\mathcal{C}$ be a ring of subsets of a non-empty abstract set T and $m : \mathcal{C} \to \mathbb{R}_+$ be a set function which satisfies the condition $m(\emptyset) = 0$.

The following notions generalize the notion of a measure in its classic sense (as a foundation of the field of mathematics, known as "measure" theory, a subdomain of mathematical analysis).

In mathematical analysis, a measure (in classic sense) is a function which "measures", assigning to certain sets of a class (family) of sets, a positive real number or $+\infty$. In this sense, a measure is a generalization of the concepts of length, area or volume.

One particularly important example is the Lebesgue measure on a Euclidean space, which assigns the conventional length, area and volume of Euclidean geometry to appropriate subsets of the Euclidean space $\mathbb{R}^n$. For instance, the Lebesgue measure of the interval $[0,1]$ is its length in the ordinary sense of the word, namely, 1 (Precupanu, 2006; Royden, 1988; Fremlin, 2000).

A measure must be additive, which means that the measure of a set representing the union of a finite (or countable) number of smaller sets that are pairwise disjoint is equal to the sum of the measures of these smaller subsets.

The notions that we shall introduce next have contributed (among many others) to the development in recent years of the theory of non-additive measures, sometimes known as the fuzzy measures theory (Pap, 1995). These notions prove their utility due to the necessity to model phenomena from the real world, in circumstances in which the condition of additivity (either finite or countable), as an immediate property of a measure, is much too restrictive.

The set function m is called:

(i) *null-additive* if $m(A \cup B) = m(A)$, for every sets $A, B \in \mathcal{C}$, satisfying the condition $m(B) = 0$;

(ii) *null-null-additive* if $m(A \cup B) = 0$, for every sets $A, B \in \mathcal{C}$, satisfying the condition $m(A) = m(B) = 0$;

(iii) *diffused* if $m(\{t\}) = 0$, whenever $\{t\} \in \mathcal{C}$;

(iv) *monotone* if $m(A) = m(B)$, for every sets $A, B \in \mathcal{C}$, so that $A \subseteq B$;

(v) *null-monotone* if for every two sets $A, B \in \mathcal{C}$, having the property that $A \subseteq B$, if $m(B) = 0$ holds, then one necessarily has also $m(A) = 0$;

(vi) *finitely additive* if $m(A \cup B) = m(A) + \nu(B)$, for every disjoint sets $A, B \in \mathcal{C}$;

(vii) *subbaditive* if $m(A \cup B) = m(A) + \nu(B)$, for every (disjoint or not) $A, B \in \mathcal{C}$.

Example. (i) Let us suppose that $T = \{t_1, t_2, ..., t_n\}$, where for every $i \in \{1, 2, ..., n\}$, t_i represents a particle, and $m : \mathcal{P}(T) \to \mathbb{R}_+$ is a set function representing the mass of the particle.

In the macrosopic world, m is a finitely additive set function. At quantum scale, however, this statement no longer remains valid due to the phenomena of annihilation. For instance, if t_1 and t_2 represents an electron and a positron, respectively, then $m(\{t_1\}) = m(\{t_2\}) = 9,11 \times 10^{-31}$kg, but $m(\{t_1, t_2\}) = m(\{t_1\} \cup \{t_2\}) = 0$;

(ii) Entropy in Shannon's sense is a subadditive set function, taking real values (Gavriluţ and Agop, 2016; Gavriluţ, 2019).

2.6 Types of atoms

All things are made up of atoms
Richard Feynman

In the following, we shall present several types of atoms in their mathematical meaning, we shall establish some relationships among these types of atoms and we shall also highlight several possible interpretations.

Unless stated otherwise, $\mathcal{C}$ will represent a ring of subsets of an arbitrary nonvoid set T and $m : \mathcal{C} \to \mathbb{R}_+$, an arbitrary set function satisfying the condition $m(\emptyset) = 0$. As we have already seen, this abstract set function represents the generalization of the classic notion of a *measure* used in the domain of mathematics called "measure theory" and it is the mathematical object through which the process of so-called "measurement" is performed.

2.6.1 Atoms and pseudo-atoms

These are the main types of atoms from a mathematical perspective:

I. A set $A \in \mathcal{C}$ is called an *atom* of m if $m\,(A) > 0$ and for every $B \in \mathcal{C}$, with $B \subseteq A$, it holds either $m(B) = 0$ or $m(A \setminus B) = 0$.

We observe that, in a certain sense, an atom is a special set, of strictly positive "measure", having additionally the property that any of its subsets either has zero "measure", or the difference set between the initial set and its subset we refer to has zero "measure".

An atom can be interpreted, from a physics viewpoint, as the correspondent of a black hole.

II. The set function m is said to be *non-atomic* if it has no atoms, that is, for every set $A \in \mathcal{C}$ with $m(A) > 0$, there exists a subset $B \in \mathcal{C}$ $(B \subseteq A)$ so that $m(B) > 0$ and $m(A \setminus B) > 0$.

III. A set $A \in \mathcal{C}$ is called a *pseudo-atom* of m if $m\,(A) > 0$ and for every subset $B \in \mathcal{C}$ $(B \subseteq A)$ one has either $m(B) = 0$ or $m(B) = m(A)$.

In other words, a pseudo-atom is a special set, of strictly positive "measure", for which any of its subsets either has null "measure", or has the same "measure" as the set itself. Thus, it can be stated that a pseudo-atom *possesses the property that any of its subsets either has null "measure" (that is, it is negligible during the "measurement" process), or it entirely "covers" the set (during the same "measurement" process).*

In other words, assuming that the set function m is monotone, then a pseudo-atom is a set of strictly positive "measure" and which does not contain any proper subset of strictly smaller and strictly positive "measure".

IV. The set function m is said to be *non-pseudo-atomic* if it does not have pseudo-atoms, that is, for any set $A \in \mathcal{C}$ with $m(A) > 0$, there exists a subset $B \in \mathcal{C}$ $(B \subseteq A)$ so that $m(B) > 0$ and $m(B) \neq m(A)$.

For instance, the Lebesgue measure on the real line is a measure (in the classic sense) which is non-pseudo-atomic (Royden, 1988), and therefore it does not have any pseudo-atom.

The non-pseudo-atomic measures satisfy the following remarkable property, which we owe to Sierpinski, a property which states that if m is a non-pseudo-atomic measure (in classic sense), defined on a σ-algebra $\mathcal{A}$ (of subsets of an abstract space T), and $A \in \mathcal{A}$ is an arbitrary set so that $m(A) > 0$, then for every element $b \in [0, m(A)]$, there exists a set $B \in \mathcal{A}$, so that $B \subseteq A$ and $m(B) = b$ (in other words, the set function m takes a continuum of values, and thus it does not omit any intermediate value).

V. A set function m is called *purely-atomic* if the space T can be represented as a finite or countable union of atoms of m.

Examples. (i) Let be the set $T = \{1, 2, ..., 9\}$. We define the set function $m : \mathcal{P}(T) \to \mathbb{R}_+$ as follows: $\forall A \subseteq T, m(A) = \text{card}A$. Then $\forall i \in \{1, 2, ..., 9\}$, the singleton $\{i\}$ is an atom of m. Indeed, $\forall i \in \{1, 2, ..., 9\}$, $m(\{i\}) = 1 > 0$ and $\forall B \subseteq \{i\}$, we have either $B = \emptyset$, in which case $m(B) = 0$, or $B = \{i\}$ in which case $m(\{i\} \setminus B) = m(\emptyset) = 0$.

Consequently, in this case, any singleton is an atom.

(ii) Generally, *there is no relationship between the notion of an atom and that of a pseudo-atom*:

Let us consider an abstract set $T = \{t_1, t_2\}$ constituted of two distinct arbitrary elements and let also be the set function $m : \mathcal{P}(T) \to \mathbb{R}_+$ defined for every $A \subset T$ by $m(A) = \begin{cases} 2, & \text{if } A = T \\ 1, & \text{if } A = \{t_1\} \\ 0, & \text{if } A = \{t_2\} \text{ or } A = \emptyset. \end{cases}$

Then T *is an atom and it is not a pseudo-atom for* m.

Indeed, $m(T) = 2 > 0$. Let be an arbitrary subset B of T.

If $B = \emptyset$, then $m(B) = 0$;

If $B = \{t_1\}$, then, by the definition, $m(T \setminus B) = m(\{t_2\}) = 0$;

If $B = \{t_2\}$, then, by the definition, $m(B) = 0$;

If $B = \{t_1, t_2\}(= T)$, then $m(T \setminus B) = m(\emptyset) = 0$.

Therefore, T is indeed an atom of m.

On the other hand, let us note that there exists the singleton $\{t_1\}$ for which $m(\{t_1\}) = 1 \neq 0$ and $m(\{t_1\}) = 1 \neq 2 = m(T)$. Consequently, T is not a pseudo-atom of m.

However, we note that, *if the set function m is null-addtive, then any atom of m is a pseudo-atom* (*).

Indeed, let us assume that $m : \mathcal{C} \to \mathbb{R}_+$ is a null-additive set function, and that the set $A \in \mathcal{C}$ is an atom of m. We shall prove that A is also a pseudo-atom of m.

Obviously, since A este atom, then $m(A) > 0$. Then, if we consider an arbitrary set $B \in \mathcal{C}$, with $B \subseteq A$, from the fact that A is an atom it follows that either $m(B) = 0$ or $m(A \setminus B) = 0$. In the latter case, because m is null-additive, it follows that $m(A) = m((A \setminus B) \cup B) = m(B)$. Consequently, A is a pseudo-atom of m.

Conversely, *if the set function $m : \mathcal{C} \to \mathbb{R}_+$* is, moreover, finitely additive, then *any pseudo-atom $A \in \mathcal{C}$* of *m is an atom*, too, and this immediately yields based on the equality $m(A) = m((A \setminus B) \cup B) = m(A \setminus B) + m(B) = m(B)$, which implies $m(A \setminus B) = 0$.

That is why, *in the framework of the classic measure theory* (a measure always possesses the null-additive property), *the notions of an atom and that of a pseudo-atom coincide*.

The converse of the above statement (*) does not generally hold since *there exist pseudo-atoms which are not atoms*, as the following example will show:

(ii) Let $T = \{t_1, t_2\}$ be an abstract set, containing two arbitrary elements, and let us consider the set function $m : \mathcal{P}(T) \to \mathbb{R}_+$, defined for every set $A \subseteq T$, by $m(A) = \begin{cases} 1, if\ A \neq \emptyset \\ 0,\ if\ A = \emptyset. \end{cases}$

Then m is null-additive and $T = \{t_1, t_2\}$ is a *pseudo-atom of m*, *but it is not an atom of m*.

Let $A, B \subseteq T$ be so that $m(B) = 0$. By the definition of m we note that we must necessarily have $B = \emptyset$, whence $m(A \cup B) = m(A)$, and this proves that the set function m is null-additive.

We prove now that $T = \{t_1, t_2\}$ is a pseudo-atom of m. Indeed, we have $m(T) = 1 > 0$ and let $B \subseteq T$ an arbitrary subset.

If $B = \emptyset$, then $m(B) = 0$.

If $B \neq \emptyset$, then the set B either is a singleton, or is the set T, itself consisting of two elements. In both situations, one has $m(T) = 1 = m(B)$, which proves that $T = \{t_1, t_2\}$ is a pseudo-atom of m.

Let us prove now that $T = \{t_1, t_2\}$ is not an atom of m. Indeed, $m(T) = 1 > 0$ and there exists the singleton $\{t_1\}$ for which we have $m(\{t_1\}) = 1 \neq 0$ and $m(T \setminus \{t_1\}) = m(\{t_2\}) = 1 \neq 0$. Therefore, $T = \{t_1, t_2\}$ is not an atom of m.

(iii) The Dirac measure (or, the unit mass measure) (or, the δ-measure) δ_t concentrated in an arbitrary fixed point t of an abstract set T, is an example of a measure (in the classical sense) which is purely-atomic (Kadets, 2018).

The Dirac measure is defined as follows:

If $\mathcal{A}$ is a σ-algebra of subsets of T, then $\delta_t(A) = \begin{cases} 1, & t \in A \\ 0, & t \notin A \end{cases}, \forall A \in \mathcal{A}$.

Obviously, T is an atom of δ_t (because $\delta_t(T) = 1 > 0$ and $\forall A \in \mathcal{A}$, it holds either $\delta_t(A) = 0$ or $\delta_t(cA) = 0$, as $t \notin A$ or $t \in A$, that is, $t \notin cA$).

Let us recall now the following:

If $\mathcal{C}$ is a ring of subsets of an abstract space T and if $m : \mathcal{C} \to \mathbb{R}_+$ is a set function satisfying the condition $m(\emptyset) = 0$, two *sets* A_1, A_2 are said to be *equivalent* if $m(A_1 \triangle A_2) = 0$.

We note that if the set function m is additionally null-monotone and null-additive, then $m(A_1) = m(A_2)$ (which justifies the terminology, since the equivalence of the sets takes place in the sense of the "measurement" process).

Indeed, since $m(A_1 \triangle A_2) = m((A_1 \setminus A_2) \cup (A_2 \setminus A_1)) = 0$ and m is null-monotone, it follows that $m(A_1 \setminus A_2) = 0$ and $m(A_2 \setminus A_1) = 0$, whence, because m is null-additive and $m(A_1) = m((A_1 \setminus A_2) \cup (A_1 \cap A_2)) = m(A_1 \cap A_2)$, $m(A_2) = m((A_2 \setminus A_1) \cup (A_1 \cap A_2)) = m(A_1 \cap A_2)$, it follows that $m(A_1) = m(A_2)$.

We note that, *with respect to the Dirac measure δ_t, the atom T (the space itself, unreduced to a single point) is equivalent to the singleton $\{t\}$*, $t \in T$ (Kadets, 2018). Indeed, we have $m(T \triangle \{t\}) = 0$ (so, *with respect to the Dirac measure, the space "collapses" into a single point*).

We shall prove in the following that, *with respect to a monotone and null-additive set function, any set which is equivalent to an atom is itself an atom*:

Let us assume that the set A_1 is an atom and we prove that the set A_2, which is equivalent to the set A_1, possesses the same property. Indeed, according to the above statements, we have $m(A_2) = m(A_1) > 0$ and let $B \in \mathcal{C}$, $B \subseteq A$, be arbitrary.

If $m(B) = 0$, then the proof ends.

If $m(A_1 \setminus B) = 0$, then, since m is monotone and $m(A_1 \triangle A_2) = 0$, it follows that $m(A_2 \setminus A_1) = 0$.

On the other hand, again from the monotonicity of m we have $m(A_2 \setminus B) = m((A_2 \setminus A_1) \cup (A_1 \setminus B)) = m(A_1 \setminus B) = 0$, based also on the fact that m is null-additive and $m(A_2 \setminus A_1) = 0$. Consequently, $m(A_2 \setminus B) = 0$, and this finally proves that A_2 is an atom of m, too.

Let us also note that, with respect to a monotone and null-additive set function, *any set which is equivalent to a pseudo-atom is, itself, a pseudo-atom*:

Let us assume that the set A_1 is a pseudo-atom and we prove that the set A_2, which is equivalent to the set A_1, possesses the same property. Indeed, from the above statements, we have $m(A_2) = m(A_1) > 0$ and let $B \in \mathcal{C}$, $B \subseteq A$, be arbitrary.

If $m(B) = 0$, then the proof ends.

If $m(A_1) = m(B)$, then, since $m(A_2) = m(A_1) = m(B)$, it follows that A_2 is also a pseudo-atom of m.

2.6.2 Atoms and fractality

Next, we shall underline the fact that both the notion of atom and that of pseudo-atom (in the mathematical sense) possess a remarkable property, namely that of self-similarity (every part reflects the whole), a property which is a characteristic to fractals, both from a mathematical point of view and from the perspective of modern physics. This finding, among others, justifies the extension we illustrate in the last section, in which we address the necessity to introduce the notion of a fractal atom (Gavriluţ *et al.*, 2019).

Penny Hardy, *You blew me away*

The self-similarity property of the atoms (pseudo-atoms, respectively)

(i) If $m : \mathcal{C} \to \mathbb{R}_+$ is a null-monotone set function, with $m(\emptyset) = 0$, $A \in \mathcal{C}$ is an atom of m and $B \in \mathcal{C}$ is a subset of A having the property $m(B) > 0$, then B is also an atom of m and, moreover, $m(A \setminus B) = 0$ (which means that the "measure" of what remains when the set B is removed from the set A is null).

Indeed, one has $m(B) > 0$ and if we consider an arbitrary set $C \in \mathcal{C}$, with $C \subseteq B$, then, since $B \subseteq A$, it follows that $C \subseteq A$.

If $m(C) = 0$, the proof ends.

Let us assume now that $m(C) \neq 0$. Because $A \in \mathcal{C}$ is an atom of m, it follows that $m(A \setminus C) = 0$.

Since $B \setminus C \subseteq A \setminus C$ and m is null-monotone it gets that $m\,(B \setminus C) = 0$ and, therefore, B is an atom of m.

Moreover, since $A \in \mathcal{C}$ is an atom of m and $B \in \mathcal{C}$ is a subset satisfying the property $m(B) > 0$, then we must necessarily have $m(A \setminus B) = 0$.

(ii) If $A \in \mathcal{C}$ is a pseudo-atom of m and the set $B \in \mathcal{C}$ satisfies $B \subseteq A$ and $m(B) > 0$, then B is also a pseudo-atom of m and, moreover, $m(B) = m(A)$ (which means that the sets A are B are "identical" with respect to the "measure" m).

Indeed, we have $m(B) > 0$ and, if we consider an arbitrary set $C \in \mathcal{C}$, with $C \subseteq B$, then, since $B \subseteq A$, it follows that $C \subseteq A$.

If $m(C) = 0$, the proof ends.

Let us assume now that $m(C) \neq 0$. Since $A \in \mathcal{C}$ is a pseudo-atom of m, it follows that $m(A) = m(C)$.

On the other hand, since $A \in \mathcal{C}$ is a pseudo-atom of m, the set $B \in \mathcal{C}$ satisfies $B \subseteq A$ and $m(B) > 0$, then $m(B) = m(A)$.

In consequence, $m\,(B) = m(C)$, and this finally proves that B is also a pseudo-atom of m.

Let us make, at the end of this section, the following observation:

Assuming that a set function $m : \mathcal{C} \to \mathbb{R}_+$ is monotone, null-additive and regular (meaning that, roughly speaking, we can, through it, approximate sets about which we have little information, with sets about which we have more information), one can prove that for each atom A of m (if it exists), there exists a unique element $a \in A$ so that $m(A) = m(\{a\})$ (Pap, 1995) (this means that the *"measure" of the atom is equal to the measure of each* *"point" it contains, and this reflects the holographic perspective, according to which the information is concentrated in a single point.*

Indeed, any part of a fractal reflects the whole, as a pattern:

> To see a World in a Grain of Sand
> And a Heaven in a Wild Flower,
> Hold Infinity in the palm of your hand
> And Eternity in an hour.
>
> (William Blake, *Auguries of Innocence*)

2.6.3 Minimal atoms

We shall now introduce a very special category of atoms, which we show to reflect the property of indivisibility (non-decomposability).

Let $\mathcal{C}$ be an arbitrary ring of subsets of an abstract space T and let $m : \mathcal{C} \to \mathbb{R}_+$ be a set function so that $m(\emptyset) = 0$.

A set $A \in \mathcal{C}$ is called a *minimal atom* of m if $m(A) > 0$ and for every subset $B \in \mathcal{C}$ ($B \subseteq A$) it holds either $m(B) = 0$, or $B = A$ (Ouyang *et al.*, 2015).

In other words, a minimal atom is a special set, of stricly positive "measure", so that any of its subsets has either zero "measure", or identifies with the set itself. Thus, a minimal atom has the property that any of its subsets has either zero "measure" (that is, it is negligible during the "measurement" process), or identifies with the initial set (without the need of a "measurement" process).

Let us note that the terminology is justified. Indeed, if $A \in \mathcal{C}$ is a minimal atom of m, then for m there cannot exist other minimal atom $A_1 \in \mathcal{C}$, which is different from A and satisfies $A_1 \subset A$.

Indeed, if we assume, on the contrary, that there exists another minimal atom $A_1 \in \mathcal{C}$ which is different from A and satisfies $A_1 \subset A$, then, since A_1 is a minimal atom, we get that $m(A_1) > 0$. Because $A_1 \subsetneq A$, then $A_1 = A$, and this is false due to the assumption we made.

Example. Let $T = \{a, b, c, d\}$ be an abstract set, constituted of four distinct elements and let also be the set function $m : \mathcal{P}(T) \to \mathbb{R}_+$, defined for every $A \subseteq T$ by $m(A) = \begin{cases} 5, & \text{if } A = T \\ 2, & \text{if } A \neq T \\ 0, & \text{if } A = \emptyset. \end{cases}$

We note that any singleton (i.e., a set containing only one element) is a minimal atom of m. Indeed, the "measure" m of any singleton is, according to the definition, 2, so it is strictly positive and any subset is either void and hence has zero measure, or is the set itself.

We note that, in general, *any minimal atom is, particularly, an atom and also a pseudo-atom.*

Indeed, if $A \in \mathcal{C}$ is a minimal atom of m, then $m(A) > 0$ and for any of its subset $B \in \mathcal{C}$ ($B \subseteq A$) it holds either $m(B) = 0$, or $B = A$. The latter posibility yields $m(A \setminus B) = 0$ and $m(B) = m(A)$, so A is both an atom and a pseudo-atom of m.

The following examples highlight the fact that there exists generally no relationship between the notions of atom/pseudo-atom and that of minimal atom:

Examples. (i) Let $T = \{a, b\}$ be an abstract set constituted of two distinct elements and let also be the set function $m : \mathcal{P}(T) \to \mathbb{R}_+$ defined as follows:

$$\forall A \subseteq T, m(A) = \begin{cases} 1, & \text{if } A = \{a\} \text{ or } A = T \\ 0, & \text{otherwise.} \end{cases}$$

Then T *is an atom of* m:

Obviously, $m(T) = 1 > 0$. Let $B \subseteq T$ be an arbitrary set.

If $B = \emptyset$, then $m(B) = 0$.

If $B = \{a\}$, then $m(T \setminus B) = m(\{b\}) = 0$.

If $B = \{b\}$, then $m(B) = 0$.

If $B = T = \{a, b\}$, then $m(T \setminus B) = m(\emptyset) = 0$.

But T *is not a minimal atom of* m:

Obviously, one has $m(T) = 1 > 0$ and let $B \subseteq T$ be an arbitrary set. We observe that there exists the set $B = \{a\} \neq T$ for which $m(B) = 1 \neq 0$.

We also note that *the set* $\{a\}$ *is an atom* (we have $m(\{a\}) = 1 > 0$ and any subset $B \subseteq \{a\}$ either is void, so $m(B) = 0$, or is the set $\{a\}$ itself, so $m(\{a\} \setminus \{a\}) = 0$). The *set* $\{a\}$ *is also a minimal atom* of m since $m(\{a\}) = 1 > 0$ and any subset $B \subseteq \{a\}$ either is void, so $m(B) = 0$, or is $\{a\}$ itself.

(ii) Let $T = \{a, b, c, d\}$ be an abstract set constituted of four distinct elements and let also be the set function $m : \mathcal{P}(T) \to \mathbb{R}_+$, defined as follows: $\forall A \subseteq T$,

$$m(A) = \begin{cases} 5, & \text{if } A = T \\ 3, & \text{if } A = \{a, b, c\} \text{ or } A = \{a, b, d\} \text{ or } A = \{a, c, d\} \\ 2, & \text{if } A = \{a, b\} \text{ or } A = \{a, c\} \\ 0, & \text{otherwise.} \end{cases}$$

Then $\{a, b\}$ and $\{a, c\}$ *are minimal atoms of* m. We shall prove the statement, for instance, for the $\{a, b\}$:

Indeed, we have $m(\{a,b\}) = 2 > 0$ and let B be an arbitrary subset.

If $B = \{a,b\}$, the statement is verified.

If $B = \{a\}$ or $B = \{b\}$, then, according to the definition, we have $m(\{a\}) = m(\{b\}) = 0$, so the statement is again verified.

If $B = \emptyset$, then $m(B) = 0$.

In the following, let us note that if $m : \mathcal{C} \to \mathbb{R}_+$ is a null-null-additive set function and $A, B \in \mathcal{C}$ are two different minimal atoms of m, then they must be necessarily disjoint, that is, $AnB = \emptyset$.

Indeed, let us assume that, on the contrary, $A \cap B \neq \emptyset$. Since $A, B \in \mathcal{C}$ are two minimal atoms of m, $A \setminus (A \cap B) = A \setminus B \subseteq A$ and $A \cap B \subseteq B$, it follows that $[m(A \setminus B) = 0$ or $A \setminus B = A]$ and $[m(A \cap B) = 0$ or $A \cap B = B]$.

(i) If $A \setminus B = A$, then $A \cap B = \emptyset$, which is false since, according to our assumption, we have $A \cap B \neq \emptyset$.

(ii) If $m(A \setminus B) = 0$ and $m(A \cap B) = 0$, then, since m is null-null-additive, one gets that $m(A) = m((A \setminus B) \cup (A \cap B)) = 0$, which is false, since $m(A) > 0$, the set A being a minimal atom of m.

(iii) If $m(A \setminus B) = 0$ and $A \cap B = B$, then $B \subseteq A$, so, since A is a minimal atom of m, one gets from the above observation that $B = A$, which is false.

Consequently, $A \cap B = \emptyset$.

The property we shall demonstrate next reflects *the non-decomposability (non-partitionability) of the minimal atoms:*

A minimal atom $A \in \mathcal{C}$ of a null-null-additive set function m cannot be partitioned in sets that are elements of $\mathcal{C}$. Indeed, if we suppose, on the contrary, that there exists a partition of a lui A, this means that there exists a family $\{A_i\}_{i \in \{1,2,\ldots,p\}}$ of nonvoid sets of $\mathcal{C}$ so that $\cup_{i=1}^{p} A_i = A$ and the sets A_i are pairwise disjoint.

Referring to the first set A_1, since $A \in \mathcal{C}$ is a minimal atom, it follows that we cannot have the situation $A_1 = A$. Therefore, $m(A_1) = 0$. Analogously, for the second set, A_2, we get that $m(A_2) = 0$. Recurrently, it gets that $m(A_3) = \ldots = m(A_p) = 0$. Since m is null-null-additive, it follows that $m(A) = m(\cup_{i=1}^{p} A_i) = 0$, which is obviously false.

Consequently, any minimal atom is non-decomposable.

In the following, we shall prove that the converse of this statement also holds, namely, we shall demonstrate that *any non-decomposable atom* $A \in \mathcal{C}$ *is necessarily a minimal atom.* Indeed, since the set A is an atom, then $m(A) > 0$.

Since the set A is not partitionable, there cannot exist two nonvoid disjoint subsets $A_1, A_2 \in \mathcal{C}$ of A so that $A = A_1 \cup A_2$.

Let be an arbitrary set $B \in \mathcal{C}$, with $B \subseteq A$.

If $m(B) = 0$, then the proof ends.

If $m(B) > 0$, since $B \subseteq A$, one gets that $B = A$ (otherwise, the family $\{A\setminus B, B\}$ is a partition of A: $A\setminus B, B \in \mathcal{C}$, $(A\setminus B)\cap B = \emptyset$, $(A\setminus B)\cup B = A$, which is false).

Consequently, A is a minimal atom.

From the two statements above, one arrives at the following conclusion: *an atom is minimal if and only if it is not partitionable (it is non-decomposable).*

In the following, we shall highlight the fact that, *in the case when the abstract set T is finite*, then *any set $A \in \mathcal{C}$, satisfying the condition $m(A) > 0$ possesses at least one set $B \in \mathcal{C}$, $B \subseteq A$, which is a minimal atom minimal of m*.

Moreover, in the particular case when A is an atom of m and the set function m is null-additive, one gets that $m(A) = m(B)$ and the set B is unique.

Indeed, let us consider the family of sets $\mathcal{M} = \{M \in \mathcal{C}, M \subseteq A, m(M) > 0\}$. Obviously, since $A \in \mathcal{C}$, then $\mathcal{M} \neq \emptyset$.

We note that any minimal element $M \in \mathcal{M}$ of $\mathcal{M}$ is a minimal atom of m. Indeed, since M is a minimal element, there cannot exist another set $D \in \mathcal{M}$ so that $D \subsetneq M$ (**).

Since $M \in \mathcal{M}$, this means that $M \in \mathcal{C}$, $M \subseteq A$ and $m(M) > 0$.

We shall prove that M is a minimal atom of m. Indeed, for any set $S \subseteq M, S \in \mathcal{C}$, we have either $m(S) = 0$ or $m(S) > 0$. In the latter case, we have either $S = M$ (which is suitable) or $S \neq M$, which contradicts the statement $(**)$.

Let us assume, moreover, that the set A is an atom of m and m is null-additive. According to the considerations proved above, there exists at least one set $B \in \mathcal{C}$, $B \subseteq A$, which is a minimal atom of m. This means that $m(B) > 0$ and, because A is an atom, we must necessarily have $m(A\setminus B) = 0$. Since m is null-additive, this yields $m(A) = m((A \setminus B) \cup B) = m(B)$.

It only remains to prove that the set B is unique. Indeed, if we suppose, on the contrary, that there exist two different minimal atoms B_1 and B_2 of m, this would imply, as before, that $m(A \setminus B_1) = m(A \setminus B_2) = 0$.

If $m(B_1 \cap B_2) = 0$, then $m(A) = m(A \setminus (B_1 \cap B_2) \cup (B_1 \cap B_2)) = m(A \setminus (B_1 \cap B_2)) = m((A \setminus B_1) \cup (A \setminus B_2))$, which is false.

If $m(B_1 \cap B_2) > 0$, since B_1 and B_2 are minimal atoms of m, it results that $B_1 = B_1 \cap B_2 = B_2$, which is again false.

Finally, we shall prove that, *if the set T is finite*, the set function m is null-additive, and $\{A_i\}_{i\in\{1,2,\ldots,p\}}$ is the family of all different minimal atoms which are contained in a set $A \in \mathcal{C}$, satisfying $m(A) > 0$ (we proved in the above considerations that such atoms exist), then $m(A) = m\left(\cup_{i=1}^{p} A_i\right)$.

(This means that *the set A identifies itself, from the "measure" m viewpoint, with the union of all different minimal atoms which it contains*, therefore the *minimal atoms are the only ones that matter from the "measurement" point of view).*

Let us note that $m(A \setminus \cup_{i=1}^{p} A_i) = 0$ (if, on the contrary, one has $m(A \setminus \cup_{i=1}^{p} A_i) > 0$, from the statement proved above it would follow that there exists at least one set $B \in \mathcal{C}$, $B \subseteq A \setminus \cup_{i=1}^{p} A_i \subseteq A$, which is a minimal atom of m, and this is false since $A_1, ..., A_p$ are the only different minimal atoms contained in A).

Since $m(A \setminus \cup_{i=1}^{p} A_i) = 0$ and m is null-additive, it follows that $m(A) = m((A \setminus \cup_{i=1}^{p} A_i) \cup (\cup_{i=1}^{p} A_i)) = m(\cup_{i=1}^{p} A_i)$.

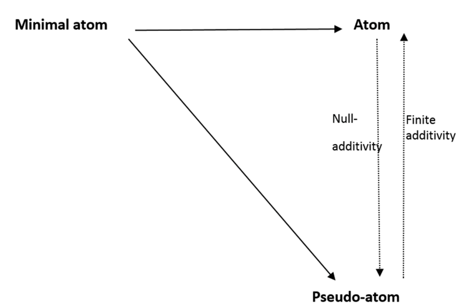
Let us finally note the following:

1. Any minimal atom is also an atom and a pseudo-atom (which justifies the terminology);

2. If the set function is null-additive, then any of its atoms is a pseudo-atom, too;

3. If, moreover, the set function is finitely additive, then the converse of the above statement is also valid, therefore any pseudo-atom is particularly an atom.

Consequently, for a finitely additive set function (which automatically possesses the null-additivity property), the notion of atom and that of pseudo-atom coincide. We summarize all these observations in the following schematic:



2.7 Extensions of the notions of atom

Generalizations of the mathematical notion of an atom have been made, so far, in two major directions. A first direction is given by the fact that, instead of set functions, which are indispensable to the process of the so-called "measurement", one could generally operate with set multifunctions (that is, functions that associate a set to another set). Thus, results with a higher degree of generalization and abstraction can be obtained. The second direction is given by the correlation that can be made by placing the notion of (minimal) atom within the fractal sets theory, thus resulting in the notion of *fractal (minimal) atom* (Gavrilut *et al.*, 2019; Gavriluţ and Agop, 2016).

It is no coincidence that in literature, Eminescu's manuscript notebooks contain observations on the holographic principle, which constitutes the essence of interrelation, of interconnection: "In the ether, each atom is an individual which is connected with everything".

But on the issue of ether, we shall find detailed considerations and references in Chapter 3.

In his *Memoirs*, Werner Heisenberg recounts that in the summer of 1920, Niels Bohr, one of the fathers of quantum theory, told him that: "When we talk about atoms, language can be used just as in poetry. The poet is not so much concerned with the description of facts, as with the creation of images and the establishment of mental connections". A language problem that Bruce Rosenblum and Fred Kuttner reprised under another guise in their book, *The quantum enigma*: "In quantum theory there is no atom in addition to the wave function of the atom. This is so crucial that we say it again in other words. The atom's wave-functions and the atom are the same thing; *the wave function of the atom* is a synonym for *the atom*." (2011).

2.7.1 Set multifunctions

A triplet $(X, +, \cdot)$ constituted of an abstract, nonvoid set X, an operation "$+$" of addition on X and an operation "$\cdot$" of multiplication with real scalars is called a *real linear space on* $\mathbb{R}$ if the following axioms are fulfilled:

1) associativity: $x + (y + z) = (x + y) + z$, $\forall x, y, z \in X$;

2) the existence of the identity element of addition θ (called the *origin of the space* X): $\exists \theta \in X$ so that $\forall x \in X$, $x + \theta = \theta + x = x$;

3) $\forall x \in X$, $\exists -x \in X$ (called the additive inverse of x) so that $x+(-x) = (-x) + x = \theta$;

4) commutativity: $x + y = y + x$, $\forall x, y \in X$;

5) $\lambda(x + y) = \lambda x + \lambda y$, $\forall x, y \in X$, $\forall \lambda \in \mathbb{R}$;

6) $(\lambda+\mu)x = \lambda x + \mu x$, $\forall x \in X$, $\forall \lambda, \mu \in \mathbb{R}$;
7) $\lambda(\mu x) = (\lambda\mu)x$, $\forall x \in X$, $\forall \lambda, \mu \in \mathbb{R}$;
8) $1 \cdot x = x$, $\forall x \in X$.

For instance, the set $\mathbb{R}$ of real numbers, endowed with the operation "+" of addition of two real numbers and also with the operation "$\cdot$" of multiplication of a real number with a real scalar, that is, the triplet $(\mathbb{R}, +, \cdot)$, constitutes a real linear space.

If $(X, +, \cdot)$ is a real linear space, then a function $\|\cdot\| : X \to \mathbb{R}_+$ is called a *norm* on the space X if the following axioms are fulfilled:

N_1 $\|x\| \geq 0,\ \forall x \in X; \|x\| = 0 \Leftrightarrow x = \theta$ (the positivity of the norm);

N_2 $\|\lambda x\| = |\lambda| \cdot \|x\|,\ \forall x \in X, \forall \lambda \in \mathbb{R}$ (the homogeneity of the norm);

N_3 $\|x+y\| = \|x\|+\|y\|,\ \forall x, y \in X$ (the triangular inequality).

The pair $(X, \|\cdot\|)$ is called a *normed space*.

For instance, $(\mathbb{R}, +, \cdot)$ endowed with the norm defined by $\|x\| = |x|$, $\forall x \in \mathbb{R}$, is a real normed space.

In what follows, let be an abstract nonvoid set T, $\mathcal{C}$ a ring of subsets of T, X a real linear normed space with the origin θ and $\mathcal{P}_0(X)$, the family of all nonvoid subsets of X.

By a *set multifunction* we mean a function (or, application) which associates a set to another set, in contrast with the notion of a function, which associates a point to another point.

So, in what follows, let $\mu : \mathcal{C} \to \mathcal{P}_0(X)$ be an arbitrary set multifunction satisfying the condition $\mu(\emptyset) = \theta$.

The notions of atom, pseudo-atom, minimal atom introduced with respect to a set function m can be generalized in this context, with respect to the set multifunction μ, as follows:

We say that a set $A \in \mathcal{C}$ is:

(i) an *atom* of μ if $\mu(A) \supsetneq \{\theta\}$ and for every set $B \in \mathcal{C}$, with $B \subseteq A$, we have either $\mu(B) = \{\theta\}$ or $\mu(A \setminus B) = \{\theta\}$;

(ii) a *pseudo-atom* of μ if $(A) \supsetneq \{\theta\}$ and for every set $B \in \mathcal{C}$, with $B \subseteq A$, it holds either $\mu(B) = \{\theta\}$, or $\mu(A) = \mu(B)$;

(iii) a *minimal atom of* μ if $\mu(A) \supsetneq \{\theta\}$ and for every set $B \in \mathcal{C}$, with $B \subseteq A$, one has either $\mu(B) = \{\theta\}$ or $A = B$.

Detailed considerations on the problem of atomicity with respect to set multifunctions can be found, for instance, in Gavriluţ and Agop, 2016, and also in Gavriluţ *et al.* 2019.

2.7.2 Towards a fractal theory of atomicity

The main idea in the quantum theory of measure and in generalized quantum mechanics is to provide a description of the world in terms of histories. A history is a classical description of the system considered for a certain period of time, which may be finite or infinite. If one tries to describe a particle system, then a history will be given by classical trajectories. If one deals with a field theory, then a history corresponds to the spatial configuration of the field as a function of time.

In both cases, the quantum theory of measure tries to provide a way to describe the world through classical histories, extending the notion of probability theory, which is obviously not enough to shape our universe.

On the other hand, ordinary structures, self-similar structures etc. of nature can be assimilated to complex systems, if one considers both their structure and functionality (Gavriluţ and Agop, 2013).

The models used to study the complex systems dynamics are built on the assumption that the physical quantities that describe it (such as density, momentum, and energy) are differentiable. Unfortunately, differentiable methods fail when reporting to physical reality, due to instabilities in the case of complex systems dynamics, instabilities that can generate both chaos and patterns, as will be seen in Chapter 5.

In order to describe such dynamics of the complex systems, one should introduce the scale resolution in the expressions of the physical variables describing such dynamics, as well as in the fundamental equations of the evolution (density, kinetic moment and equations of the energy). This way, any dynamic variable which is dependent, in a classical sense, both on the space and time coordinates, becomes, in this new context, dependent on scale resolution as well.

Therefore, instead of working with a dynamic variable, we can deal with different approximations of a mathematical function that is strictly non-differentiable. Consequently, any dynamic variable acts as the limit of a family of functions. Any function is non-differentiable at a zero resolution scale and it is differentiable at a non-zero resolution scale.

This approach, well adapted for applications in the field of complex systems dynamics, in which any real determination is made at a finite resolution scale, clearly involves the development of both a new geometric structure and a physical theory (applied to the complex systems dynamics) for which the motion laws, that are invariant to the transformations of spatial and temporal coordinates, are integrated with scale laws, which are invariant to transformations of scale.

Such a theory that includes the geometric structure based on the assumptions presented above was developed in the scale relativity theory and, more recently, in the scale relativity theory with constant arbitrary fractal dimension. Both theories define the class of fractal physics models.

In this model, it is assumed that, in the complex systems dynamics, the complexity of interactions is replaced by non-differentiability. Also, the motions forced to take place on continuous, differentiable curves in a Euclidean space are replaced by free motions, without constraints, that take place on continuous, non-differentiable curves (called fractal curves) in a fractal space (Agop *et al.*, 2019).

In other words, for a time resolution scale that seems large when compared to the inverse of the largest Lyapunov exponent, deterministic trajectories can be replaced by a set of potential trajectories, so that the notion of "defined positions" is replaced by the concept of a set of positions that have a definite probability density.

In such a conjecture, quantum mechanics becomes a particular case of fractal mechanics (for the structural units motions of a complex system on Peano curves at Compton scale resolution).

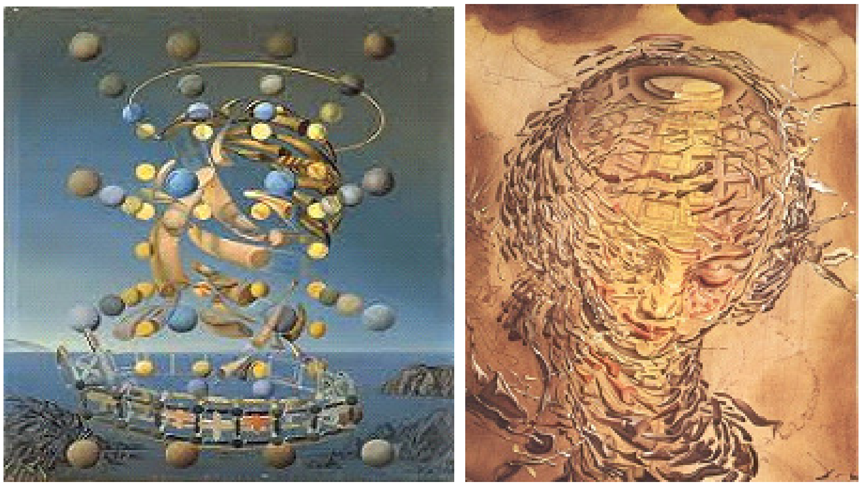
Therefore, the quantum theory of the measure could become a particular case of a fractal measure theory.

One of the concepts that needs to be defined is that of a fractal minimal atom, as a generalization of the concept of a minimal atom (for details refer to Gavriluţ *et al.*, 2019).

Current research in mathematics and physics brings us closer to the ultimate structure of matter and the understanding that, on the one hand, the notion of identifiable particle is becoming increasingly irrelevant, this kind of divisions and sequencing being in fact operative notions required for experiments and gradual understanding, rather than natural elements; on the other hand, that this approach to the core, to the essence, reveals laws of overwhelming simplicity, and that mathematics, also scattered, in the last hundred years, in structures and increasingly luxuriant and complex formulas, finds thus its role as an agile, beautiful, universal language through which nature expresses itself, as Galileo used to say.

Not only nature expresses itself thus, art does, too! Here is just one example of the decomposition / recomposition of a classic masterpiece, in the vision of Salvador Dali:

Let us leave Steven Weinberg the - provisionally - final word of this mathematical overview on the atom and its integrative relationship with the other fields of thought and expression:



Dali's *Maximum Speed of Raphael's Madonna* and *Raphaelesque Head Exploding* stage objects or suspended fragments of objects reminiscent of electrons around an atom, about to aggregate into an object, character, figure or, conversely, to decompose into an image constructed according to the rigors of the golden ratio.

There is one clue in today's elementary particle physics that we are not only at the deepest level we can go to right now, but that we are at the level which is in fact in absolute terms quite deep, perhaps close to the final source.
There is reason to believe that in elementary particle physics we are learning something about the logical structure of the universe at a very, very deep level. The reason I say this is that as we have been going to higher and higher energies and as we have been studying structures that are smaller and smaller we have found that the laws, the physical principles, that describe what we learn become simpler and simpler.
I'm not saying that the mathematics gets easier, Lord knows it doesn't. I'm not saying we always find fewer particles in our list of elementary particles. What I am saying is that the rules we have discovered are becoming increasingly coherent and universal. We are beginning to suspect that this isn't just an accident of the particular problems we have chosen to study at this moment in the history of physics, but that there is simplicity, a beauty, that we are finding in the rules that govern matter that mirrors something that is built into the logical structure of the universe at a very deep level.

(Weinberg, Facing Up, 210)

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Chapter 3

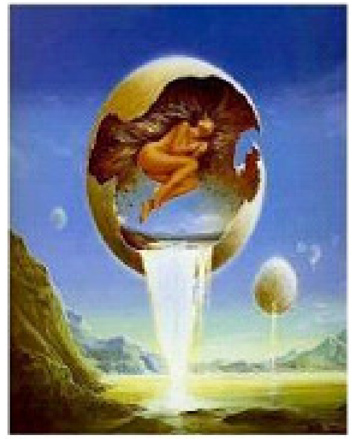
The atom of the physical "reality" or the essentiality of the vacuum

All perceptible matter comes from a primary substance,
or tenuity beyond conception, filling all space,
the akasha or luminiferous ether,
which is acted upon by the life giving Prana or creative force,
calling into existence, in never-ending cycles all things and phenomena.

Nikola Tesla

The ether, or the fifth element, is represented by all the "materials" that make up the universe, being, in essence, everything that exists in the space vacuum. The concept was theorized in the nineteenth century as the main medium through which light travels. .

The word "ether" comes from the Greek and refers to "heaven" or "pure air." According to Greek beliefs, this is the air that the gods breathe, the equivalent of the oxygen we breathe. The ether plays an important role in the mythology of creation, according to which the beginning of the universe known to man comes from a single hatching egg, the "cosmic egg". This cosmogony is found in many civilizations of the world, with the same general concepts. For example, in the Hindu Vedas, Brahmanda is spoken of in detail - the egg-shaped cosmos (*brahman* means cosmos and *anda*, egg). The egg floats in the vacuum of space and eventually breaks into two pieces, creating Dyaus Pitar, or Heaven and Prithvi, or Earth. This symbol marked not only the cosmogonies of many peoples, but also the imagination of visionary artists such as Salvador Dali.



3.1 The universal information matrix

The self-structuring of matter, from the smallest scale (the subatomic one) to the largest scale (the cosmological one) represents in itself the information present everywhere (in all the structures of matter, both living and non-living). In other words, nothing that is gained through evolution is lost, but remains instead fixed in an informational structure. As any structure is part of another class of structures, up to the macrostructure called the Universe, one arrives, step by step, at the universal information matrix. Through one of the links (umbilical cords) of this chain, the biostructures are also connected to this universal information matrix. Biorhythms, the fluctuation of the functionality of all biostructures according to the periodicity of events that occur, for example, on a cosmogonic scale (in our solar system, etc.) are clarifications of such a statement (Dulcan, 2009):

i) the explosion of morbidity by strokes in years of intense solar activity;

ii) the behaviour of the Eunice worm living in the Atlantic Ocean, the fact that it detaches a part of its body, filled with gametes, exactly on the eighth night after the first full moon of early autumn, at two o'clock at night - the calendar date varies, but the phenomenon is synchronised with the moments that follow the full moon;

iii) the behavioural changes of consumers, with profound implications in economic crises (by saturating the financial markets, the commodity market, etc.), in correlation with variations in the dynamics of the terrestrial electromagnetic field, etc.

3.2 Informational patterns

The concept of *archetype* can be translated here by the phrase *general informational pattern*, through which the information accumulated through the experience of each species is sedimented and from which the individual informational pattern emerges. In any biostructure whose complexity is comparable to that of the human being, with in billions of cells, each cell involving a multitude of chemical reactions per second, it would be difficult to understand, by simple guidance by the vegetative nervous system and genetic information, how this "universe of reactions" works, well oriented towards a biological purpose, if we do not admit the idea of informational pattern. It is very likely that the individual informational pattern will itself have the "command" in the general informational pattern. Here is "located" probably the "great attractor" of any complex structure, the hub through which they integrate into the universal information matrix, and in the particular case of the human being, the hub through which they integrate as being, species, life form, etc.. (Dulcan, 2009).

3.3 The coherence of the "whole" through individual informational pattern / global informational pattern connections

As the substance in the triad that defines matter - "state", information, substance - self-structures itself on increasingly complex successive levels up to the infinite universe, so we can imagine a self-structuring on levels of succession based on informational patterns. The interdependence and integration of subsystems into systems, of systems into supersystems - and the hierarchy could continue -, is made explicit by the coherent functionality of the "whole", whether it is defined as atom, molecule, cell, organism, biocoenosis or universe.

Admitting such an approach here, we could answer many questions that do not yet have a complete answer. For example, in this manner one could understand and explain both the relative stability of species over time and the preservation of new "acquisitions" that add to their evolution, one could understand and explain the modelling of shapes, tissues according to "location" and "needs" incompletely explained by genetics, etc. From such a perspective, the universe no longer appears as an "agglomeration of disparate objects and biostructures", but as parts of a whole, between which logically determined connections are established, connections that determine its meaning, a purpose, a destiny.

From this perspective, it is easy to understand the "boom" generated by quantum mechanics in understanding and explaining microscopic phenomena on the basis of a simple wave-corpuscle duality (de Broglie's hypothesis). In such a conjecture, the "coherent" functionality of the whole, no matter what it is called, implies logically determined connections between individual informational patterns and general informational patterns, based on the mixture of states, the superposition of states etc.

3.4 Implicit information, explicit information and their decryption as interaction

The "algorithmic" functionality contained in informational patterns, either individual or general, implies the existence of implicit information at any scale. For example, if we refer to cells, biological reactions, genetic code, nervous and endocrine structures, the immune system, ion exchanges, etc., they all become "tools" for explaining intrinsic information. It is the information that opposes entropy.

At the "interface" between individual informational pattern and general informational pattern, another type of information is "manifested", namely explicit information. Thus, the limits of the functions of an individual informational pattern are exceeded and the "algorithms" contained in the default information are coordinated. Consequently, the correlation of the functions and structures of various individual informational patterns for a purpose implies, *ab initio*, the existence of explicit information, which transcends individual informational patterns.

In such a theoretical construction, the "interface" decrypts the structuralities and functionalities of the individual information patterns "stored" in the form of information implicit in the structuralities, and functionalities of the general information pattern stored in the form of explicit information. The result of decryption is the "interaction", usually assimilated to the concept of force, regardless of its nature, and cause of motion (Newton, 1956). We present in Figure 1 such a decryption in the form of heart rhythm problems. The individual informational patterns are assimilated to the attractors of the myocardial dynamics in a space of states reconstructed using the lag time method, the time being determined through the method of the autocorrelation function (Cristescu, 2008; Zală, 2019).

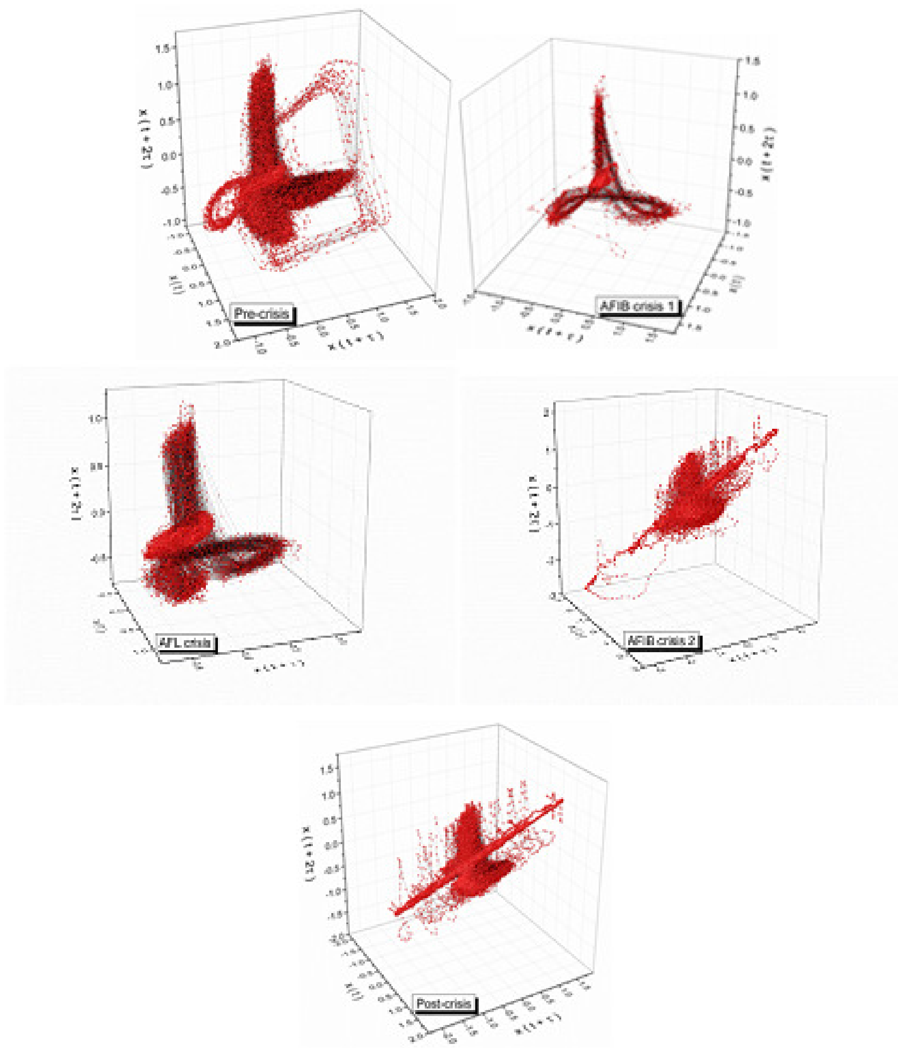


Figure 1 a-e. Attractors of the myocardial dynamics in the reconstructed space of states:
a) pre-crisis; b) the first episode of auricular fibrillation (AFIB1); c) flutter fibrillation episode (AFL); d) the second episode of auricular fibrillation (AFIB2); e) post-crisis (according to Ză̆lă, 2019)

3.5 The ether made explicit through light, a possible universal informational matrix

In drafting this paragraph, we used the results from (Mazilu, Agop, 2010). Ether has naturally established itself as the medium that allows the mechanical explanation of the structure of light. In the beginning, it was fiction (see Chapter 1). We could not say that it *is* currently considered to be something else, but we will endeavour to rehabilitate it. Let us remember that Fresnel discovered that light actually means the propagation of a motion perpendicular to the direction of propagation. This could only be explained by a mechanical model involving a continuum with certain properties that would make it support the propagation of local oscillating motion. The continuum in question was the ether. It also had a molecular structure, for motion referred to “molecules,” as well as a continuous structure, in order to propagate that motion from molecule to molecule, as the classical experiment with pendulums swinging perpendicular to their support shows. This is how the ether began to be structured, being lent properties which would satisfy immediate scientific needs and which, as it usually happens, would come into contradiction with each other.

The ether has therefore become intolerable because it has contradictory properties: it is incompressible, having a huge rigidity that would allow speeds such as that of light, and yet it does not oppose at all the movement of material bodies through it. The rigidity of matter has always been associated by our sense of touch with its impenetrability: it is difficult for us to imagine how a very rigid material could let material bodies pass freely through it. In *Orthofizica*, a work that aroused the enthusiasm of the philosopher Constantin Noica, academy member Mihai Draganescu develops a model of the subquantum level of reality, in which ether, as a material medium that fills the spaces between material particles (under the names of *dark energy* and *zero-point energy*), is described as consisting of very fine particles - *etherons*, of mass mg $\approx 10 - 60 \div 10 - 70$ kg, behaving, on the whole, like an ideal fluid (1985). Therefore, if we consider ether to be a form of matter, the perspective of reality as we know it convincingly shows either that either we might be wrong in our conclusions when we mix the criteria based on the senses with those based on reason, or that we must reject the existence of the ether. The idea that ether may not be matter has never been scientifically studied. In our opinion, however, this is the case, and the *concept* of ether serves us as a lesson, the introduction of which was written by Huygens and the content of which was developed, to a certain extent, by Fresnel. This section shows how the achievements of these two geniuses come together to help us understand ourselves.

We believe that the Fresnel moment in human knowledge has a special gnoseological significance: the total elimination of mechanical descriptions from the considerations regarding the ether. This task has obviously not been fulfilled, or at least has not been fully completed, since the issue of the ether resurfaces from time to time. *Our question is whether the ether must remain a fundamental notion in physics.* Among the modern sciences, special relativity says no, general relativity says yes, and these are the only points of view involved in the argument that we could take as fundamental. Electrodynamics, which can be taken as an exponent of classical theory, maintaining the existence of action at a distance as a force, can follow any of them. It is not surprising, then, that while it has provided the substance of the arguments when the ether was rejected from existence at the beginning of the last century, it became the advocate of the ether, so to speak, towards the end of the same century. One of the proponents of the thesis on electrodynamic ether is H. E. Wilhelm (Wilhelm, 1985, 1993). The most important programmatic point raised by Wilhelm is, in our opinion, the connection of the ether issue with that of the *cosmic background radiation.* This requires a different approach to the issues, indeed more on the side of electrodynamics, making this branch of physics one of the fundamental lines of thought, something of the rank of special or general relativity. The resulting controversy, or perhaps the absence of such a controversy at a scale that we think would be natural for such a topic, shows that Wilhelm's attempt was not quite clearly understood. This can be clearly illustrated by the fact that any point of view on the ether issue is automatically associated with either special or general relativity as a fundamental line of thought.

Let us remember, however, that at the time when the concept of ether was taking shape, that is in the early nineteenth century, electrodynamics was one of the fundamental ideas. So it should come as no surprise that it aspires to the place it had, so to speak, by birthright. On the other hand, the fact itself seems to show that the issue of the foundations of electrodynamics itself is as deep as that of the ether, more precisely that they are in fact identical, and therefore it is necessary that it be traced from the very beginning, from the very origin of this concept. And since this origin is related to light, it seems very natural to go with the idea of evaluating the first dynamic theory of light, that of Fresnel. This is where the principles of Newtonian dynamics were first brought to trial. However, the really guilty party - *the concept of force* - not only managed to evade conviction, but was not even incriminated in any way. The explanation for this is very simple.

Fresnel's theory of light does not really require classical mechanics to be completed. It only requires the idea that light can be represented, at every point in space, by *a vector that is periodic in time.* Classical dynamics enter here only "fraudulently," so to speak, through the back door. Namely, a vector that is periodic in time can be considered as a solution of a second-order ordinary differential equation, and this equation can, in turn, *be considered as an expression of the second principle of Newtonian dynamics.* In Fresnel's time, the second principle was the main line of argument in all theoretical problems. In reality, the periodicity of light, as well as many other phenomena related to light, can be presented as a consequence of the deformation of the wave surface when light propagates in empty space or in matter. This is actually a kind of generalized Huygens principle.

Towards the end of the nineteenth century, however, it was understood, under the external pressure of facts, that mechanics had other principles suitable for the purpose, not only that of inertia. As it were, mechanics had therefore resources in the ether problem, so that while in places it was concluded that it was imperative that it leave the stage, it became in fact even more deeply involved. In order to understand the issue more closely, we need to refer to an appropriate paper, which should be the product of debates on the issue of the ether. Too early works may not be appropriate, because in those days the concept of the ether was not, as it were, fully shaped. On the other hand, contemporary works may again not be appropriate, because our experience clearly shows that they are prone to succumbing to the mirage of mathematics. Therefore, we must refer to a work that intended to be the *summa summarum* regarding the state of the ether problem, when the intellect realized that the time was right for such an action.

Two well-known scientists have reached, in the ether issue, a speculative level not reached by any other scientist. One of them, Joseph Larmor, analyzed the ether problem in its entirety, evaluating the chances of mechanics as they presented themselves at the end of the 19^{th} century. Indeed, we could not have found any other classic more relevant than him for revealing in detail all the aspects of the mechanical problem of the ether. Larmor captured the moment when mechanics was about to hand the ether baton to electrodynamics, and this moment was fixed, as it should be, naturally, through a comprehensive assessment of the contribution of mechanics to the matter at hand. That is why we start here with some of Larmor's remarks on the issue of the ether. On the other hand, at about the same time as Larmor, Henri Poincaré analyzed the electrodynamic point of view on the ether problem, with notable conclusions that do not seem to have appropriate consequences, not only for scientists, but not even for historians of science. We will show here that these conclusions must be taken seriously, because they do offer a whole new approach to the problem of the ether, forcing us to recognize its true significance. Namely that the ether puts limits on mechanics as an environment that does not respond to forces. That is why we start here with some of Larmor's remarks on the issue of the ether. On the other hand, at about the same time as Larmor, Henri Poincaré analyzed the electrodynamic point of view on the ether problem, with notable conclusions that do not seem to have had commensurate consequences, not only for scientists, but not even for science historians. We will show here that these conclusions must be taken seriously, because they do offer a whole new approach to the problem of the ether, forcing us to recognize its true significance. Namely that the ether puts limits on mechanics, *as a medium that does not respond to forces.*

Considering the physical bases of the problem itself, we must mention that they do not appear much in the literature: we speak instead of mechanical or electromagnetic bases. The ether has no conceptual rank that transcends science, such as matter or space (of course, insofar as it is not an a priori intuition). As we have mentioned before, it was clear from the beginning that the ether problem had to be assigned to mechanics, more precisely to Newtonian dynamics, because, by any standard, ether had something to do with matter, *it was a material formation.* This is how the contradictions that tarnish his existence were discovered. In order to have an idea of the ether as a concept of the rank of matter, we must insist on sometimes reading between the lines of classical productions. Persistence is of course rewarded, because from time to time we find observations that explicitly refer to the concept itself. A case in point is the following footnote by Larmor in the preface to *Aether and Matter* (Larmor, 1900):

> It is not superfluous to repeat here that the object of a gyrostatic model of the rotational aether is not to represent its actual structure, but to help us realize that the scheme of mathematical relations defining its activity is a legitimate conception. Matter may be and likely is a structure in the aether, *but certainly aether is not a structure made of matter.* This introduction of a suprasensual aethereal medium, which is not the same as matter, may of course be described as leaving reality behind us: and so in fact may every result of thought be described which is more than a record or comparison of sensations.

This excerpt requires some explanation. Note, however, an explicit reference to the physical basis of the problem, the first and last of all literature:

the ether *is not a category given by the senses*, but instead makes its presence felt only in the face of reason. Moreover, it must be raised to the same rank as that of matter. In this sense, the above fragment is an original program which, unfortunately, was not followed *ad litteram*.

No one has bothered with a philosophical definition of this "category" as, for example, Lenin tried to define matter: "given to man by the senses... but existing independently of them". No one seems to have seen a philosophical category per se in the ether, and that probably explains why he was not given special attention. But the excerpt above contains an explicit allusion, which also shows us why this happened: it cannot be said that ether is made of matter, as mechanics requires, but, on the contrary, *that matter is made of ether*. What physicist or philosopher would accept this fact? At the end of the road we see the danger: matter is not primordial, there is something beyond it, so our senses do not help us in obtaining the truth!

Specifically, Larmor refers in the above quote to the gyrostatic model of the ether, assiduously promoted by Lord Kelvin. It can be said that through this model, the second principle of dynamics is back in power, because the model avoids only the polar inertia, ie the inertia due to the central action of a force on a material point, replacing it with rotational inertia: gyrostatic ether it is a continuous, inertial medium sensitive only to rotations. Following Larmor, what could be challenged here would be the right to mix up reasonings, so to speak. Classical physics, as represented by Newtonian dynamics, filled these reasonings only with their practical part represented by the concept of central force. It appears therefore that there is no doubt about the legitimacy of the mechanical approach to the ether problem. However, our opinion is that *pure reason*, in Kantian terms, must have a substantial weight here when it comes to the description of the ether, because, as Larmor states, it is *supersensory*. In other words, force is the quintessence of man's perceived reality, but the ether must be described as "leaving reality behind"; therefore, through a common inference, *leaving reality behind* would mean *leaving the central force aside*. This would, in our view, be the profound significance of Fresnel's theory, which has not been completed, however.

Another point that needs to be emphasised again is the definition of ether based on its relationship to matter: *the latter is a structure in the ether*! It is true that we have a unilateral relationship here, but it nevertheless indicates the fundamental fact that, if we want to form the concept of ether, it must have two essential determinations: *ether in space* and *ether in matter*. Only the first of these determinations is not at all accessible to us through the senses, while the second is nevertheless accessible to us in certain circumstances: only second-hand, so to speak, *that is, through matter*.

And because we started quoting from Larmor, let us continue with him, because he seems to be, indeed, the most explicit of the classics in terms of human possibilities when it comes to describing the ether. Once again, it is no coincidence that Larmor chooses mechanics as the right science for the purpose: in fact, mechanics was the universal instrument of nineteenth-century physics. However, a fact that is never mentioned, precisely because the ether is not a transcendent concept, but has been and always is taken only as such, is that *the ether has revealed the limits of mechanics itself*, the content of which is fully and clearly set out in Annex B of the same work, *Ether and Matter* (1900: 269-288). This is, in our opinion, Larmor's indisputable merit, on the realization of which the very future of science may depend. In order to understand the problem in its essence, it must be emphasized from the beginning that by mechanics Larmor means... the dynamics of matter in volume, in contrast to molecular dynamics.

Let us remember that, in the mechanical explanation given to the propagation of transverse waves representing light, we are dealing with two components of the medium: the molecules that vibrate and which are referred to by molecular dynamics and the support of these molecules - the continuum that transmits motion. The laws that describe this continuum form the mechanics which Larmor refers to, and which he identifies with the dynamics of matter in volume. Indeed, because we are dealing with a continuous medium we can define a dynamic with the help of the notion of *Newtonian density*. However, the laws of this dynamic are something special.

This was also what led Larmor to recognize that the mathematical theory of the ether in this general mechanics could go far beyond the second principle, but still cannot go beyond *the third principle of dynamics*. Indeed, this principle and that of D'Alembert are considered by Larmor to be fundamental to the ether problem, because they are the only ones involved in describing "material systems treated as continuous systems and not as molecular aggregates". Because the ether is a continuum, these are the only principles left for its description. They are then reformulated by Larmor as follows (1900, pp. 268-269):

> 1) "The mechanical action and reaction between any two parts of a material system, *which are capable of separate permanent existence*, must compensate each other, and therefore must have for their statical resultants equal and opposite wrenches on the same axial line"
>
> 2) "... if we set down the effective forces which would directly produce (...) motions in (...) separate parts or differential elements of volume (...) con-

> sidered by themselves as *individually continuous but mutually disconnected*, then for each part finite or infinitesimal (...) these forces are the statical equivalent of the *actual forces acting in or on that part* either from a distance or through the adjacent parts".
>
> (*our highlights*)

To understand the need to reformulate the essential principles of mechanics in order to use them in the problems of the continuum, a simple browsing of the classical works of Newton, Huygens, Fresnel, or Cauchy would suffice to see how easily one spoke of "ether molecules" or "ether parts" that act upon one another. This action is not beyond what Newton presented in his *Principia*, but it does lead to an obvious contradiction that has erupted as requirements on the shape of molecules or parts of the ether. Namely, the universality of the interaction force was first recognized between material formations that can be considered as material points, and then carefully extended, through a geometric consideration, to finite bodies and even to the continuum. But the essential feature of material points, which interests us here, is especially that they are "capable of permanent separate existence", as Larmor says, or are "individually continuous but mutually unconnected", and this is true whether we perceive them or not. In this context, it is also easy to understand why we must include D'Alembert's principle in the issue of the continuum, as Larmor did.

In other words, after all considerations, the concept of force is maintained by any theory of ether. "The foundation on which the whole subject develops lies in the notion of force" (Larmor, 1900: 271). This may not seem surprising when it comes to mechanics, but we want to note in particular that force comes here with the third principle of dynamics, which is actually the instrument by which *force is interrogated and defined.* In our opinion, Fresnel's use of the second principle was not even fortunate in terms of physics, because it masks the true nature of the problem. Had Fresnel used Newtonian philosophy *ad litteram*, he would have understood the importance of the third principle, in that it is necessary to define the action and reaction between matter and ether, just as Newton defined gravity as a centripetal force in comparison with the centrifugal force. It could rightly be said that this gives transcendence to this principle: *it belongs not only to mechanics, but to human experience as a whole.* By comparison, D'Alembert's principle is only an addition that allows us to broaden the scope *of the concept of force* itself, that is all.

For this reason Larmor finds it necessary, for example, to explain the difference between the two kinds of forces that fall into D'Alembert's principle: *external* or *imprinted* and *internal*, such as inertia. The latter are directly linked to virtual movements by classical mechanics. While this distinction is indeed necessary for the development of an explanatory theory, the essential fact to be remembered here is that, whether internal or external, those forces still remain forces, their action is described the same, the main feature of this action being polarity or centrality. And, to say it once again, by keeping the forces in the broader scheme, we cannot "leave reality behind"! It is then very natural to know about the ether as much as we know about inertia itself: almost nothing! Moreover, insisting on the extension of the field of action of the concept of force, not only must any action have a reaction according to the determination of the concept of force contained in the third principle, as it seems philosophically safe and sound, but this reaction must be of a nature revealed to us by the senses, that is, a force. It could be said that because the third principle of dynamics is a kind of principle that transcends mechanics, it leaves room for manoeuvre, and cannot be eliminated from the philosophical discussion of the ether.

However, it must be emphasized once again that the hard currency of mechanics, here and everywhere, is the concept of central force, and this is the point that needs revision first of all. Going deeper, one could say that even today the idea behind the ether problem is that whenever the intellect describes this "result of thought", recognized as an "environment above sensations", it does so through concepts built on the results of sensations, once they are based on the notion of force. While this fact is taken, classically speaking, as an advantage of a sound philosophical attitude, we are now in a position of disagreement with the idea. Our view is that there is a contradiction here that must erupt somewhere, despite the fact that science, like any human enterprise, does not need revolutions, except on paper, so to speak! However, if it has not erupted so far, all we can say is that at least the spirit of contradiction has persisted throughout the history of electricity and magnetism, and that discussions about the ether have never stopped, being even revived lately. But, as always when such a work is taken over, it is conducted with attacks on special relativity which, in our opinion, has nothing in common with the topic. But what can we say?! Special relativity is a fad, and it is fashionable to attack it in any way, even politically!

Speaking of the transcendence of the third principle of dynamics, we must make special reference to Henri Poincaré. Among the few critical studies, which could be said to concern, albeit indirectly, the problem of ether, that of Poincaré (1897, 1921) must be taken very seriously into consideration. Not just for its meticulous detail on the topic, but also for the complete discussion of the ether from the point of view of electrodynamics,

and for the fact that Poincaré holds with conviction on the explicit principles of his profession. Specifically, Poincaré strives to judge every up-to-date electrodynamic theory from three points of view, one of which, represented by the third principle of dynamics, seems purely mechanical in essence, and we would be tempted to believe that it is out of place. Those points of view are as follows:
1) The dragging of light waves, a fashionable topic in terms of astronomy;
2) The conservation of electricity and magnetism, from a purely electrodynamic point of view;
3) The mechanics principle of the equality of action and reaction, that is the third principle of dynamics.

The first two criteria seem to be specific to electrodynamics. It may be interesting to note that Poincaré's basis of judgment is here a *transport theorem*, as it has only recently been seriously considered in electrodynamics. But the most interesting fact on which we must insist is, as I said, that the third criterion does not belong at all to electrodynamics, but to mechanics. However, as we have seen before, that principle must be considered transcendent, which, in our opinion, gives Poincaré the full right to use it in electrodynamics, and it gives us confidence that the results he has reached are sound and reliable.

This is where Poincaré went, through one of his results, far beyond Larmor and, in fact, beyond any of the classics, and we would like to emphasize this as a special moment of knowledge, and give it due importance. Poincaré's results show that Lorentz's electrodynamics is the only up-to-date theory that *does not meet* the third of his criteria, namely the third principle of dynamics, according to which the action of the ether must be equal to the reaction on it from material formations "capable of separate existence" as Larmor puts it. However, it is known that Lorentz's theory has many other virtues that make it worth saving in all instances where it appears to lead to contradictions. Following Poincaré's line of thought, one of the natural attempts to save it, apart from the theory of special relativity, of course, is to update it in the light of the third principle of dynamics.

Let us recall here that the essence of Lorentz's theory of electrodynamics is the discrepancy between the time and coordinates that enter the equations of classical mechanics of the motion of electric charges, and those that enter Maxwell's equations of electrodynamics. Lorentz, like Fitzgerald before him, showed that the latter equations refer to the same thing from any point of view in the universe (i.e. they are invariant) only if we accept that the dimensions of an extended body which the equations happen to describe shortens in the direction of movement by a factor that depends on the speed of movement. Lorentz explained this as a contraction, i.e. a *physical process of deformation* due to the resistance the ether puts up against the movement. Later, theoretical physics took it as a pure transformation of coordinates, eliminating the ether from the considerations, and this is the shape in which we know it today.

It is at this point that we are tempted to place the well-known fact which, in our opinion, has a special significance for the issue we are referring to, namely that Poincaré introduced certain stresses of a mechanical nature - *the Poincaré stresses* - in order to explain the Lorentz contraction and therefore to save the theory (Poincaré, 1897). Indeed, if we think about it: the mechanics of the continuum teach us that there is no *deformation* of material structures without an accompanying *stress*. Poincaré will have intuited that Lorentz himself, like Fitzgerald before, had described an incomplete procedure when defining the contraction that bears their name. We view it today as a coordinate transformation, and it has always been viewed that way. Originally, however, it was defined as what it needed to be in order to put the theoretical facts in order, that is, a deformation. Nevertheless, those who defined it gave it an incomplete definition, in the sense that it was not physically justified by an appropriate stress. Poincaré's procedure is thus one of the classic examples, probably the first of its kind, in which Lorentz's transformation restores the determination of what it was meant to be from the beginning. As history has shown, this logical step is not enough. As far as we understand the problem, Poincaré was only trying to save a dynamic principle that was out of place: *equality of action and reaction.* Indeed, there is no reaction in this case!

If the ether can be labelled "suprasensory" it is only because it has the ability to penetrate matter freely, that is, because *matter does not respond to the extension of the ether.* Only such an answer could be qualified as a reaction in the classical sense. Conversely, the ether does not respond in any way to the extension of matter. This is the only way to explain the free movement of material formations through the continuous ether. Consequently, there can be no action in the classical sense. Therefore, if we call this extension of the ether a deformation, then it is a deformation that is not accompanied by stresses. This means that the Lorentz contraction cannot be explained by forces between ether and matter, because they do not exist. And if the forces do not exist, it turns out that, *positively*, the ether does not exist. This was the conclusion of special relativity, which gave the Lorentz transformation the determination we know today: that of a transformation of coordinates and time.

There is, however, another positive part of this story: it teaches us how to overcome the concept of force in the problem of the interaction between ether and matter. Indeed, as long as the ether is characterized as a continuum, it is *a continuum that is deformed without producing stresses*. On the other hand, what distinguishes ether from matter is that it can withstand stresses *without apparent deformations*: those stresses that produce deformations only when they are "released". Now, according to Larmor's conception, we can imagine that matter is made of ether, but not the other way around. Therefore, there is ether in the form of matter and ether in free space, and so we are in a position to characterize the same continuum in two different instances. This is where the concepts of stress and deformation seem to be tailor-made to fulfil Larmor's program of "leaving reality behind". Because the mechanics of the continuum have, as we have seen, an instrument precisely suited to the purpose: *the constitutive law*.

The main advantage of the existence of such a constitutive law is that it allows us to express what we have just said about the ether in space and about that in matter, in an algebraic form. Then it becomes apparent that the shape of the stresses that are not accompanied by deformations is the characteristic of the case of a classical electric field, and the shape of the deformations that are not accompanied by stresses is that characteristic of a classical magnetic field; or vice versa. Consequently, the ether in space is perceived as an electric field, while the ether in matter is perceived as a magnetic field, or vice versa. But since we do not have only ether in matter or only ether in space, the true ether must somehow be a combination of the two species of ether. The simplest combination of the two reveals a mathematical structure that describes *electromagnetic radiation*, that is *light*. Therefore, to sum things up in a philosophical manner, neither matter, "given to man by the senses", is truth, nor the ether "given to man by reason", is truth, but *light is their truth*.

A simple way to obtain a characterization of the ether, in a birefringent crystal for example, is simply to allow into play, in a certain manner, the fact established by Larmor's thesis, namely that there is ether in space and ether in matter. A first natural test would be to admit that the ether is characterized by tensors corresponding to two characteristic vectors, say $\vec{u}$ and $\vec{v}$. A complete tensor describing the ether could then be of the form:

$$w_{ij} = \alpha\delta_{ij} + \beta u_i u_j + \gamma v_i v_j. \tag{1}$$

Somewhere along this line one will notice that the calculations are much more symmetrical if we write (1) in a more convenient form, that is

$$w_{ij} = \lambda u_{ij} + \mu v_{ij}, \tag{2}$$

where λ and μ are real parameters describing the extent to which ether is "spatial" and, respectively, "material", the matrices **u** and **v** being defined through

$$
\begin{aligned}
u_{ij} = u_i u_j - \frac{1}{2}u^2\delta_{ij};\ v_{ij} = v_i v_j - \frac{1}{2}v^2\delta_{ij} \\
u^2 = u_1^2 + u_2^2 + u_3^2;\ v^2 = v_1^2 + v_2^2 + v_3^2,
\end{aligned}
\tag{3}
$$

where δ_{ij} is Kronecker's pseudo-tensor. This tensor contains eight measurable quantities: λ, μ, and two intrinsic vectors. When detailed, matrix (2) becomes

$$
w_{ij} = \lambda u_i u_j + \mu v_i v_j - \frac{1}{2}(\lambda u^2 + \mu v^2)\delta_{ij}. \tag{4}
$$

It is then easy to see that this particular tensor has three main values that are real and distinct. Indeed, its orthogonal invariants are

$$
I_1 = -e;\ I_2 = -e^2 + g^2;\ I_3 = -e(e^2 - g^2) \tag{5}
$$

where we have used

$$
e \equiv \frac{1}{2}(\lambda u^2 + \mu v^2);\ \vec{g} \equiv \sqrt{\lambda\mu(\vec{u}\times\vec{v})}. \tag{6}
$$

The main values of w_{ij} can then be calculated as roots of the matrix's characteristic equation, and they are

$$
w_1 = e,\quad w_{2,3} = \pm\sqrt{e^2 - g^2}. \tag{7}
$$

It so happens that the pair in equation (6) is one of the own vectors of **w**, together with its own value. The other two own vectors of **w** are perpendicular, and they are located in the planes of vectors $\vec{u}$ and $\vec{v}$.

The magnitudes

$$
w_n = \frac{w_1 + w_2 + w_3}{3},\ w_t^2 = \frac{1}{15}[(w_2 - w_3)^2 + (w_3 - w_1)^2 + (w_1 - w_2)^2] \tag{8}
$$

are *the Novozhilov averages* (Novozhilov, 1952) for the normal and shearing components of the **w** tensor in any given point. These quantities can be described, as we shall see, as components of a vector in a frame characteristic for *any* point in space (whether in free space within matter) given by the **w** matrix own vectors. Let us foreshadow in brief what will be discussed in more detail in the next section. We shall define the vector formed by the **w** matrix own values:

$$|w\rangle \equiv \begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix}. \tag{9}$$

Now, if we choose the *octahedral plane* with a normal given by the unitary vector

$$|n\rangle \equiv \frac{1}{\sqrt{3}} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \tag{10}$$

the normal component w_n on this plane will be given by

$$\langle n|w\rangle \equiv \frac{w_1 + w_2 + w_3}{3}. \tag{11}$$

The other quantity in equation (8) appears when we consider the norm of the tangential component in the octahedral plane, that is the vector's norm:

$$|w_t\rangle \equiv |w\rangle - |n\rangle\langle n|w\rangle \begin{pmatrix} 2w_1 - w_2 - w_3 \\ -w_1 + 2w_2 - w_3 \\ -w_1 - w_2 + 2w_3 \end{pmatrix}. \tag{12}$$

A simple calculation yields

$$\langle w_t|w_t\rangle \equiv \frac{1}{5} w_t^2. \tag{13}$$

For the special case of own values (7), the two magnitudes become:

$$w_n \equiv \langle w|n\rangle = -\frac{1}{\sqrt{3}} e,\ |w_t\rangle = \frac{2}{3} \begin{pmatrix} -2e \\ 3\sqrt{e^2 - \vec{g}^2} + e \\ -3\sqrt{e^2 - \vec{g}^2} + e \end{pmatrix}. \tag{14}$$

As long as we claim that only the values (8) are measured - they are in fact averages - the orientation of the vector in (14) in the octahedral plane remains undecided. This orientation is outside out control, but it can be measured in relation to a direction of reference in the octahedral plane. Let us assume that such a direction is given by a particular tensor $\boldsymbol{\xi}$ of those given in equation (3), with the characteristic vector $\vec{\xi}$. Repeating for this tensor the calculations above referring to the normal and shearing component in that particular point in space, we obtain:

$$\langle \xi | n \rangle = -\frac{1}{\sqrt{3}}\xi^2,\ |\xi_t\rangle = \frac{2}{3}\xi^2 \begin{pmatrix} 2 \\ -1 \\ -1 \end{pmatrix}. \tag{15}$$

When vector $\vec{\xi}$ is perpendicular both on $\vec{u}$ and on $\vec{v}$, the tensors $\mathbf{w}$ and $\boldsymbol{\xi}$ commute. We have therefore a common reference system, and we can proceed in such a manner that the octahedral planes of these tensors coincide. In this case, the direction of the vector in equation (15) is fixed and can be taken as reference in the octahedral plane. The angle ψ of the vector in equation (14) in relation to this direction is given by the usual geometric formula as:

$$\cos\psi = -\frac{e}{\sqrt{4e^2 - 3\vec{g}^2}}. \tag{16}$$

Therefore, in the given conditions, ψ is independent of the reference vector, and depends only on the description of the ether. By appropriately choosing the a sign of the square root in the denominator of this formula, the origin $\psi = 0$ of that angle appears at $e = g$. In its turn, this condition means that the angle θ between vectors $\vec{u}$ and $\vec{v}$ is given by the equation

$$|\sin\theta| = \frac{1}{2}\left|\frac{\lambda u^2 + \mu v^2}{\sqrt{\lambda\mu} uv}\right|. \tag{17}$$

As the quantity on the right-hand side of this equation is always greater or equal to one, the angle between the vectors $\vec{u}$ and $\vec{v}$ can only be 90°. Thus, the *initial condition* of the $\mathbf{w}$ tensor in the octahedral plane translates into the fact that vectors $\vec{u}$ and $\vec{v}$ are perpendicular on each other, and their plane is perpendicular on vector $\vec{\xi}$. If this last vector is given by the direction of a light beam, for example, we have here the classic image of light propagation according to Fresnel.

Now, to conclude, Wilhelm (1985) is right, in our opinion: not only the cosmic background radiation, but *the electromagnetic field in general*, in its Maxwellian form, is indeed the expression of the existence of the ether. For that reason, the electromagnetic theory of light, far from denying the existence of the ether, is the one that imposes the idea that the ether must remain a transcendent concept, of the rank of matter. Our position is therefore that the ether does exist, and we can see this “with our own eyes” in our daily lives! In fact, in this life we actually see much more: the first of the points of view used by Poincaré in judging current electrodynamic theories is also a universal point of view, an expression of how our eye has adapted to perceive material structures. The stellar aberration related to the dragging of light waves, which is the basis of special relativity, is actually only a measure of our proximity to the physical structures from which we receive light on Earth, the way the colour of light is a direct indication of those physical structures.

3.6 "Quantification" as meant by Barbilian, a fundamental property of light

In drafting this paragraph, we used the results from (Mazilu, Agop, 2010). For one reason or another we say that matter is restricted, forced to occupy a limited space. This is how we perceive it - in pieces. Because the pieces of matter come in a wide variety of sizes, and as we have learned to use force to "split" them, we imagine that matter is made up of very small pieces forced to stick together by certain forces between them. The minimal image we have of the components of a piece of matter is that of a material particle in Hertz's sense: an ultimate material component, indestructible by force, which occupies a single point in space, and exists only within matter. According to the same philosophy, the most general material structure we can think of is the material point. Although the name suggests a geometric point, this is not the case in reality, because the definition of the material point depends on the spatial scale to which we refer. For example, stars or galaxies can be considered material points, but they are not material particles: they are made of material particles!

This idea of different dimensional appearance due to distance suggests the fact that the structure of a material point is a function of the distance between it and the point of view. If we therefore imagine that two material points move towards each other, for example in a collision process, then the relative motion cannot be completely described only by the kinematics of their relative position, but also by the continuous variation of the internal structure the points present to each other. They "see" more and more material particles in each other as they get closer to each other. This is the general idea behind, for example, the parton model (Feynman, 1969). Now the possible structures of a material point can be framed in a quantitative model. In general, it can be said that its material particles are confined to a space region contained in a sphere from which they cannot exit, a sphere of a radius given by the maximum possible dimensions, consistent with our experience, of that material point. As we have seen, geometry has here an instrument which has proven effective in giving reality to the strange non-Euclidean geometries: *the idea of the absolute* (Cayley, 1859). An absolute is the "bag" that contains all things, and that cannot be touched. On a certain scale the absolute is the heaven of our entire experience. If it is a sphere, then the geometry that describes the inner structure is Lobachevsky's geometry or hyperbolic geometry.

This has been the case, for example, with the association of atomic structures, if we look at it from the point of view of a certain gnoseological evolution. At first they were viewed as impenetrable spheres, then it was discovered that these spheres are in fact empty and even very penetrable. They then became maximum spheres of the existence of material particles in atoms. This conclusion could be drawn based on the Geiger-Marsden type experiments, and its first form resulted in Rutherford's (1911) atomic model. Thereby, the fact that hyperbolic geometry is involved here becomes explicit: the eccentricity of the trajectory in the Kepler problem describing Rutherford's atom is a vector of a size limited by the physical properties of the structure. Subsequently, the physical structures describing the atomic nucleus were also tied to hyperbolic geometry.

Currently, according to Hertz's philosophy (Hertz, 2003), material points are made of material particles. Material particles are the receptors of possible forces that realize the distance action between two material points. Consequently, when two material points move relative to each other, their component particles must somehow reflect, through their behaviour, the fact that the action of the two material points on each other varies with the distance between them. Everything thus focuses closer, to the level of the component material particles of a material point.

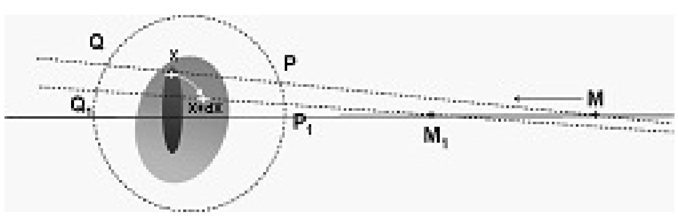


Figure 2. The dynamics of the image of a material particle in relation to the Absolute (according to Mazilu, Agop, 2010)

It is therefore worth considering the study of the evolution of the image of a material particle inside the absolute, from the point of view of a material particle outside the absolute, moving towards the absolute or away from it (Figure 2). Such an evolution is an indication of the structure that a material point within the absolute exhibits to the universe at any time. Let us therefore consider a particle M outside the absolute. What the particle sees of this absolute, assuming that it is opaque, is a disk: the base of the cone tangent to the absolute with the vertex at the point marked by our particle. The equation of the plane containing the disk, the polar plane of the point where the particle is, can be easily obtained by the algebraic process of polarizing the absolute equation, using the coordinates of the particle. Now, if this particle moves towards the absolute, the polar plane moves towards the particle. When the particle and the plane meet, the plane is tangent to the absolute at the point represented by the particle. As the particle penetrates inside the absolute, its polar plane becomes imaginary and moves outside the absolute.

Let a X be a material particle inside the absolute, part of the structure of a material point, which moves towards the outer particle. This inner particle will have an apparent straight-line movement along the direction of relative motion. If initially this direction meets the absolute at two points P and Q, as the two particles approach or move away from each other, the line PQ - let us call it *radius* henceforth, for reasons that will become obvious immediately - changes position, describing what is called a congruence of lines. Concomitantly, the inner particle, which indicates a point on the generic radius of congruence, describes a certain motion inside the absolute, which can be decomposed into two components: along the radius and outside it. The component of this motion outside the PQ radius is *a measure both for the proximity between the two particles and for their relative velocity.*

This measure will be given by the component of the motion of the internal particle perpendicular to the right PQ. Of course, the condition of perpendicularity is understood here in the sense of absolute geometry: two directions are perpendicular if they are conjugated in relation to the absolute of space. Knowing the equations of directions, this condition can be expressed algebraically through the process of polarizing the equation of the absolute. Another way to express perpendicularity is that provided by the incidence relation: the condition that a line, (D) say, incident to PQ, be perpendicular to PQ, is that (D) be incident to the line conjugated to PQ with respect to Absolute. And this conjugate line can be obtained as an intersection of the planes tangent to the absolute at points P and Q.

Therefore, our problem becomes purely algebraic and has the form given below. Assuming that in the absolute of space we have a congruence of lines, which is well defined if we know the points P and Q where the generic line of congruence meets the absolute. So the two points satisfy the equation of the absolute, which can be given in the form of cancelling the norm generated by the equation of the absolute:

$$(p,p) = (q,q) = 0. \tag{18}$$

Here p and q (and in general the lower case letters) represent the set of the four homogeneous coordinates of the respective points. If p and q are functions of a parameter, the corresponding line describes a *ruled surface* in absolute space.

A generic point X, indicated by a material particle on the generic line of congruence, can be written in the form:

$$x = p + \lambda q, \tag{19}$$

where λ is a nonhomogenous continuous parameter on the line PQ. For $\lambda = 0$ we have $X \equiv P$, and for $\lambda = \infty$ we have $X \equiv Q$. Our problem now is to find the condition that would make $X(t)$ describe a trajectory orthogonal to the current radius PQ of the line congruence. This problem was solved by Dan Barbilian (Barbilian, 1974) in the manner thaw will be described here.

As we have mentioned before, we can translate the orthogonality through the condition that the points X, dX and the conjugate $P'Q'$ of the radius PQ in relation to the absolute be in the same plane - the polar plane of point X. Let us write the corresponding equations. The equation of the polar plane of the point X located on PQ can be written as

$$(p,\xi) + \alpha(q,\xi) = 0 \tag{20}$$

where ξ is the image of the current point of the plane, and α is a parameter. This equation represents a sheaf of planes that intersect along the line $P'Q'$. Let us now write the condition that one of these planes, let us call it the current plane, contain the points X and $X + dX$. Given that

$$dx = dp + \lambda dq + q d\lambda, \tag{21}$$

the condition for plane (20) to contain the two points reverts to

$$\begin{aligned} &\lambda(p,q) + \alpha(p,q) = 0 \\ &\lambda(p,dq) + \alpha(dp,q) + (p,q)d\alpha = 0, \end{aligned} \tag{22}$$

where we used equation (18). The product (p,q) is always nonzero, except when $P \equiv Q$. Therefore the system (22) defines the 1-differential form

$$\frac{d\lambda}{\lambda} + \frac{(p,dq) - (dp,q)}{(p,q)} = 0 \tag{23}$$

and here we have Barbilian's theorem.

Equation (23) provides the necessary and sufficient condition that the trajectory of the current point (19) be orthogonal to the radius PQ when this radius is variable.

Based on this theorem, a "quantification" relation can be proven: *the orthogonal trajectories of a given radius are equidistant.* Indeed, if for one trajectory we have the parameter λ_1 and for another trajectory we have the parameter λ_2, while all other symbols in equation (23) remain the same, then we have

$$\frac{d\lambda_1}{\lambda_1} - \frac{d\lambda_2}{\lambda_2} = 0 \leftrightarrow \ln\frac{\lambda_1}{\lambda_2} = const. \tag{24}$$

But this logarithm represents the Cayleyian distance between the two points of the trajectories located within our radius. Indeed, the ratio λ_1/λ_2 is the anharmonic ratio of the four points (X_1, X_2, P, Q). Using Laguerre's formula, the logarithm of this bi-relation is the Cayleyian or absolute distance between points X_1 and X_2, hence the conclusion of the theorem.

In general, the motion of a particle internal to the absolute is not perpendicular to the generic radius of the congruence. However, Barbilian proves that the differential form

$$\Omega \equiv \frac{d\lambda}{\lambda} + \frac{(p, dq) - (dp, q)}{(p, q)} \tag{25}$$

is invariant in relation to all the linear transformations of the points in space. It represents the component of the motion of the material particle internal to the absolute along the variable direction PQ. Therefore, the component of motion perpendicular to the radius of PQ is also an invariant, and can be calculated from geometric considerations. Here, however, we are not interested in these details, but in a few historical observations, which, in spite of the fact that they are apparently different, can be subsumed to the same concept in the current mathematical philosophy.

The differential form

$$\omega \equiv \frac{(p, dq) - (dp, q)}{(p, q)} \tag{26}$$

represents the non-Euclidean generalization of the corresponding Euclidean form defined by Carathéodory (1937) in the case of a sheaf of radiuses, in order to characterize the propagation of the wave surface in relation to the light beams. Let us remember that Fresnel had to undertake a serious imagination effort to define the light beam, which is a key concept of the modern theory of light, starting from physical considerations. The light beam is, however, a fundamental concept that can be extracted directly from our experience, without any physical considerations. Using it as a primary concept, we have to explain the propagation of light according to Huygens' principle in a different way from the usual geometric one, and this implies the progress of similar points along different light rays. The differential form given by Carathéodory (26) is the most appropriate tool of mathematics involved in such a problem.

However, through the differential form (25) given by Barbilian we still have much more than pure geometric optics. For example, the "quantification" announced earlier is in fact the reason why we see the colours of light: the distance along the rays is quantified, it is *the wavelength.* Moreover, the mathematical procedure explains natural phenomena such as the Doppler effect: the non-Euclidean distance between the wave surfaces depends on the relative motion of the two material particles. Nevertheless, the current mathematical philosophy draws our attention to the fact that great caution must be exercised here: the effect is "pure" only as long as equation (23) is met. If the Barbilian form is not zero, our conclusion could very well be biased in some way. We could find, for example, that there is no Hubble constant, no great attractor or other such concepts. These are indeed reflections of relative motion, but not "laws" or real objects. Needless to say, we can think of *spectra* from exactly the same point of view.

In this sense, there is a significant current of ideas in modern astrophysics according to which there can be no "great attractor" (Bell, Comeau 2003) as long as in the data on the red or blue shift of the spectrum of radiation received from celestial formations there is also an indication of the internal motions of galaxies (Tifft, 1997), hence of their internal structure. It is therefore imperative, in order to have a systematic analysis of astrophysical data, to theoretically evaluate the significance of the various components of spectral displacements. Absolute geometry in the form given by Barbilian provides us an effective means for such a theoretical evaluation, in that it shows that in fact quantification lies in the nature of the human perception of the world. However, the problems of current astrophysics are of many different natures, of which that of the cosmic background radiation to which all current observations refer, and from the point of view of which the problem of quantification is judged exclusively, is fundamental.

We shall only mention here that judging redshift based on absolute geometry is not a new concept. It was proposed more than half a century ago by Holmberg (Holmberg, 1956), but it was not met by the scientific community with the attention it deserves. Let us hope that the multitude of contradictions in solving experimental data will cause us to change our attitude towards the technology that makes them possible, and no longer have blind faith in what those data appear to show.

3.7 The creation of light and the structure of matter

In the elaboration of this section we have used the results of (Mazilu, Agop, 2010). The description of the creation of light according to human understanding involves a certain image of the relationship between light and matter, in which matter already has a certain atomic structure, while light itself has an undecided structure. We shall render this story here in a very abbreviated version, in order to make our argument a little more intelligible.

The history of the scientific relationship between matter and light begins in earnest with Hertz, the same Hertz that gave us the concepts of material point and material particle. He was able to describe and realize action at a distance in the form of electromagnetic signals, thus taking his place in history as the discoverer of *electromagnetic action at a distance*. While this kind of action is not revealed at all by our senses and therefore it cannot be said, for example, to be locally performed by forces, Hertz has succeeded in describing it in the language of Maxwell's theory of electromagnetic waves, and this language is exclusively indebted to forces. The Hertz dipole, as the material structure capable of creating and receiving electromagnetic waves is commonly called, is the cornerstone of all decisions about material structures related to the creation of light, starting very early in the last century. But what are these material structures?

At first of there was *the electron*. It was discovered by J.J. Thomson in 1897. Based on this discovery, as well as on the fact that matter appears to be in an electrically neutral natural state, that is, without electric charge, and the electron is charged with negative electricity, J.J. Thomson proposed the idea that if matter is made up of atoms, then they can be viewd as islands of negative charge in a continuum of positive charge. This is the so-called "plum pudding / raisin bread" model of the atom. However, this explanation of the structure of the atom soon had to be rejected under the pressure of experimental facts which it could not support or allow. Let us remember these facts.

In the late 19^{th} century, it became increasingly obvious that matter was unstable. Not from the common point of view of chemistry, but, we could rightly say, from the point of view of *alchemy*: the elements themselves, and therefore the atoms, are unstable, turning into other elements - the dream of alchemists! Specifically, heavy elements break down into lighter elements, emitting three types of radiation, called by Ernest Rutherford alpha, beta and gamma. The first two of these have been shown to be corpuscular radiation, as they respond to electrical and magnetic forces. Beta radiation was easily identified using Thomson electrons. Alpha radiation was positively charged electrically, but made up of particles much heavier than electrons. These particles had the mass of a helium atom, the only difference being that they were electrically charged. Gamma radiation was electrically neutral and very penetrating into matter. The nature of gamma radiation could not be decided so easily.

It is worth mentioning that here natural philosophy used, for the first time in the case of matter, the logic commonly used when experimenting with light. The quantitative properties of matter, like those of light, are not offered directly to our senses, but through the effects induced by parts of matter on other parts, only the latter being directly accessible to our senses. For example, the experimental radiation studies mentioned above were all performed in the manner of J.J. Thomson, in very high vacuum tubes, with electrodes that created deflecting electric fields. If the particles are not electrically charged, they are simply not deflected.

During such experimental studies, whose scientific findings were based on Thomson's atomic model, Rutherford and Geiger accidentally noted that if a small plate is interposed between the *alpha radiation* source and the particle recording film, the intensity recorded on the film changes. This means that not all alpha particles pass through matter: some of them are stopped. A quantitative evaluation study of this effect was immediately initiated in the case of various materials and, in order to satisfy the scientific completeness required in any study by simple professional ethics, Marsden was asked to experimentally document that there were no scattering events at any other angles to the source-target direction. This was in a way the last experimental "retouching" needed in order to fully confirm the theory based on Thomson's model of the atom. The surprise was overwhelming: the scattering of alpha particles occurs in all directions, even back towards the source. Of course, most of the particles were moving forward ahead, but not all of them!

Based on these experimental results, Rutherford realized that the "plum pudding / raisin bread" image of the atom was not exactly correct. Much more realistic was the Newtonian-inspired idea of a predominantly empty atom with a positive charge concentrated in a nucleus and electrons at a great distance from the nucleus. Since Charles Coulomb had long ago shown that the force between electric charges behaves in relation to distance exactly like the Newtonian gravitational force, all that remained was to assume that electrons move around the nucleus on elliptical orbits, just like the planets around the Sun. This is how the *planetary*, or *nuclear model* of the atom emerged (Rutherford, 1911).

A brief digression: here we have a typical example of an analogy of knowledge that transcends the contemplation scale of the universe. This analogy is primarily a consequence of the fact that, regardless of the specific scale of contemplation, the Newtonian force is a vacuum force, a feature of space without matter. Secondly, the dynamic equations of motion in the two issues, of the atom and the solar system, are the same, and they are explicitly invariant to a scale transformation discovered by Mariwalla (1982). Therefore, the nuclear atom is scientifically legitimate, even if only on the basis of this analogy.

At the historical moment we are discussing here, theoretical physics had a fortunate encounter with astrophysics, a science that awaited a physical explanation of the production of light by the Sun and stars. The spectra of that light had significant regularities, called *spectral series*, with light lines in perfectly defined positions in the spectrum. Experimental physics had the means to attribute the spectra of light received from celestial bodies to chemical elements that exist in abundance on Earth, especially *hydrogen*, which seemed to be dominant in the spectra of celestial bodies. It was therefore very natural to distribute the creation of the light of the hydrogen atom in the various existing environments, certainly in the stars and the Sun.

As long as light was viewed as electromagnetic radiation, the situation was quite clear and easy to explain: the hydrogen atom imagined by Rutherford can naturally produce electromagnetic radiation, because its electron has an acceleration and therefore it emits radiation like a dipole antenna. Indeed, a Rutherford atom can be assimilated with a plane harmonic oscillator, which can be treated as a Hertz dipole. The radiation emission is then continuous. Here it was found that Rutherford's atom does not work according to the usual classical rules. Indeed, the emission of radiation means the emission of energy, and this can only take place as long as the energy lasts. When it is consumed, the emission ceases. It would therefore have been expected that the atom as a structure would perish due to light emission, but there was no experimental fact to show that this was the case in reality.

This is the historic moment marked by Niels Bohr. By comparing the regularities of the hydrogen spectrum with the mechanical possibilities of the classical planetary model, he did find the answer in the energy of the model in question: the model works in such a way that only certain orbits of the electron around the nucleus are possible, and they have fixed energies (Bohr, 1913). *The light created by the atom corresponds to instantaneous transitions of the electron between different orbits, and carries with it the energy difference between the orbits between which the transition is made.* In the construction of this image, Bohr used the idea, new at the time, that light in such cases is not very dense and can be represented, in Einstein's opinion, by an ideal gas of particles each carrying with it a certain *quantum of energy*: at atomic level, light is thus emitted and absorbed as a *photon*.

With that, Bohr really went back to the days when Newton explained *how the planetary system worked.* Both Newton and Bohr actually explained the same structural model, but on different scales of the universe. Newton's idea was perfect. However, on an atomic scale we have a new explanation of appearances, which seems to entail the fact that the electron, unlike a planet, can have multiple replicas! In the case of a planet, there can be no such replicas, this makes no sense. We can obviously talk about several planets, but that is a completely different story. The conclusion was that Rutherford's atom is unstable only because we assume that it works in a classical manner, something contradicted by reality. Although apparently dictated by the same type of force, the mechanics of the atom are *different* from Newtonian mechanics: it is the future quantum mechanics developed by Heisenberg, Born, Jordan and Dirac.

One shortcoming of Rutherford's atomic model, however, remains, and still haunts science today: the way man understands electric charge, the atomic nucleus should be unstable. Not the way, for example, the Sun is unstable but in a way that is, we'd say, much more radical. While the Sun is constantly changing, but still remains in place and in a predictable space region in all respects, the nucleus should break and scatter, according to our ideas about charge and electric force. In a way, this is indeed the case, as it is presented to us by the existence of the three kinds of radiation that generated the conclusions that changed physics. However, the instantaneous destruction of the nucleus is not *a permanent phenomenon*, a common occurrence, as the idea of electric charge would require, but *an incidental phenomenon.* Thus, if, for example, there are reasons to think that all other atoms have an unstable nucleus, hydrogen at least does not have this peculiarity, and this is enough to create the enigma: how come the repulsive electric forces not break the nucleus into pieces?

Here, for the first time since Newton, a wonderful thing happened: a new force came into play, and it did this in the Newtonian manner, based on experience. First, the neutron was discovered, which was immediately assigned as a component of the nucleus structure, having no electrical charge but still being able to develop strong bonds with the proton - the positively charged component of the nucleus. Therefore, at least in the case of atoms with a mass number different from the number of charges, physics recognized the existence of other *fundamental forces* besides the Newtonian ones. These forces, called *nuclear forces* for obvious reasons, are very strong at short distances - inside the nucleus - and prevail over any kind of repulsive forces inversely proportional to the square of the distance between the material particles. They were explained by Yukawa (1935) in the old manner in which Seeliger, for example, solved the paradox of the difference between light and gravity. However, this time it was obvious that the problem to be solved *was that of the density of matter*, essential in determining the forces according to the ideas of classical mechanics. Indeed, whereas density determines the potential of forces through Poisson's equation, it itself must be defined by rules other than Newtonian ones, otherwise it can lead to a vicious circle. These rules, used by Yukawa, are given by the so-called *theory of isospin* in quantum mechanics.

The question of why the hydrogen nucleus is still stable, despite the fact that it has no neutrons, persisted, until it was realized that the Geiger-Marsden experiments, which led to the idea of the nuclear atom, carried additional information. By speculating on the relationship between the types of fundamental forces and the structure of matter in which these forces are involved, one can arrive at the idea that nuclear forces *do not affect the electrons*. Therefore, high-energy electrons can be used as "probes" of the hydrogen atom nucleus in Geiger-Marsden type experiments. And so it happened that *quarks* and *partons* were "discovered", fact that has a special meaning. What is this meaning?

The fundamental feature of man's path to truth is that he never looks back to reevaluate the concepts he has created: we are always dealing with "new discoveries". Everything is progress to infinity, as Hegel once said, progress without a goal. Feynman's theory of parts is a striking example in this respect. We have here a testimony that we must reconsider the ideas of Hertz's natural philosophy: Feynman's partons are the *fashionable*, so to speak, version of Hertz's material particles. They were revealed exactly where they should be according to the ideas of the theory of light and material points. It is indeed expected that, in close collisions, the material points will gradually highlight each other's structures given by other material points consisting of the same material particles - partons - exactly as we explained in (Mazilu and Agop, 2010).

This conclusion is never expressed scientifically, and therefore it is normal that it is not used as a working hypothesis either. This is the reason why there has never been any impetus to reconsider and reevaluate Geiger-Marsden-type experiments or the nuclear model of the atom. Today we can instead witness an enormous scientific effort to decide the relationship between partons and quarks, for example. For the same reasons, Rutherford's atomic model is still carved in stone today - a monument to Hertz's forgotten philosophy. What would the reconsideration we are talking about entail?

First of all it would first mean us accepting that the structure revealed in Geiger-Marsden-type experiments is accidental and dictated by the distance between the atom and the alpha particles in that experiment, as it seems intuitively normal and, moreover, as Feynman's parton model describes. But reconsideration would mean much more: the electric charge itself is accidental and revealed only under special conditions, as is the case in practice and as Feynman's model can certainly tell us. But no! The nuclear model is still there, we are required to study it diligently in elementary school, despite the fact that nothing is finished, that science is still struggling to explain its structure. There was, however, a voice that once rose in support of the reconsideration we are talking about here, namely that of the physicist Dewey Larson (Larson, 1963). He did make a great "case against the nuclear atom", but only from a phenomenological point of view. Probably due to the fact that Larson did not back up the phenomenology, a very healthy one in fact, with equally healthy mathematics, his success in the scientific circles was weak, in fact non-existent.

We cannot hope, therefore, that science will return to reconsidering the planetary model of the solar system, in order to reevaluate Newton's ideas, as it would be fitting due to the fact that the equations of motion describing both the atom and the solar system are identical. This state of affairs would also have a somewhat scientific, objective explanation: according to our experience in the microscopic field, here would be involved the essential connection of matter with light and therefore, according to current opinions, we could not have a field of analogy like the one that led to Rutherford's model for the atom. Indeed, in Kepler's model for the solar system, a connection to light in Bohr's manner is inconceivable. The current scientific opinion is that light is electromagnetic in nature and is therefore closely related to *the dynamics of electrical charges*. Therefore, Bohr's rules have nothing to do with the solar system.

However, in such an undertaking it would be good to note first of all that all the mathematics required for electromagnetism is a tribute paid to the mechanical concept of frequency. Insofar as light belongs to a science that is built on the sense of sight, two concepts must first be considered: that of *light beam* and that of *wave surface*. They precede electro-magnetism from any point of view. If, for example, we accept that Huygens' principle is a manifestation of the *deformation* of light's wave surface rather than the fact that each point in space becomes a light source, then the frequency is a clear expression of the change in the curvature of the wave surface which can be activated, for example, at the separation surface between the vacuum and the material or at the separation surface between two transparent materials. Moreover, in this approach, mathematics tells us that only zero-average curvature wave surfaces can travel indefinitely in a vacuum. This indeed brings strong arguments in favour of Fresnel's concept of plane wave - the plane is only a special case of zero mean curvature surface - but also an alternative explanation of the light phenomenon. In addition, a meticulous mathematician might find it significant that average zero-curvature wave surfaces are much more general than plane waves: they also include *non-plane minimum surfaces*. The periodic structure of crystalline solids seems to be a consequence of this simple, mathematically revealed fact.

On the other hand, if we were to consider the gnoseological meaning of Bohr's theory of the structure of the nuclear atom, it is certainly twofold: first, it shows that we can recognize the past in the present simply by the light *produced* by the atom. Secondly, and related to the first aspect of meaning, according to classical mechanics, the light source is not the atom as a whole, as a system, but especially its *nucleus*, just as the Sun is the light source of the solar system. The explanation of these statements is based on mathematics, but it can be given in ordinary terms. Namely, in a Kepler problem, which describes in terms of dynamics both Rutherford's atom and the solar system, we will need to have certain *initial conditions* of the electron's motion, regarding its velocity and position at the moment when the motion *started*. In general, this means that the electron or the planet cannot have the motion they have *now*, if this motion did not start from *a certain* place with *a certain* speed. It is, of course, absurd to think that we could somehow find out these initial parameters for the electron, but this also how we should think of a planet in the case of a solar system.

However, the mathematical reading of the solution to the Kepler problem, when done from a somewhat more general point of view than usual, tells us something very interesting: if we note *now* that the motion of the planet or electron occurs in closed elliptical orbits, we can read, at least partially, *those initial conditions* in the current eccentricity of the orbit, i.e. in the ratio between its two diameters. This is the meaning of our earlier statement about being able to recognize the past in the present. Furthermore, the eccentricity of the elliptical orbit can be represented as a vector in space, of a size limited to the region that closely surrounds the attractive central body in the corresponding Kepler problem. This means that, from a mathematical point of view, the parameters of the orbit of the electron or the planet are dictated by the position of the vector that causes the eccentricity in the above mentioned central region. Thus, if we think that the set of initial conditions is traversed by a movement from the past, which obviously we cannot attest directly, as it is long extinct, then at least we are able to recognize the trace of this past movement in our present. The current shape of spiral galaxies and the behaviour of atoms are then, in our opinion, evidence of this. Therefore, the structure of the solar system is as "accidental" as that of the atom.

The "accidental" structure of the atom can be explained by the way experiments that reveal the structure of matter are performed, if we take into account the fact that *action at a distance, regardless of its nature, is carried out according to the model provided by light* and described above. This is nothing else than the Newtonian view in science, applied word for word to action at a distance, just as it was applied to the first action at a distance - gravity - by Newton himself. Gravity itself is a testament to the fact that the "bright" model for action at a distance is somewhat realistic. Indeed, while its algebraic expression, as a force vector, can be deduced from Newton's considerations by the analogy between the motion of the planet and the slingshot, it fully shows its true character of action at a distance when we assume that this force acts, and we demand that dynamics gives us the shape of the planet's trajectory as well as all the other features of motion. That is when it is emphasised that this action at a distance cannot, however, be a pure central force, since the direction of action does not coincide with the direction of the force. Instead, we can say that gravity is a remote action that manifests itself between the planet and the centre of its orbit, realised *in this centre* by a vector that measures the asymmetry of the planetary orbit, just as light is an action at a distance along the direction given by the light beam, realised locally by a vector oriented in a completely different direction than that of light beam.

The geometry of the allowable region of space for this eccentricity vector is, as shown above, a hyperbolic geometry, which can be represented through a complex variable number. This complex number represents in turn a system of generalized elliptical coordinates, which can be attached in Barbilian's manner to a tensor, a mathematical being having precise physical meaning, both in relativity and in classical mechanics. Indeed, the material point represented by the atomic nucleus, the Sun or even the nucleus of a galaxy, reveals to the universe a variable structure *that is dependent on the* *point of view*, as we have shown above. According to Hertz's philosophy, regardless of the particular shape of this structure, it results from agglomerations of material particles between which forces act. We cannot comment on the nature of these forces: we cannot say whether, for example, they are central or not, whether they have an intensity inversely proportional to the square of the distance, etc. We can, however, say that they have overall results that can be represented by a stress tensor that can be measured, and that is, in fact, all that matters. Indeed, any structure of a material point can be characterized by a balance of forces between its material particles, and a plurality of equilibrium material particles can define a stress tensor, and certainly other kinds of tensors associated with the forces. These tensors vary with the structure of the material point in the manner described above.

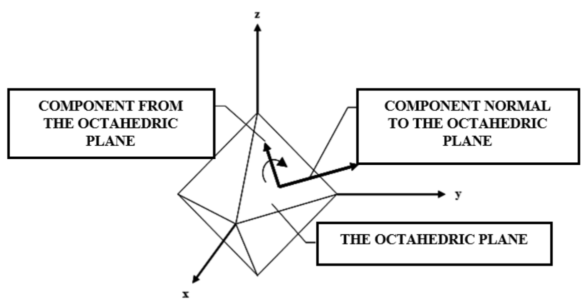


Figure 3. The octahedral planes attached to the reference system (according to Mazilu and Agop, 2010)

The variation in question has a form to which modern physics of elementary particles often refers, and which is contained in the algebraic structure of the complex number characteristic of the tensors we are discussing here. Indeed, the stress tensor mentioned above determines an orthogonal reference system formed by its main directions. For example, in the case of the solar system this reference system results from the plane of the planets' orbits and a direction perpendicular to this plane. The generalized elliptic coordinates are then given by the values of the stress tensor in the three directions. The evolution we are talking about can be described in relation to a fixed reference system, by the variation of the generalized elliptical coordinates. Indeed, when we measure the intensity of the stress tensor associated with a structure, we do so by the so-called orthogonal invariants, which have a physical meaning related to the octahedral planes attached to the reference system (Figure 3). These invariants represent the physical quantities of the normal and tangential components of the octahedral plane, of the tensor, therefore of the vector having as components the three main values of the stresses. Therefore the evolution is represented by a rotation of the tangential component in the octahedral plane, and can be described through a transformation within the kinematics generated by the hyperbolic geometry that describes the eccentricity of the orbit.

There are eight such possibilities, as obviously, there are eight octahedral planes. They are revealed, as the case may be, in situations where the physical structure of an atom for example - to cite the classical case - is exposed to variation, as in the collision experiments that revealed the validity of the so-called "eightfold way" discovered by Murray Gell-Mann and Yuval Ne'eman in 1964 (Gell-Mann, Ne'eman, 1964). The fact that the eight possibilities are considered as material points in elementary particle physics is non-essential to our argument. In fact, if we are talking about physical structure here, it is instead given by partons - material particles in Hertz's sense - only the experimental form in which the connections between them can be revealed is the one related to the "byte path" (meson octet, baryon octet etc).

The same philosophy can be applied to a solar system or a galaxy. For example, in the case of our solar system, the structure "exhibited" by the Sun to its planets is approximately "constant", the only variation being that which produces the energy emitted by the Sun in the form of light and heat. In general, the principle at work here is the one at work in the case of heating a metal by processing. The "processing" force here is the weight of matter.

Light can therefore be viewed as the way of life of the world in which man lives. Two aspects of this world need thus required to be considered as related to light. First, regardless of the fact that a material structure is perceived indirectly or directly, the mode of perception is represented by colour, it is quantified, that is, on the direction of perception. This is a reflection of the fact that any physical structure must be limited in space, *otherwise it is not a structure at all.* Secondly, light as a physical object, and therefore as perceived directly, *is created* in a quantified manner, exactly as Bohr explained. Correctly understood, Bohr's method of describing the creation of light is universal in the sense that gravity must be universal: it is equally valid for the atom as for a planetary system or for a galaxy. That is, it is invariant on the scale of contemplation of matter in the universe. So it should come as no surprise that nuclear-scale matter can be described by the same methods as gravity...

3.8 Fundamental structures and substructures of the universal informational matrix

Approaching such a topic involves an explanation of the fundamental constituents of matter in the form of elementary particle physics. A simple and clear synthesis in this sense is the one presented by the late university professor Gheorghe Zet, PhD, in *Simetrii unitare şi teorii Gauge* (*Unitary Symmetries and Gauge Theories*) (Gheorghe Asachi Publishing House, Iaşi, 1998), which we shall use here.

It is known that elementary particle physics is changing continuously, both in terms of experiments and of theory. Over two hundred particles have been discovered, and their number is growing.

It is known that matter in the form of substance is made up of molecules which, in turn, are made up of atoms. The atom consists of a nucleus surrounded by an "electronic cloud", while the nucleus is composed of protons and neutrons (such particles being called nucleons). The diversity of chemical elements is given by the number of nucleons in the nucleus, more precisely by the number of protons, Z, which also defines the position of each element in the periodic table.

It was generally accepted that protons and neutrons are fundamental particles, in the sense that they would be the ultimate constituents of the nucleus. Beginning in 1964, Gell-Mann and Ne'emann eliminated thus idea, in the sense that protons and neutrons were considered to be made up of other fundamental particles called *quarks* (Gell-Mann and Ne'emann, 1964). Quarks have the fractional electrical charges $+2e/3$ and $-e/3$, where $e = 1,6 \cdot 10^{-19} C$, is the elementary electrical charge (that of the electron). So far, six types of quarks have been identified: u (up), d (down), s (strange), c (charm), t (top) and b (beauty). Moreover, it is not clear why so far there are only six quarks and whether or not others will be discovered in the future, using suitable particle accelerators.

We present in Table 1 the fundamental constituents of matter, as well as some of their characteristics. These fundamental constituents of matter in the form of particles are characterized by rest mass, spin and charges of various types (electrical, baryonic, leptonic, colour, etc.). In such a context, each quark can be associated with three colours R (red), B (blue), and Y (yellow). Complementary colours can be associated with antiquarks: G (green = anti-red), O (orange = anti-blue) and V (violet = anti-yellow) (Kane, 1987).

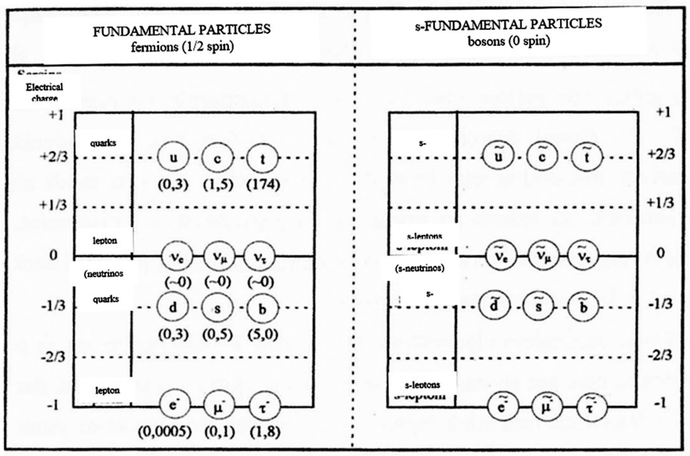


Table 1. The fundamental constituents of matter (according to Zet, 1998)

Therefore, admitting the colour charges, the number of distinct quarks triples. Quarks are fundamental particles with 1/2 spin (fermions), with non-zero resting mass, fractional electric charge and colour charge (of three types). Moreover, it has been established that, in nature, quarks cannot exist in a free state, as they always manifest as “mixtures”, i.e. composite particles (of “white” colour). Quarks have a baryonic charge B = 1/3, while protons and neutrons have B = 1. Baryonic charge B is conserved in all interactions, but so far there is no explanation for this fact (Kane, 1987).

Between these fundamental constituents (particles) there are four types of decryptions in the shape of fundamental interactions: strong, electromagnetic, weak and gravitational. According to the interactions presented above, the fundamental constituents (particles) are classified into the following four categories:

1. **Hadrons**: strongly interacting particles; for example, protons (p), neutrons (n), quarks (q = u, d, s, c, b, t), pions ($\pi \pm \pi^0$), etc. Strong interactions occur only between hadrons. In turn, hadrons are divided into **baryons** (particles with a large rest mass) and **mesons** (particles with a medium rest mass).

2. **Leptons**: lightweight particles, such as electrons (e^-), muons (μ^-), tauons (τ^-), neutrinos (ν_e, ν_μ, ν_τ) etc. Weak interactions occur between all particles except photons, i.e. they affect both hadrons and leptons.

3. **Photons** (γ): particles that mediate electromagnetic interactions; these interactions are manifested between all electrically charged particles.

4. **Gravitons** (G): particles that mediate gravitational interactions;

these interactions are manifested between all particles.

A proton consists of two ***u*** quarks and a ***d*** quark, while a neutron consists of a ***u*** quark and two ***d*** quarks (Figure 4). Similarly, other hadrons are made up of specific "mixtures" of quarks. If we want to release quarks, for example by colliding two hadrons, then we shall find that, in fact, new hadrons appear as a result of such a process. Everything happens as if quarks appeared in nature in the form of "mixtures" of various colours which, by composition, always result in the colour white (hadrons). Note that this concept of "colour" of quarks has nothing in common with the colours (usual spectrum) of nature, and is therefore only an analogy.

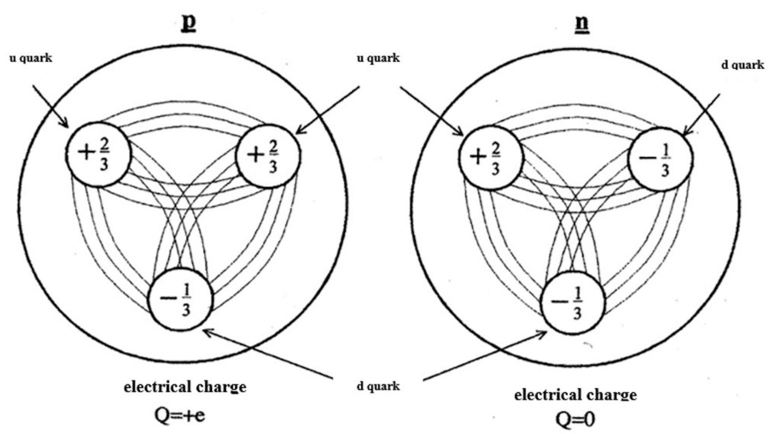


Figure 4. The quark structure of nucleons (according to Zet, 1998)

The six quarks can be grouped into doublets in the form: $\begin{pmatrix} u \\ d \end{pmatrix}$, $\begin{pmatrix} c \\ s \end{pmatrix}$, $\begin{pmatrix} t \\ b \end{pmatrix}$, the way the proton and the neutron form the doublet $N = \begin{pmatrix} p \\ n \end{pmatrix}$, called nucleon. The six standard quarks were evidenced experimentally, while the t quark was evidenced through proton-antiproton $(p - \overline{p})$ collision experiments carried out at Fermilab (USA) (Belletini, Clarke, 1994).

Unlike protons and neutrons, electrons (e^-) are considered to be fundamental constituents (particles), just like the quarks. Electrons are part of the lepton family, which includes six fundamental constituents (particles): the electron (e^-), the muon (μ^-), the tauon (τ^-), the neutrino ν_e, the muon neutrino ν_μ, and the tauon neutrino ν_τ (see Table 1). Note that all 12 fundamental constituents (particles) (six quarks and six leptons) are 1/2 spin fermions. These constituents are given in Table 1, specifying their electrical charge (in $\boldsymbol{e}$ units) and rest masses (in $\boldsymbol{GeV}$) (figures in parentheses).

As we recall, fundamental leptons can also be grouped into doublets:

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix}, \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}, \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}.$$

Experimentally, the masses of neutrinos have not been measured yet. It is stated, however, that their masses are zero, but certain considerations, both theoretical and experimental, would lead to the idea that they may be non-zero. We present in Table 2 the limits for the neutrino masses established experimentally.

Table 2. Neutrino masses (according to Zet, 1998)

Particle	Mass
ν_e	$< 17eV$
ν_μ	$< 0,27MeV$
ν_τ	$< 39MeV$

Regarding the fundamental constituents of matter, experience shows that current matter consists only of $\boldsymbol{u}$ and $\boldsymbol{d}$ quarks, ν_e neutrinos and gauge (standard) bosons that mediate their interactions (Table 3).

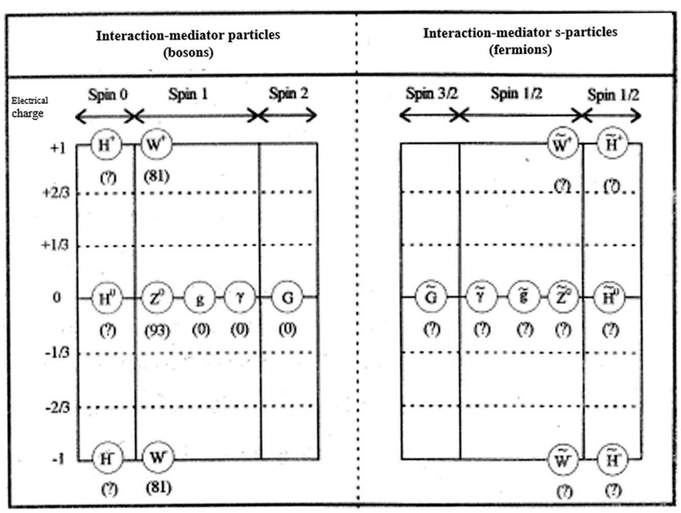


Table 3. Constituents (particles) that mediate interactions (according to Zet, 1998)

The other quarks and leptons were demonstrated experimentally, using particle accelerators with appropriate energies. It is assumed that these particles existed in the first stage of the universe's existence because they have an extremely short lifespan and therefore play no role in the current universe.

All fundamental constituents (particles) have an antiparticle, which has the same mass of rest and the same spin as the particle, but opposite-sign charge (electric, baryonic, leptonic, colour, etc.).

3.9 Types of decryptions in the form of interactions between matter constituents

As mentioned earlier, decryption in the form of fundamental interactions can be of four types: strong, electromagnetic, weak, and gravitational. The first of these interactions to be discovered was the gravitational one (Newton, 1687), while the second was electromagnetic interaction (Maxwell - late nineteenth century). Strong and weak interactions were discovered in the first half of the twentieth century. They were not discovered earlier because they act at short (subnuclear) distances, while gravitational and electromagnetic interactions, having an infinitely large range, were more easily accessible to experimental measurements.

Electromagnetic interactions "correlate" the electrons and the nucleus into atoms. They are also responsible for generating molecules through "mixtures" of atoms. Strong interactions "correlate" quarks inside protons and neutrons. They are also responsible for generating nuclei from protons and neutrons, in which case they define nuclear interactions. Weak interactions involve specific types of decays or processes of synthesis (fusion) of atomic nuclei.

Table 4 presents the main characteristics of the four types of fundamental interactions. It is obvious that these interactions have completely different properties. They differ both in range and intensity (strength). Strong interactions are strongest at short distances. If we choose the strong interaction between two protons as a unit, then the electromagnetic force is 10^{-2} (one hundred times smaller than the strong one), the weak force is 10^{-5} (one hundred thousand times weaker than the strong one), and the gravitational force 10^{-38} (extraordinarily small compared to the strong one). This explains why, even today, gravitational interaction remains the greatest unknown, although it was the first to be discovered experimentally.

Interaction	Relative value of force	Action range	The particles it is manifested between	The particles that mediate the interaction			Type of force between identical particles
				Name	Mass	Spin	
Strong	1	Short	Quarks	Gluons	?	1	Repulsion
Electromagnetic	10^{-2}	Long	All electric charges	Photons	0	1	Repulsion
Weak	10^{-5}	Short	Leptons and quarks	Vector bosons	50-100 GeV	1	Repulsion
Gravitational	10^{-38}	Long	All particles	Gravitons	0	2	Attraction

Table 4. The characteristics of the four types of fundamental interactions (according to Zet, 1998)

According to quantum field theory, interactions between particles are performed by exchanging gauge (standard) bosons (Table 4). Thus, the photon (γ), the quantum of the electromagnetic field, mediates electromagnetic interactions. Similarly, strong interactions are performed through an exchange of gluons (g) (eight of them). Photons have zero rest mass. Weak interactions between leptons and / or quarks are achieved through the exchange of vector bosons $W^{\pm}$ and Z^0. Compared to photons, $W^{\pm}$ and Z^0 vector bosons have nonzero rest mass (about 100 times that of the proton). Finally, the gravitational interactions between any particles are performed by the exchange of gravitons (G) (hypothetical particles for the time being). Table 4 also includes the $H^{\pm}, H^0$ particles, called Higgs particles (or higsons). These particles do not mediate interactions, but are absolutely necessary for theoretical models in order to lend them mathematical consistency (Kane, 1987). The Standard (SM) model for electroweak interaction requires a single, scalar, electrically neutral boson. There are also theoretical models in which several such particles feature, but their existence has not been confirmed experimentally so far. Tables 1 and 4 also include superparticles (or s-particles), introduced by supersymmetry theories. Such particles are also called supersymmetric "partners" of ordinary particles (Freund, 1986, Wess, Bagger, 1992) (Kane, 1987).

Table 3 shows the following general characteristics of the fundamental interactions:

1. The action ranges are dictated by the masses of the particles that mediate the respective interactions. At long distances only the interactions mediated by particles with zero rest mass (electromagnetic and gravitational) are manifested, while at short distances only the interactions mediated by particles with nonzero rest mass (strong and weak) are manifested.

2. The character of the interaction forces (either attractive or repulsive) between two identical particles is determined by the spin of the particles that mediate them. Thus, for odd spin, the forces are repulsive (strong, electromagnetic or weak), and for even spin, the forces are attractive (gravitational). Since the gravitational force is the only force of attraction, it is the one that can describe both the structure and the operation of the universe.

3. The particles that mediate interactions are the bosons, while the fundamental particles, constituents of matter, are the fermions.

In order to study matter at ever deeper (microscopic) scale resolutions and to experimentally demonstrate particles such as quarks, leptons, gauge bosons, gluons, gravitons, higsons, or s-particles, increasingly higher energies are required. Figure 5 shows the energy scale and the dynamics of experimental research towards increasingly higher energies.

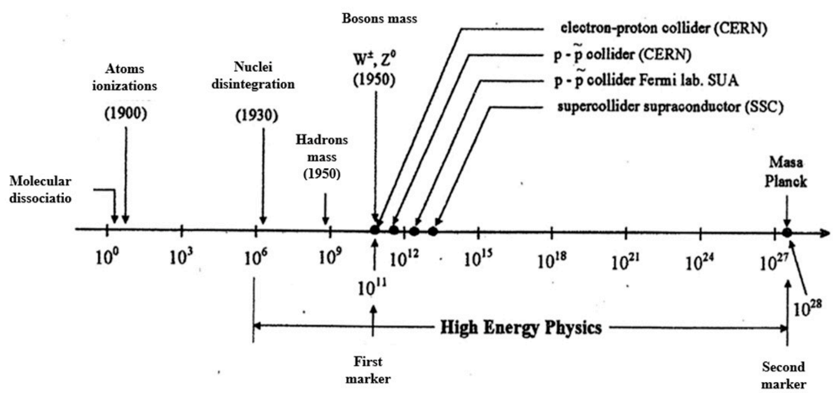


Figure 5. The scale in particle interaction energies (according to Zet, 1998)

At energies of the magnitude of 1 eV, the dissociation of molecules into atoms occurs. At energies of the magnitude of 10 eV, the atoms “break” into electrons and nuclei (ionization), while at the energies of the magnitude of 1 MeV, atomic nuclei disintegrate. Hadrons composed of quarks have masses of the magnitude of 1 GeV, and $W^{\pm}$ and Z^0 gauge bosons have masses of the magnitude of 100 GeV. Such energies were obtained around 1980, when $W^{\pm}$ and Z^0 bosons were discovered. The value of 100 GeV is considered as a first important landmark on the energy scale. The second landmark is the so-called Planck energy - 10^{19} GeV, which corresponds to the Planck mass PM = 10^{19} GeV. The Planck mass is one of the most important physical magnitudes, which must appear in any theory that aims to unify the four types of fundamental interactions (the great unification) (Salam, 1980). If there were elementary particles of mass equal to the Planck mass, then the gravitational interactions between such particles would be stronger than any other fundamental interaction.

From the above it follows that the four types of fundamental interactions have properties that differ greatly from each other. However, currently theoretical and experimental research is aimed at developing a model of their unification, in which all interactions would have a unique feature.

3.10 The grand unified theory of everything

Forty years ago, electromagnetic and weak interactions were unified in a theoretical model developed by S. Weinberg, A. Salam, and J. Ward. This model was based on the gauge symmetry SU(2)xU(I) and is currently known as the Standard Model (SM) for the electroweak interaction. Regarding the strong interaction, we mention that an adequate quantum theory has already been developed under the name Quantum Chromodynamics (QCD). There is also hope of achieving a unification of the strong interactions with the electroweak ones within the Grand Unified Theory (GUT) based on the symmetry groups SU(5) or SO(10) (Figure 6).

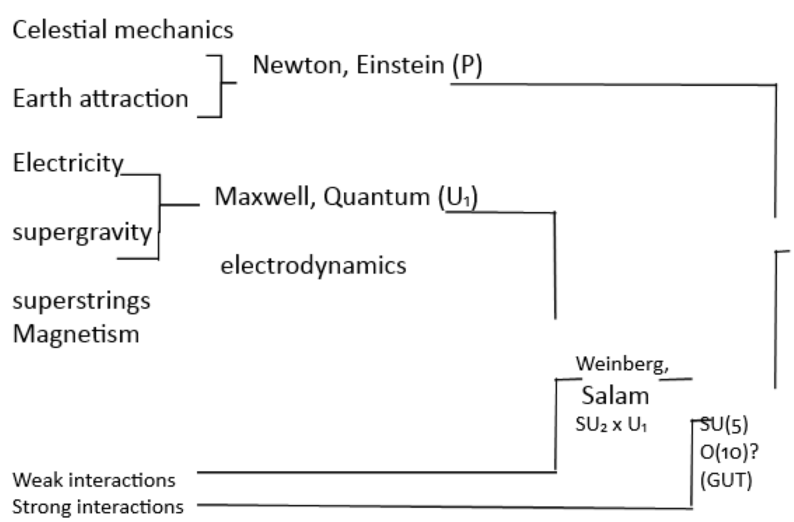


Figure 6. The unification scheme of interactions (according to Zet, 1998)

"There is also a direction of unification of all the fundamental forces in nature, based on the idea of supergravity (Ferrara, 1976). Supergravity is a generalization of Einstein's theory of gravity, but at quantum level it differs radically from the theory of general relativity (TGR). Thus, in calculating the probabilities of specific processes in which gravitational interactions occur, TGR result in infinite values of such probabilities, which is nonsense in terms of physics. But in supergravity, these calculations result in finite values of probabilities (renormability).

Both supergravity and other field theories are based on the symmetry properties of interactions between fields. "Symmetry" means that the Lagrangian describing a certain interaction is invariant with respect to a group G of transformations, for example, with respect to the Lorentz or Poincaré groups, or U(l), SU(2), SU(3) etc. The respective interaction (or the physical system considered) is said to have G symmetry. Symmetries based on the Lorentz or Poincaré groups are called external, and those based on the groups U(I), SU(2), SU(3) etc., are called internal (or unitary).

Symmetries can be global or local. A global symmetry has the property that its transformations have the same shape at all points in space-time, while in the case of local symmetries the transformations at different points are independent. The Poincaré symmetry, commonly known, is global because the connection between two coordinate systems is the same for all points in space-time. More general is the condition of local symmetry that requires that the physical laws be invariant with respect to coordinate transformations that depend on the considered point. In this case, observers whose relative movement is not uniform are admitted. At first glance it would seem that the laws of physics will be different for different observers, because acceleration results in forces such as those of inertia.

Einstein has shown, however, that the inertial forces that occur in accelerated systems are closely related to gravitational forces. He proved that the laws of physics remain invariant to general coordinate transformations if the gravitational field is introduced, thus creating TGR.

Theories based on local symmetries are called gauge theories and they are much more "powerful" than global ones. TGR and Maxwell's theory for the electromagnetic field are based on the Poincaré local P and U(I) symmetries, respectively. Likewise, the Weinberg-Salam-Ward model is based on the local symmetry SU(2)xU(I). So all these are gauge theories. Quantum chromodynamics is based on local symmetry SU(3), so it is a SU(3) gauge theory. Supergravity is also a gauge theory based on local supersymmetry. "Supersymmetry" means the invariance of fundamental interactions with respect to boson-fermion transformations. The set of these transformations no longer forms a Lie group, as in the cases mentioned above, but instead a supergroup. If local invariance with respect to a supergroup is imposed, then the theory of supergravity is obtained, just as imposing local invariance with respect to the Poincaré group results in Einstein gravity. Due to the fact that supergravity results in models in which the gravitational field appears together with the other fundamental fields, it is expected to result in a unification model for all four types of interactions known today. A possible unification scheme is shown in Figure 6.

One of the fundamental problems that has not yet been solved is the quantification of the gravitational field. Although quantification through the functional integral method has been carried out for Gauge theories, this has not been possible for gravity. The main reason is that, in the case of gravity, the coupling constant is not dimensionless as it is in the case of other interactions. As a result, in a quantum theory of gravity it is not possible to add Feynman diagrams that correspond to different powers of the coupling constant. This means that general relativity cannot be a renormable theory (Kaku, 1987).

It is currently considered that a possible path for the development of a quantum theory of gravity is provided by the string model (Green *et al.*, 1987). This model assumes that the particles are not punctiform, but instead have the shape of strings. These strings have microscopic dimensions ($10^{-35}m$) and can vibrate at various frequencies. Along with supergravity, this hypothesis led to the creation of the Superstring Theory. For this theory to be mathematically correct, it is necessary to admit a ten-dimensional space in which strings move. Of these, four dimensions are commonly known (space and time coordinates), and six are called "hidden coordinates". It is assumed that the six dimensions are "curled" (compacted) into circles billions of times smaller than the size of the atomic nucleus and hence not observable. It is possible that, immediately after the Big Bang, when the size of the universe was of the magnitude of Planck's length ($10^{-35}m$), all ten dimensions were curled. Then, with the expansion of the universe, four of the dimensions unfolded, and the other six remained curled (hidden). The superstring theory can ultimately provide a unification of fundamental forces, as shown in Figure 5. This possibility remains to be confirmed in the future!" (Zet, 1998).

Like many other hypotheses, the Big Bang theory did not have a smooth existence either. Let us remember the hypothesis of the primordial atom, stated by Georges Lemaître in a letter published by the journal *Nature*, on May 9, 1931, which represented a genuine revolution in cosmology. At that time, most scientists believed that the universe could not have a beginning.

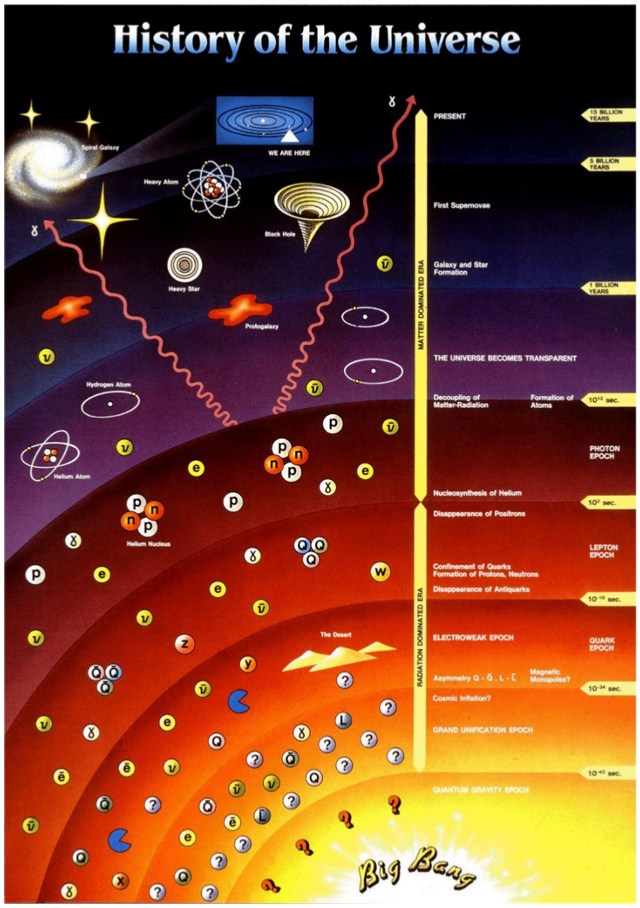
He argued: “If the world started from a single quantum, the notions of space and time no longer have any meaning in the beginning; [the two notions] only make sense when the original quantum has been divided into a sufficiently large number of quanta”.

By “original quantum”, Lemaître meant a hypothetical *primeval atom* that may be the source of all matter in the Universe. However, based on the data we currently have, we can say that there was no primeval atom that would disintegrate in the sense described by Lemaître. But his theory remains valid precisely in its most difficult part for the physicists of the 1930s, namely that time and space have a beginning. There is a moment of zero time.

After World War II, in 1948, a new theory was proposed, which excluded from the start the moment of a beginning of the Universe. This was the Steady State Theory, developed by physicists Hermann Bondi, Thomas Gold and Fred Hoyle. They considered the Universe to be perfectly homogeneous and isotropic in both space and time. Hence, on a large scale, the universe would be homogeneous. The debates on this topic were particularly heated. In their midst, the phrase “Big Bang”, ironically formulated by Hoyle, was born, during a radio show on the BBC.

Nevertheless, in the late 1950’s, problems began to arise with the theory of the stationary universe, after the first quasars were discovered with the help of radio telescopes. Quasars are extremely intense radio sources, and when they could be associated with visible objects with optical telescopes, they were found to be at a great distance from us, belonging thus to the distant past of the Universe.

Then came the coup de grace for the stationary universe hypothesis, brought about by the discovery of the cosmological background radiation in 1964, which brilliantly confirmed the theory of the Big Bang, previously mocked by Hoyle. And the circle seemed to be completed...



3.11 The self-similarity of the world. From atoms to planetary nebulae through the holographic universe

Recent research and astronomical observations have shown that there exists an atomic system-stellar system analogy for the classical images of the probability density distribution of the electron in the atom (Christmas, 2008). Moreover, it has been confirmed that *Rydberg atoms* (i.e. strongly energized atoms with the principal quantum number n of the magnitude of several hundred and therefore increasingly "classical"), currently called also *planetary atoms*, have a strong analogy with stellar systems.

To date, there is no theoretical gravitational model for explaining the atom-object astrophysics analogy. We can, however, offer such a model based on the fractal theory of motion (Nottale, 2011), accepting that even in the macroscopic case, probability densities $\psi\psi^*$ do not have only the "abstract" interpretation of the location of a "punctiform" electron in one place or another in space. For example, when electrons become bound (to the atom), their mass (and charge) is "scattered" (diffused) along a structure that is isomorphic with the probability density distribution that depends on the energy state of the atom. Thus, abstract probability densities become proportional to actual mass distribution densities.

Since atom - star system analogies manifest themselves on very different scales, we can consider that the Universe has a *multifractal* (holographic) *structure* also called a self-similar cosmological paradigm. Direct observational verification of this hypothesis is difficult because only the shape of one star (the Sun) can be observed from Earth. Although the shape of the sun is consistent with the atom-star similarity, data on several stellar systems in the Universe are needed in order to generalize this analogy.

The difficulty of observation derives from the fact that near the stars there are "punctiform" sources that prevent the accuracy of the observations with existing telescopes. Thus, their detailed form remains unknown for the time being. However, there are solar systems (for example, so-called "planetary nebulae") that expel ("eject") their outer layers in a distribution that could be related to the initial shape (state) of the star. Obviously, in the process of expulsion some diminutions, some losses of pre-symmetries can occur, for these expanding astrophysical objects.

In support of this hypothesis come also the results obtained with the Hubble telescope, which have shown that very young planetary nebulae have structural characteristics similar to those of mature planetary nebulae. The large number of similar atomic-star systems should exclude a major influence of subjective or random factors. Moreover, considering the equations (Crăciun, 2008):

$$E_n = -\frac{\mu}{2}\left(\frac{GM}{2\sigma n}\right)^2 = -\frac{\mu}{2}\left(\frac{v_0}{n}\right) \tag{27}$$

where

$$\mu = \frac{m_1 m_2}{m_1 + m_2},\ M = m_1 + m_2. \tag{28}$$

It is possible that the relative recession velocities, v_n, in binary galaxies to be "quantified" according to the equations:

$$v_n = \frac{v_0}{n},\ v_0 = \frac{GM}{2\sigma}. \tag{29}$$

The meanings of the magnitudes involved in equations (27)-(29) are given in (Crăciun, 2008). For certain binary galaxies we present as a comparison in Table 5 the observed and the "quantified" values of recession velocities.

Double galaxy	n	m_1 and m_2 $\times 10^{10} M$ ←	v_{obs} (kms^{-1})	$v_{pred}$$(kms^{-1})$	$nDM \cdot 10^{67} Js$
NGC-3958	1	12.0	72.03	72	8.0
NGC-3963		9.0			
NGC-4294	2	1.4	34.98	36	7.77
NGC-4299		8.8			
NGC-4085	3	1.3	25.04	24	8.34
NGC-4088		6.0			
NGC-3504	4	1.0	20.58	18	9.10
NGC-3512		5.0			
NGC-6542	5	2.7	15.09	14.5	8.38
NGC-6528		1.7			

Table 5. Observed and theoretical values of recession velocities in binary galaxies.

It follows that: i) for binary galaxies there exists a maximum recession velocity of a value $v_0 =< w > /2 = 144kms^{-1}/2 = 72kms^{-1}$ (for further details, pleas see (Tifft, 1998); ii) there exists a gravitational type analogue of Planck's constant. It has the value $h_g \approx (8.3 \pm 0.2) \times 10^{67} Js$ (Crăciun, 2008).

Next we present images (Figure 7 a-d) that support the stellar atom-system (planetary nebula) analogy. The figures on the left represent a state of energization of the atom, characterized by the quantum numbers n, l, m, while the photos on the right are of similar planetary nebulae. [http://www.amherst.edu/rlolders/MENU.HTM].

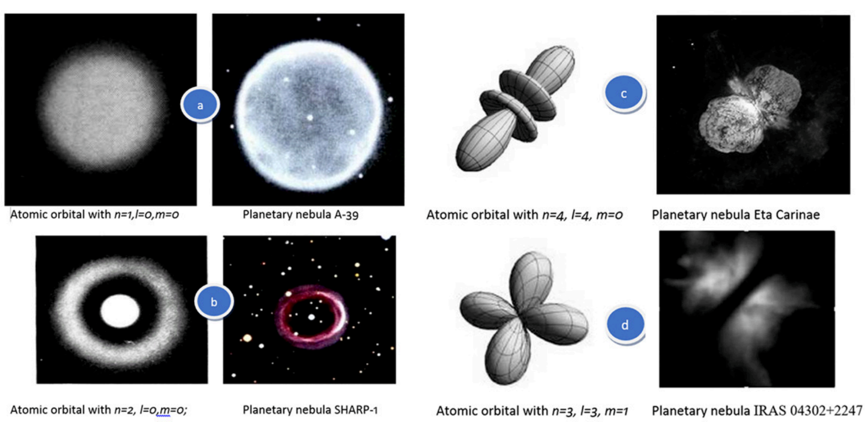


Figure 7 a-d. The analogy atom - planetary nebula

Therefore, the process of discovering the Whole (be it the observable universe) in Nothingness (be it the common grain of sand) represents both structural and functional sequences of the hologram of this world.

Nothingness has now become the centrepiece of modern physics; it is the starting point of our universe and it also conditions its future. Nothingness, or vacuum, possesses its own energy and is by no means a nonexistence, but rather a state of hibernation of matter. Pure nothingness, as we conceive it, cannot exist, on the contrary, it is extremely complex and contains mysteries that we must decipher if we are to understand the whole universe.

3.12 Towards the holographic universe

All the previous results concluded that the usually principles beginning from the Classical Mechanics ending with the Quantum Theory require the introduction of a new fundamental principle, namely: the holographic structural and functional principle of the universe.

The holographic principle represents the idea that the universe around us, which every one is used to thinking of as being three dimensional - there are three dimensions of space - is actually at a more fundamental level two-dimensional and that everything that is seen that is going on around everyone in three dimensions is actually happening in a two-dimensional space.

It turns out that the idea of the holographic principle or that the universe is a hologram, although at first, it might seem like a completely random idea, it actually helps to solve some of the thorniest puzzles that arise when it is tried to combine quantum mechanics and general relativity.

In the following we will base on the work entitled “The holographic Universe” written by Jean Perre Luminet (Luminet, 2016).

The holographic principle is a principle of string theories that states that the description of a volume of space can be considered encoded on a lower size limit of the region - such as a light-like boundary like a gravitational horizon. First proposed by Gerard ’t Hooft, he was given a precise interpretation of string theory by Leonard Susskind, who combined his ideas with those of ’t Hooft and Charles Thorn. The first example of holography is AdS/CFT correspondence.

The holographic principle was inspired by the thermodynamics of the black hole, which conjectures that the maximum entropy in any region is scaled with radius squared and not with cubes, as would be expected. In the case of a black hole, the idea was that the informational content of all objects that fell into the hole could be entirely contained in the surface fluctuations of the event horizon. The holographic principle solves the paradox of black hole information in string theory.

Black Holes Thermodynamics

In order to describe a black hole three elements are needed, namely: mass M, electric charge Q and kinetic moment J. The dynamics of interacting black holes can be described by four laws that are analogous to those in thermodynamics, but two of them imply that the dimension of such a hole does not decrease, which as the loss of entropy by falling into a black hole is a violation of the second law of thermodynamics. This law stipulates that entropy is always an increasing function in a closed system, and the Universe itself is a closed system.

Jacob Bekenstein identified the fact that the surface of a black hole can never decrease with entropy: if this area is a measure of the entropy of the black hole, the second principle of thermodynamics is no longer violated. This implies that if a black hole has entropy, then it also has a temperature, which in turn implies that any body that has temperature radiates energy, in a spectrum that corresponds to its temperature.

When material body going through a horizon of events is taken into consideration, it is said that all knowledge about their material properties is lost and the only ones left are M, J and Q, so it can be said that a black hole takes up a lot of information and entropy that can be attributed to this information and it is described by the formula Bekenstein-Hawking:

$$S = \frac{c^3}{A} = 4\hbar G. \tag{30}$$

In the late 1960s, physicist Roger Penrose proposed a way to extract energy from a black Kerr hole. It should not be forgotten that, once he enters the ergosphere, nothing can remain motionless, he is attracted by the moving black hole. One of the results is that there are negative energies inside the ergosphere. If a particle enters the ergosphere and breaks into 2 new particles, one of the particles falls inside the hole with negative energy. Of course, such a process is valid only with precise trajectories. From a physical point of view, it is an unlikely phenomenon.

In 1975 Hawking suggested that black holes could evaporate by emitting black body radiation, radiation characterized by temperature $T_H = g/2\pi$, where g is the gravity of the surface of the black hole; which results in the fact that the black hole eventually evaporates due to the decrease in energy resulting from mass transport, electric charge and angular momentum.

String Quantum Gravity

When a black hole evaporates, all the information contained in it disappears, which contradicts the Schrödinger equation, according to which any physical system that changes over time cannot create or destroy information. When the Hawking semi classical approximation is no longer valid, namely when the radius of curvature at the event horizon reaches the Planck length 10^{-33} cm, matter, energy and gravitational field must be quantified, and with the quantum field theory, the techniques of this theory were applied to physical materials, such as the electromagnetic field.

In theoretical physics, Feynman diagrams are pictorial representations of mathematical expressions that govern the behavior of subatomic particles. While diagrams are mainly applied to quantum field theory, they can be used in other fields. Each such diagram is considered a contribution to a continuous process of interactions. To calculate these interactions, the contributions are taken into account in descending order, from the strongest to the smallest one until the desired accuracy is reached, which can work as long as these contributions can become negligible as more interactions are taken into account.

When it comes to quantum gravity theories, string theory has been studied the most. String theory is a theoretical attempt to unite all four fundamental interactions into a single unified theory. Several string theories are currently being developed, such as superstring theory and M theory. String theories are being developed on the same basic assumptions of quantum theory. String theories start from quantum theory. Quantum theory is a combination of all fundamental interactions except gravity. So they are based on three fundamental interactions. Eventually, string theory becomes a unification of the four fundamental interactions. Thus, string theory is considered to be a theory of quantum gravity.

However, in string theory, particles of zero point-like dimensions assumed in fundamental particle physics are replaced by one-dimensional string-like objects. These strings are able to vibrate and stretch. They are the quantum blocks of matter.

In string theory, the concept of supersymmetry is essential to include fermions. According to the concept of supersymmetry, all fermions must have a superparten boson. So supersymmetry is a conceptual intermediate that refers to bosons (force carriers) and fermions (particles of matter). String theories that use the concept of supersymmetry are called superstring theories. Normally, string theories require more than four dimensions. In superstring theory, space-time is considered to be dimensional. In M theory, space-time is considered to be 11 dimensional.

The spatial dimensions of M theory have given rise to a new concept called p-branes, in which a complete system of such branes forms a multi-dimensional space-time, namely the matrix. Our three-dimensional space is 3-brane and the strings are 1-brane, and the ends of the open strings rest on 3-brane and the closed strings represent gravitons, which live in other dimensions.

Basically, string theories are classified according to the type of strings assumed in theory. There are two types of string loops: closed-loop loops that can be separated into open-loop loops and closed-loop loops that cannot be separated into open-string loops. The size of the strings is considered to be around the Planck length or 10^{-35} cm. So if there really are strings, it would be very difficult to detect with current technologies.

String theory is believed to be a promising candidate for a quantum theory of gravity and is a unification of the four fundamental interactions in nature.

Holographic Hypothesis

The generalization of black holes in classical general relativity is represented by black branes that are generated by the sufficient bending of the space-time of the branes under a strong coupling.

Using static quantum mechanics, the entropy and temperature of a black hole must be calculated according to its surface and gravity. This is not easy to accomplish because entropy measures the total number of internal microscopic states of an external state of the black hole, which is defined by the parameters M, J, and Q, and the degrees of freedom from which the entropy is calculated must be countable. For this to be possible, the fundamental constituents at the deepest structural level need to be known, which in particle physics refer to quarks and leptons, but when string theory is discussed, this constituent is just excited states given by overstrings.

In 1993, Gerard 't Hooft calculated that the total number of degrees of freedom in the volume of space-time inside a black hole was proportional to the surface of the horizon or the two-dimensional surface that can be divided into fundamental quantum units, called Planck zones (10^{-66}cm^2). Virtually every bit in the form of 0 or 1 corresponds to four Planck zones. Basically the information is encoded on the two-dimensional surface of a black hole and the information about the entropy of a black hole of the objects that crossed the event horizon is not lost for an external observer.

Considering a black hole as a gas string and counting the quantum states associated with string vertebrae, in the general context of M theory, Andrew Strominger and Cumrun Vafa managed to calculate the entropy of an extreme black hole loaded in 5 dimensions.

This led to the idea that string theory could prove that Hawking radiation contains all the information about the internal properties of a black hole. Unfortunately, it has been observed that once the extreme conditions are removed, control over the calculations is lost. Despite this, the idea that the amount of information left in a black hole depends on the area of its event horizon and not on its volume, was still of great interest.

Leonard Susskind developed the holographic principle, hoping that it could be applied to all systems that occupy a space-time column.

The standard cosmological model is an open Friedmann-Lemaître solution of the field equation of general relativity, with near-zero spatial curvature and accelerated expansion. Unlike a black hole, this model does not have a defined edge on which to place such a hologram. In addition, the holographic limit of entropy deduced from black holes is destroyed in an expanding, spatially homogeneous and isotropic universe; the entropy of a region of space-time full of matter and radiation that does not collapse into a black hole is actually proportional to its volume, not to its boundary area.

Juan Maldacena's Conjecture

Everyone knows about holograms on credit cards or banknotes. Although they are two-dimensional, they appear to us to be three-dimensional.

In 1997, physicist Juan Maldacena proposed the idea that there is a correspondence between gravitational theories in anti-sitter curved spaces and quantum field theories in smaller spaces.

Gravitational phenomena are described by a theory that considers space to have three dimensions, while the behavior of quantum particles is described by a theory that considers space to have only two dimensions.

AdS-CFT correspondence argues that statements of quantum theories can be translated into statements of gravitational theories and vice versa. Such correspondence is quite surprising. As if it is learned that the equations in astronomy textbook can also be used to repair a CD player.

Practically Maldacena considered a black hole in a space-time model with 5 macroscopic dimensions namely the anti-de-sitter space and showed that the details of the phenomena that take place in such a universe can be completely coded by quantum non-gravitational fields, which take place at the four-dimensional boundary of this universe.

This space is a void of matter that involves a cosmological constant called a positive repulsive force. Space can become space-time anti-de-sitter with a hyperbolic spatial geometry of negative curvature, if the sign of this constant changes and implicitly the force becomes from a repulsive one an attractive one.

Even if anti-sitter space-time is considered to be an infinite space, it actually has a well-defined edge. For a space-time anti-de-sitter in five dimensions, its edge is actually in four dimensions, and locally, around each point, it resembles a Poincaré-Minkowski space, which means that a black hole in this space with 5 dimensions (AdS5) is equivalent to a field of particles and radiation existing in the time-flat space and with four dimensions of the edges.

What is most interesting about this equivalence is that the gravitational physics in AdS5 is in a strong coupling regime and therefore cannot be treated in perturbation theory, while the non-gravitational physics on the four-dimensional boundary is a gauge theory with poor coupling and is therefore calculable. Because gauge theories are well defined, regardless of the strength of the coupling, Maldacena assumed that his description would apply in general, regardless of the intensity of the coupling on both sides of the equivalence.

His conjecture can be summarized as follows:

(31) String theory on $AdS_5 \times S^5 \sim$ Gauge theory on the 4D border.

Maldacena's conjecture was renamed the AdS / CFT correspondence or gauge / gravity duality, to emphasize that gravity in the context of string theory arises from gauge theory and vice versa, a correspondence that brings together two types of theories, namely quantum gravity theories formulated using M theory and field theories where elementary particles are described.

One benefit of Maldacena's work was solving the information paradox, at least in the particular case of a black hole in AdS5. It seems to be equivalent to a hot plasma at the edge, characterized by Hawking TH temperature and described by a gauge theory. Both the plasma and the black hole have the same entropy. Moreover, plasma follows the usual laws of quantum mechanics; in particular it evolves uniformly, which means that the black hole evolves uniformly and also respects the principles of quantum mechanics.

Dualities

It was hoped that with the help of the Maldacena conjecture, the gauge / gravity duality could establish a kind of practical dictionary corresponding to the properties of a physical system in quantum gravity, described by strings or M theory in a high dimensional space curve (matrix), at those of another simpler physical system, quantitatively described by a theory of gauge at the edge of the matrix, namely, a flat space of smaller dimensionality.

Quantum chromodynamics (QCD),represents the theory that describes the action of the strong force. QCD was constructed in analogy to quantum electrodynamics (QED), the quantum field theory of the electromagnetic force. In QED the electromagnetic interactions of charged particles are described through the emission and subsequent absorption of massless photons, best known as the "particles" of light; such interactions are not possible between uncharged, electrically neutral particles. The photon is described in QED as the "force-carrier" particle that mediates or transmits the electromagnetic force. By analogy with QED, quantum chromodynamics predicts the existence of force-carrier particles called gluons, which transmit the strong force between particles of matter that carry "color," a form of strong "charge." The strong force is therefore limited in its effect to the behavior of elementary subatomic particles called quarks and of composite particles built from quarks - such as the familiar protons and neutrons that make up atomic nuclei, as well as more-exotic unstable particles called mesons. It has been shown that an Ads-QDC duality can be used to understand some aspects of quark-gluon plasma.

QDC is a gauge theory but it is neither compliant nor supersymmetric, unlike Yang Mills theory. When it comes to solving complex problems, the most ok to use is Ads / CMT correspondence because it allows modeling the transition from a superfluid to an insulator or high temperature superconductors.

The Kerr/CFT correspondence can be viewed as a concrete proposal for realizing the holographic principle in a physically realistic 3 gravitational setting. The starting point of the Kerr/CFT correspondence is the observation that the extremal Kerr geometry admits a decoupled near-horizon limit. This program began in 2009, and sought to demonstrate that holographic duality can be used to understand certain astrophysical black holes. Unfortunately, this correspondence could only be used for black holes with the largest possible angular momentum. However, when this correspondence was applied to black holes with a lower angular momentum, the Bekenstein-Hawking formula was discovered for any value of M or J.

No one has been able to demonstrate that the Ads / CFT duality can be applied to our physical universe.

Some researchers have also tried a possible DS / CFT correspondence, linking quantum gravity in Sitter space to a conformal theory of Euclidean fields, but this duality could not be used to describe our holographic universality, which leads us to the idea that the gauge / gravity duality has no use in rational cosmology.

Black Holism

In recent years, modern physics has begun to increasingly implement Einstein's theory of relativity.

The theory of relativity and its extensions of string theories helped to describe phenomena that have nothing to do with gravity in strong fields, and the key factor was Ads / CFT correspondence, but this correspondence has not been demonstrated mathematically.

It is not known whether the string theory is true or not. It could be, but all the research that was done was based on certain conditions that describe universes similar to ours, so the equations obtained describe worlds similar to ours, but not identical. So string principles have been tested in limited cases to show the consistency of the theory.

If the string theory is assumed to be false, then the formation and vaporization of black holes could be described by unitary processes that follow the laws of quantum mechanics. Similarly, black holes described in the non-commutative geometry approach do not vaporize completely and therefore escape the informational paradox.

At first black holes were thought to be esoteric objects, but from the 1960s and 1990s they became quite irrelevant in the field of astrophysics. These are essential topics to be able to understand certain concepts such as quantum gravity.

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Chapter 4

The being is round...

Symbolic representations of the part and of the whole - the humanist spheres

When it is experienced from the inside, devoid of all exterior features,
being cannot be otherwise than round.

Gaston Bachelard

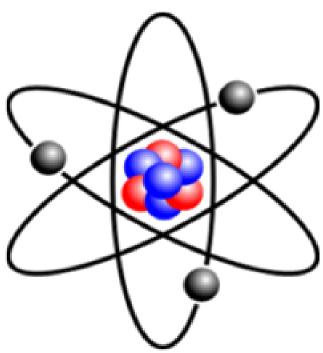
4.1 Objectivation and anchoring

Contrary to popular belief passed down through a narrow conception of rationality, science and myth are two systems of understanding the world meant to jointly provide an explanation of natural events based on causality. In both cases, there exists, therefore, a world order, which is often based on a "symbolic form", a direction taken by meaning, as Ernst Cassirer (2015: 234) puts it. According to this neo-Kantian philosopher, very close to the world of quantum physicists and especially close to Heisenberg, symbolic forms (and therefore meaning) denote an original activity, which cannot be derived from anything but the human mind: their reality does not exist beforehand, a symbolic form is not a reflection of an existing reality independent of it, but on the contrary, this reality becomes intelligible through a symbolic form.

The idea of the atom, its form and functions, concerns not only scientific thinking, but also common sense, which manipulates it to fit it in an intelligible manner, through the lens of social representations.

These cover all stereotypes, beliefs, opinions, mental images, knowledge, etc. shared by the individuals of the same social group, regarding a given object. Nevertheless, these elaborations are opposed to the constructions of the expert or of the scientist, states Christian Guimelli. In his opinion, "social representations are a privileged place where social thinking is expressed" (1999:63). But how could an academic, abstract elaboration, for example, on the atom - to focus on our original topic - conveyed by treatises, textbooks, websites, and other media, eventually allow knowledge of a social group? Through two processes, social psychologists explain: objectification and anchoring (cf. §6.3). In short, objectification makes it possible to simplify, to give concrete form to abstract theorizing in order to be able to integrate it into common sense. Anchoring leads to the establishment of the articulation of representation with the previous system of social thinking; in other words, it is the integration of new elements of knowledge into a network of existing categories more familiar to the group.

In this sense, Wagner and Hayes (2005), quoted by Bangenrter (2008), offer the example of atomic theory. The fact that the notion of atom has been circulating in popular consciousness for a long time has resulted in a shift in its meaning towards something more concrete: a small object, similar to a ball. Matter thus appears to be composed of a multitude of "beads." This representation constitutes the objectivation of the theoretical and abstract concept of the atom. It is shared by adults and even children in all modern societies (2008: 21). And thus, through translations and similarities increasingly distant from reality and through simplifications required by a general acceptability, the atomic model came to be anchored in a familiar, friendly and shiny structure, such as the Brussels Atomium.



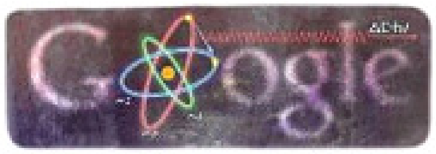
Bohr's atomic model

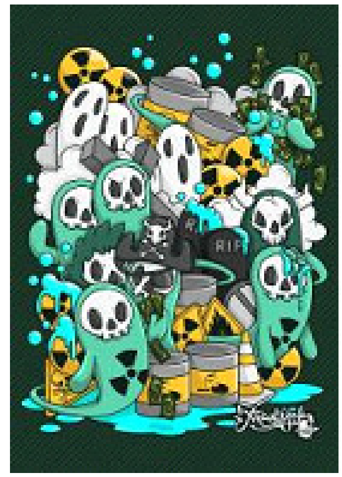
Atomium, Brussels

But before that, long before them, the artist builders and the scholars who imagined the iconographic program of the monasteries in Northern Moldavia, in what ways did they reach this information? How can we decipher, or at least explain the figurative presence of an “atom” on the northern wall of the Voroneţ narthex? It is not just an element of decoration, it differs from the other geometric representations, and it cannot be found it in any other fresco in the area. Maybe someone will one day try to decode it by opening the context of its production...

In addition to these figurative occurrences, the topic of the atom arouses the interest of artists, producers, media figures, etc. from all over the world, and their works fill our daily lives. As an example, we mention the song “Enola Gay”, a musical success from the ’80s, whose title refers to the eponymous plane that, in August 1945, dropped the first atomic bomb on the city of Hiroshima. Another song, by Moby, an American electronic music artist, is titled “We Are All Made of Star Dust” something that NASA has “verified” (at least in the literal sense of the word) with astronomers and scientists who have explained that the iron in our blood comes from explosions of archaic supernovae.

Another form of “anchoring” the atom in the collective mind is the evocation of Niels Bohr, every year, on October 7, the anniversary of his birth. Curious evocation, by the way, because, on that day, the search engines on the Internet dedicate a *doodle* to him, that is, a kind of scribble that somehow resembles his atomic model. In addition, we should mention the countless articles, stories and photo reportages, the interviews and documentaries that recount the nuclear and civilian facts. For example, one of the recent spectacular incidents, with universal media coverage, that of the Fukushima explosion, continues to sting the virtual creators.





Perhaps the most surprising, however, is the way in which the atom penetrated the sacred book of the Muslim religion, where the word is mentioned in several Quranic suras, but not in the context of any cosmogony or physical demonstration, but instead in moralizing contexts, with the most significant meaning of “the smallest particle known to man”. The Romanian translation, for instance, does not use it, preferring “dust”; in fact, the original Arabic term (*dharra*) is not directly translatable by “atom”, but this is how it appears in the English and French versions, at least. The metaphor of the atom resonates in the mind of the believer, telling him that every good deed, no matter how small, and that every mistake, even infinitesimal, will be reminded to its author on the day of the Resurrection: *Whatever you may be doing, and whatever portion you may be reciting from the Quran, and whatever deed you may be doing, We [Allah] do witness when you are doing it. And nothing is hidden from your Lord (so much as) the weight of an atom on Earth nor in heaven, not less than that nor more but is (written) in a clear record (on the Preserved Tablet).* (The Quran 10: 61).

4.2 The linguistic atom

It is also in the ancient Indian writings that we find the most interesting elements that introduce another line of reflection: the connection between the structure of language and atomism. The terms used by the Sanskrit language to describe atoms guide us to a conception of them as a subtle and fine “seed”. They appear as a measure of length or time, but none of the texts suggest that they are indivisible. The use of the terms *anu* and *paramanu* is implemented as an imperceptible unit on which all metric measures are based. We might indeed wonder what considerations led ancient Vedic phoneticians and grammarians to the need to introduce *paramanu* as an imperceptible interval between two phenomena.

Bhartṛhari is less well known than Pānini, although he was a fascinating personality. A grammarian, philosopher of language, a poet, born in the late sixth century, he is the author of numerous grammatical-philosophical commentaries, his best known text being *Vākyapadīya*, unanimously considered one of India's major contributions to modern linguistics. Although Bhartṛhari did not create a school of thought, he enjoys recognition beyond any doubt, and can always be placed alongside Pānini, Kātyāyana and Patañjali.

He is the first grammarian to have systematically combined two fundamental traditions of Vedic grammar: *śabda* or *prakriyā grantha*, specific to Pānini - the purely linguistic tradition, and *darśana-grantha* - the tradition with obvious philosophical inclinations. It can also be said with certainty that Bhartṛhari provided the oldest and clearest connection with the mystical tradition of *vāc* (the Word - Logos), which has survived in India since the Vedic period, a tradition that has been maintained before him, without, however, enjoying the role of *darśana* (which could be translated as "appearance, vision of the divine"). The system proposed by Bhartṛhari revolves around the eternal Logos, the Word, through his energetic monistic vision of the universe viewed as Brahman - the Essence-Principle - of the Word. The same view of the indestructible unity between the Creator and the created world, which we have found in cosmogonic and physics texts, is now illustrated at the level of word and language.

> The Brahman, the Essence-Principle of the Word, is the one without beginning and with no end, the indestructible syllable that manifests itself in the state of things, the one from which the world is produced. The one that is revealed as unique, being the bearer of many powers; although indivisible it appears to be divided, given its powers. [It is That] whose six types of changes, beginning with birth, reside in the power of Time, with overlapping parts, these being the sources of the various types of existence. That whose unity [Brahman], The One, the seed of everyone, that [is perceived] as existing in a state of multiplicity: in the shape of the experiencer of those experienced, and of experience itself.
>
> (BK I.1-5)

Bhartṛhari is certainly the first grammarian-philosopher to analyze language on at least two levels: language as an act of communication - speech with all its phonetic and normative particularities, historical evolution, and language as a principle. At the second level, the Principle of Language, the Word is nothing but the Ultimate Reality - Brahman. The universe in its entirety is a manifestation - transformation - its emanation. It sounds familiar to Christians, who are familiar with this first form of creation: "In the beginning there was the Word, and the Word was with God, and the Word was God," this is how the *Gospel of John* begins. And how can it not be so, when everything has been the same, together, since the beginning of time?

Bhartṛhari emphasizes more strongly the unity of principles - the premise and structure of his monistic edifice. The types of evolution and involution of the phenomenal world through the unfolding of Brahman's power-factors do not involve in any way any substantial change of the Ultimate Reality. The individuation and plurality of power-factors (*śakti*) emerge only at the moment of their manifestation and not at the moment of their pre-manifestation, when they are completely resorbed in the essence of the One.

The grammarian demonstrates that all knowledge is practically imbued by the word and, therefore, it is difficult to imagine knowledge that is not of a verbal nature. In this world there is no knowledge other than that which comes through the word. "Any kind of knowledge appears as if impregnated by the word" (BK I.131).

But Bhartṛhari goes a step further than his predecessors, showing not only the possibilities of language, but also the limits to which it, in its phonemic and mental aspects, stops to make room for supersensible, integrative knowledge. Interestingly, the two planes of knowledge are not mutually exclusive, instead complementing each other, because, for Bhartṛhari, the Word is the very ordering principle of the universe, Brahman himself.

The grammarian's vision is holistic. But he did not stop here, instead showing directly how the only possibility of understanding the communication mechanisms of language occurs solely at the level of the *phrase* - the minimal but also fundamental semantic language unit, he says, many centuries before European linguists. The existence of the One as a paradigm of the reduction of multiplicity and plurality is the invariable constant of Bhartṛhari's thinking. From the integrative intuition, which linguistically constitutes the meaning of the sentence, to the visualization of Brahman as the Essence-Principle of the Word, his system does nothing but capture the universally valid principle of the world's existence: that of a matrix that encompasses both potentiality and actualization.

Therefore, the meaning of a sentence is synonymous with the instantaneous awareness of unity, it is a holistic flash of understanding that occurs at a given time, while listening to words spoken in succession. Here, too, we encounter the systemic thinking that claims that the whole is more than the sum of its parts:

> When the meanings [of the word] are understood through separation [of words in the phrase], a meaning emerges, different [from the meanings of the words]. The one obtained through the meanings of words is called the meaning of a phrase.
>
> (*Vakyapadiya*, II:46)

A powerful propositional holist, this Bhartṛhari!

4.3 The point and the sphere

So far, we have discussed various symbolic representations (graphic or imaginary) of the ultimate, irreducible element in the composition of the universe and of man, and we cannot fail to notice the recurrence of round shapes: *point, circle, sphere, loop.* Whenever we look for a representation for the small infinity or for the greater infinity, the thought naturally veers towards them, as if there were an inherent pattern, a predetermination inscribed in our genetic data. Of course, there is also a principle of economy at work when choosing the sphere, for instance, as a symbol of the whole, because the sphere has the smallest surface area for a given volume, respectively the largest volume for a given area, being therefore the most small container for the largest content, if we can put it that way.

As for the point, it has also haunted the ancient and the medieval imaginary, practically all thinkers and writers were referring to it, to numbers and to the circle, when it came to the holistic expression of unity and multiplicity. The point, and every indivisible thing, is known through the negation of division, says Aristotle in *On the Soul* (1969: 31); the centre is the "beginning of the circle," says Pythagoras in the *Golden Verses* attributed to him; Dionysius the Areopagite, in a famous excerpt, commented upon throughout the Middle Ages, resumes this idea in the text *On the Divine Names*, identifying God with the One in whom all things pre-exist in a communion without division:

> And this is common and unitary to the entire Godhead, to make itself shared whole and entire by each of those that partake in this sharing and not one of these exists through anyone part. It is like the point in the middle of the circle, surrounded by all the circle lines.
>
> (Chap. 5, art. 6)

The Neoplatonist Proclus, in a Commentary on Plato's *Timeus* (II 72, 7 and 73, 26), "provides us with a philosophical, a physical and a mathematical motivation to explain the spherical shape of the world" (in Beierwaltes, 1988). The world "imitates the Spirit" and the intelligible has in the proper sense a spherical shape (Tim. II, 77, 16-18) The sphere is as symmetrical as possible, identical with itself, unitary (II, 73, 14), simple and, in conclusion, it is the shape in which the spirit more clearly reflects its own limit and beauty; being a creative and unity-giving power, the spirit has a spherical shape: "Being thus the spherical element, being one and at the same time able to embrace the multiple, it is what is truly divine: to not leave unity and to dominate in itself any multiplicity." (II, 72, 28-31)

In his turn, Plotinus considered that the One is entirely present in any intelligible reality and substantiates the infinite multiplicity of the intelligible sphere in the unity of the One, which is the essential premise of the text in the *Book of 24 Philosophers* (probably written in the twelfth century). Here we find a number of definitions of God that, for centuries, have played a considerable role in the imagination of theologians, philosophers, writers, scientists (especially the second one):

> I. God is the monad that gives birth to monad and which reflects in itself a single fervour.
>
> II. God is an infinite sphere, the centre of which is everywhere, and the circumference - nowhere.
>
> III. God is entirely in any of His own.
>
> (pp. 19-21)

Vasile Lovinescu says approximately the same thing in *The torn myth*, but in a much more enigmatic and poetic manner:

> [...] in order to escape the voracity of the cosmic vortex, one must, at the apogee, jump back onto the shore; in other words, one must discover new perspectives on the same thing, from a different point on the circumference.

And he continues by evoking the primeval matrix, the source of creative and unifying energy:

> The spheroid would be an amorphous mass, a chaos of discontinuous points, at an infinitesimal distance from each other, raw material in the full sense of the word, if it were not furrowed by Oneness, by tendencies in various directions, none similar to the other. It thus becomes the cosmos, the vibratory Vortex, the force field, which leads every possibility to its own completion [...]"
>
> (1999: 107, 110)

The circle is the symbol of the psyche (even Plato described the soul as a sphere) while the square (and often the rectangle) is a symbol of telluric matter, of the body, and of reality (Jung, 2017). In Freemasonry, the disciple's work is essentially an ego-centred activity descended to the Earth, which is symbolized by the terrestrial sphere, while an imaginary sphere whose centre is occupied by the Earth is called the celestial sphere. And *the squaring of the circle*, an insoluble problem in geometry, represents the dream of transmuting and sublimating matter for alchemists, the symbol of the reunion of spirit and matter in the same language. The circle is transcendent, the square is mundane, but as it rotates, it also becomes a circle, and therefore matter contains in its essence the potential to sublimate its own nature.

In turn, the neo-Kantian philosopher Ernst Cassirer, very close to the world of quantum physicists, especially to Heisenberg's theories, takes as reference the point in order to illustrate the relationship between part and whole:

> As the point is possible as a simple and unique situation only "in" space, that is, logically speaking, assuming *a system* of all determinations of situations, as the idea of the notion of temporal "now" allows to be determined only by considering a series of moments and the order and sequence of the successive we call "time", the same is true for the work-quality ratio. In all these relations, the determination and dismemberment of which are a matter of the special theory of knowledge, the same basic character of consciousness is shown: that here the whole is not obtained from parts, but that each setting of a part encloses in itself the setting of the whole, and depending not on its content, but on its general structure and shape. Each individual is here initially part of a certain complex and expresses the rule of this complex in itself. Only the totality of these rules realizes the true unity of consciousness as a unit of time, space, objectual bond, etc.
>
> (2015: 52)

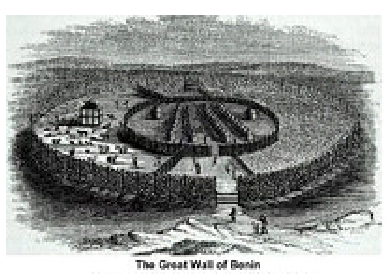
4.4 The *tondo* in art

Tondo is the euphonic abbreviation of the Italian word *rotondo*. It is an artistic style dating from the fourteenth century Florence (actually merely updated by the Italian Renaissance, as it has been known since antiquity), consisting of a profile carved very slightly in relief or painted on a round surface, or inside a disc, and has its origins in the custom of gifting a child at birth a round or oval plate made of painted wood. This probably explains the large number of Virgins with children painted on round canvases during the Renaissance, such as Raphael's famous *Madonna of the chair*. The painting of a *tondo* is a symbolic act, emphasizing the relationship with the matrix, or with the germinating cell, and evoking the perfection of the circle and the sphere, as the *forma mentis*. "The circle is the formal consequence of any act which has an origin and which, privileging a place, bestows on it the function of a centre" (wrote the Genevan critic Jean Starobinsky in his Foreword to Georges Poulet's *Metamorphoses of the Circle*, 1963).

However, not only the imagination of painters was shaped by this symbol of the universal perfection we carry inside us as aspiration, but also architecture, or, in a broader sense, the organization of human space. Of the many examples whose traces have come down to us, we will mention only two exceptional achievements, somehow similar in structure and time of construction, denoting a communication beyond the boundaries of time and place, a communion within the same expectation horizon. These are the Walls of Benin (the current capital of the Edo state of Nigeria) and the round city dreamed up by the Abbasid caliph al-Mansur.

Benin seems to have been built according to what we would call today a fractal layout - a complex, repetitive model, including similar models on an ever-smaller scale, up to the centre from which 30 streets fanned out. Four times larger than the Great Wall of China and consuming a hundred times more material than Khufu's Great Pyramid (as Fred Pearce informs us in *New Scientist*, 1999), the Walls of Benin surrounded an integrative urban and rural design, amazingly modern and efficient for the Middle Ages, but unfortunately largely destroyed by the punitive British Expedition of 1897.

As for ancient Baghdad, it is a miracle of a holistic vision in which the engineering genius is ideally combined with the business, aesthetic and spiritual requirements. For the construction of his new capital on the banks of the Tigris River, the caliph hired the most skilled astronomers and craftsmen from the entire Abbasid empire, raising in just four years a landmark in the history of city planning, a cultural archetype emblematic of all human civilization.



Benin's Great Wall (Nigeria, 8^{th} -15^{th} c.)
Baghdad (Iraq) The round city founded by caliph Al-Mansour (8^{th} c.)

We return for a moment to painting and its *tondo*, which helps us approach in a different manner Leonardo da Vinci's world - unitary, coherent and round. The great Florentine master knew all too well that the whole is One, and the parts that make it up exist only within and through him, expressing this reality in various ways. Above all, he sought to restore the unity of the world, an old principle at once visceral and rational, but also the structuring of this world into parts, as well as the relationship of these parts with the whole, a rather mysterious relationship of identity. "The part always retains in itself something of the nature of the whole. [...] Each part tends to reunite with its whole, in order to dispose of its own imperfection," wrote the brilliant creator in his notebooks (*Codex Atlanticus*, 59).

Let us take a closer look at *Salvator Mundi*, the painting on a wooden panel attributed to Leonardo da Vinci, discovered only a few years ago. The image of Christ making a blessing gesture with His right hand and holding a globe (*orbe*) in His left hand appears in the West towards the end of the Middle Ages, promoted first by Simone Martini, then by the Flemish painters. Leonardo's work has several remarkable features, two of which are illustrative of the Florentine's vision. We first notice a somewhat strange element, known in painting as *pentimento* (a word meaning "repentance" in Italian), which designates the emergence, in a work, of images or postures from previous versions of it, abandoned in the final form, as the author changed his mind, "repented" and made a change. A kind of pictorial palimpsest.

Prior to the unfortunate restoration made in 2011, Leonardo's Christ had a double thumb on His right hand. The very restoration of this extremely valuable and expensive painting was certainly done after consulting the greatest specialists in Renaissance painting, iconography, theology and painting techniques. Everyone saw there a genuine *pentimento*, that is, an "error", the mark of a change of perspective. Without getting into sterile disputes here, we raise only one (double?) question mark: knowing Leonardo's extreme meticulousness, his obsessive attention to detail, which made him work on a single painting for decades, is the hypothesis of a banal *pentimento* sustainable, especially considering the theological significance of the thumb, but also the symbolic symmetry with the globe in the left hand? The double human and divine nature of Christ, two in One, the Son who is inseparable from the Father and from all creation - ideally reunited in that *pentimento* - ties in perfectly with the second essential element of the painting - the transparent crystal sphere through which light passes without undergoing any significant refraction, which makes the sphere barely visible.

It is generally believed that the sphere represents the globe (it is true that in a world still dominated by the idea that the earth was flat, Leonardo intuited its sphericity, studying the horizon line and the curvature of the sea, as evidenced by some notes in his notebooks), but in fact, everything we know about Leonardo leads us to a much greater symbol, that of the whole universe, the circle/sphere signifying totality and perfection, a quality doubled here by the pure transparency of the crystal. In addition, this globe appears to be an empty sphere, with curious optical properties, functioning as a kind of magnifying glass and creating a distortion of the robe, a clear discontinuity, as demonstrated by a team of researchers from the California Irvine University, using infographic software to get a 3D reproduction of the image.

Salvator Mundi, *Pentimento*, before the restoration,
The perfectly round and transparent Universe in Christ's hand

Leonardo da Vinci, the epitome of the Renaissance Man, was an undoubted representative of holism, his entire creation and all his comprehensive research combining intuitive and scientific knowledge, realistic and esoteric vision. He had a universal program and global and complex perspectives, focused on the search for universalia and the creation of paradigms. He did not observe, he did not draw, he did not work on any part without understanding, without comprehending the whole. Thus, the elements of his paintings have an indisputable structural character. Leonardo was not content with narrow naturalism and realism, he wanted to understand the world in depth. His paintings are a synthesis of the image of the world and the universe, parts of which needed to be given depth in order to showcase their systemic relationships. Through abstraction, conceptualization, and construction, he operated a creative synthesis in order to develop a causal model and the theory of the relationships between the elements that made up his knowledge, works, and paintings. His warning, clearly noted in the Notebooks, was “Let no one who is not a mathematician read my principles!” Because only by analyzing his paintings as a beautiful mathematical demonstration can we understand their depth.

*

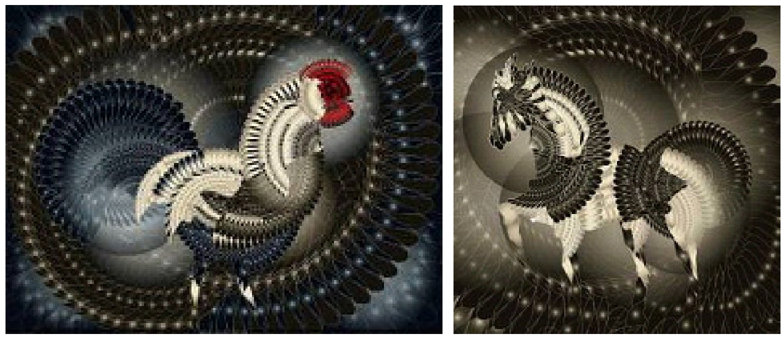
The dream of the circle as open circularity has permeated the centuries and the artists’ imagination. Here is what Kandinsky wrote in a letter to Will Grohmann, on 12 October 1930:

> You speak of the circle and I agree with your definition. It is a connection to the cosmos. But I use it “formally” [...]. Why am I so captivated by the circle? Because it is 1. the most modest form, but asserts itself unconditionally, 2. a precise but inexhaustible variable; 3. simultaneously stable and unstable; 4. simultaneously loud and soft; 5. it has a single tension that carries countless tensions within it. The circle ... is the synthesis of the greatest oppositions. [It] combines the concentric and the eccentric in a single form, and in equilibrium. Of the three primary forms [triangle, square, circle], it points most clearly to the fourth dimension.

Vassili Kandinsky, sketch for *Several circles*


Vassili Kandinsky, *Blue circle*

... and the endless recursivity of fractals. The painter and sculptor Jean-Claude Meynard works using “the fractal principles of expansion, saturation, interlacing, simultaneity of scales, hybridizations and infinite networks” (2018: 12), according to a fragmentation geometry, creating structures without centre, and asking, visually, fundamental questions about the existential game with shapes, about the multiplication of the self: "At what precise moment does the player play? At what precise moment does the «I» exist?" (2018:61)



Jean-Claude Meynard, *Fractal bestiary*

The current interest in the fractal dimension of the human sciences is unquestionable, and for those who seek them, there are countless examples regarding the relationship between visual artists and the circle, the sphere, the One in worldly manifestation...

4.5 The point at the centre and literature

At the end of this frustratingly short and inexhaustive foray into the world of fundamental symbols and of the smallest universal structures, let us review a few literary reflections on these issues that have always badgered inspired and fertile imaginations.

When Dante describes divinity, in the last songs of *Paradise*, he chooses the point as an illustration of the universal order in the thought of God, before unfolding into creation: "The wain, that, in the bosom of our sky, / Spins ever on its axle night and day" (Canto XIII); "looking at the point whereto / All times are present," (XVII); "Here is the goal, whence motion on his race / Starts; motionless the centre, and the rest / All mov'd around. Except the soul divine, / Place in this heav'n is none, the soul divine, / Wherein the love, which ruleth o'er its orb, / Is kindled, and the virtue that it sheds; / One circle, light and love, enclasping it, / As this doth clasp the others; and to Him, / Who draws the bound, its limit only known" (XXVII); the radiant point of God, the light before creation ... "a point I saw, that darted light / So sharp, no lid, unclosing, may bear up / Against its keenness." (XXVIII); "Deeper into the truth, wherein rest is / For every mind.."

(XXVIII); "Beyond time's limit or what bound soe'er / To circumscribe his being" (XXIX) "... the point, / That overcame me, seeming (for it did) / Engirt by that it girdeth."(XXX).

In the strange and complex philosophical poem of the Renaissance writer Maurice Scève - *Microcosme* - for the reading of which many keys are needed, there is a line, the first in fact, of exceptional conciseness and plasticity, which may very well represent a synthesis of all these ideas: "The first in his shielded Nothingness was hidden in his Everything", a concentrate of the equivalence between Nothing - the full void - and Everything, therefore the whole still unfolded in creation. The theory of the wrapping and unfolding of the world, of the implicit and explicit order that David Bohm would develop (and which is discussed in more detail in Chapter 2) is fully contained in this line. It is another way of formulating the Pythagorean and Plotinian monad, it is the point from which matter, time, space will spring. "The essence itself full of latent infinity" - this is a definition of the vacuum, offered by the same Scève, five hundred years before today's equations and experiments came to demonstrate what, through intuitive knowledge and instantaneous connection to the imaginary, to the *akaşa*, poets, like artists, had accessed it on a different path.

Surprisingly many medieval or Renaissance texts address this major cosmogonic issue with unexpected intellectual ease and synthetic force of expression. For some authors, such as the poet and scientist Guy Le Fèvre de La Boderie, the only topic worthy of approach is that of the sphere whose centre is everywhere, and the circumference nowhere. Here is another example that, beyond prosodic harmony and Platonic allusions, could have confidently competed even with the likes of Niels Bohr:

> ... to penetrate the deep infinity that swirls at its centre.
> Its centre moves inside it, but it does not budge,
> What we call Universe is the Point of its Centre:
> And how does fold into itself
> The ungirded Circle girding the Encyclia?

Paradoxically (for us, maybe, but not for them!), God is at the same time the centre from which the universe emerges, but also the infinite sphere that contains Him as a point. In the line of Nicolaus Cusanus, God is also the conceivable minimum, i.e. the point, but also the maximum, respectively the sphere. The circumference is equal to the centre and each point of the sphere *is* the centre. As Georges Poulet summarizes, *the final God is identical with the original God.* A starting point, the centre / point is also a point of arrival.

Almost no one today is familiar with these genuine “universal people” of the Renaissance, an age in which all science, all forms of creation and knowledge intertwined and grew organically, without the hiatus introduced by the Age of Enlightenment and constantly aggravated ever since. Obviously, the amount of specific knowledge, or the variety and refinement of current research tools and methods, can hardly be compared with those existing at that time, but do we really have the upper hand from this perspective? Does the fact that I have acquired an almost perfect knowledge of the fragment compensate for the loss of the bigger picture, of the feeling of belonging to a fabulous network of structures, to a whole?

Cyrano de Bergerac’s universe (*L’autre monde / The Other World*, 1657) consists of an “infinity of small invisible bodies” having as features solidity, incorruptibility and simplicity. In this science-fiction novel, Cyrano resumes many of Lucretius’ arguments from *De rerum natura*, but without following the line of the classical Greek vision, which rejected the vacuum as uninteresting, even frightening nothingness. Cyrano’s man is no longer at the centre of the universe, but, on the other hand, he lives in an infinite universe where matter made up of atoms can take on an infinity of shapes and where he is offered an infinity of possibilities.

The character Dyrcona, who travels to the Sun and then to the Moon, states that near the hot star, the Icosahedron, his spectacular ship, which is an ingenious assemblage of mirrors, vessels and spheres, slows down: “... because of the serenity of the ether which became more rarefied as I approached the source of daylight; for matter, at this altitude, is very much thinned by the great vacuum of which it is full, consequently this matter is very lazy because of the vacuum, which does not act.” (44)

Indeed, the entire text, almost unread today, of *The Other World* provides not only an atomic theory, but also a kind of “experimental proof” of the existence of vacuum!

The vision of the intelligible sphere, without boundaries and end, which generates multiplicity and which, in a second movement of the cosmic motion, absorbs creation in its centre, continued into the next century, but man is increasingly present in the equation - in his turn centre and point, like the Creator. It is also interesting to evoke the progressive union, of the reunion in fact, of the soul with the Nothing-All, with the One-Point, which we find in the work of poets as well as of theologians and of scholars. For example, Pastor Jean de Labadie, also in love with the symbol of the infinite sphere, wrote:

In a perfect circle, with no beginning and no end,
Which, without a circumference, has its centre everywhere:
It has everything, it is everything, nay, it is the ultimate Everything,
Which, without being anything is Everything, it is but the Being itself.

Nevertheless, the eighteenth century comes with a level break, and the centres, circles and points of the predecessors are passionately mocked by the Enlightenment generation, so that they lose their prestige and transcendent symbolic force, soon becoming unintelligible, or mere secular symbols of scientific systems, such as the Cartesian and Newtonian ones, and then of the entire industrial era that followed.

And yet, we cannot detach ourselves, temporarily, from this brief evocation of poet-philosophers without mentioning Eminescu and his insightful verses in which shines, refined, the ancient wisdom of the Rig Veda, X (*The Hymn of Creation*, which he had in fact translated, in order to always have it at hand):

THEN was not non-existent nor existent: there was no realm of air, no sky beyond it.
What covered in, and where? and what gave shelter? Was water there, unfathomed depth of water?

(*Rig Veda*, tr. by Ralph T.H. Griffith, [1896], at sacred-texts.com, *HYMN CXXIX. Creation*)

Back through thousands upon thousands of hoar ages
To the very first, when being and non-being were nought still,
When there was but utter absence of both life-impulse and will,
When unopen there was nothing, although everything was hidden,
When, by His own self pervaded, resting lay the Allforbidden.

First Epistle, translated by Leon Levitchi)

The echoes between the two visions, so similar to each other, connected through utterances seemingly separated by eons, continue in a similarly spectacular manner in *A Dacian's prayer*:

When there was no death, nor immortality,
Nor any seeds of light for life's entity,
There was no today, or tomorrow, yesterday, or forever,
Because life springs from one and everything was together

(*A Dacian's prayer*, translated by Brenda Walker)

mirroring the second verse of the *Rig Veda*:

> Death was not then, nor was there aught immortal:
> no sign was there, the day's and night's divider.
> That One Thing, breathless, breathed by its own nature:
> apart from it was nothing whatsoever.
>
> (*Rig Veda*, tr. by Ralph T.H. Griffith, [1896], at sacred-texts.com, *HYMN CXXIX. Creation*)

All further comment seems to be superfluous...

4.5.1 Fractal literature

There is even a fractal literature, one that multiplies the linguistic signs into an order of words, as if it were a game of mirrors looking for a dynamic in the heart of infinity, the most accessible form being the labyrinth or the circularity. In other words, namely in those of Spanish critic Alberto Viñuela (in *Literatura fractal*, July 29, 2001), starting from Lucca Paccioli and his first evocation, in 1497, of the "divine proportion", or "golden ratio", fractal literature is the one that manifests itself in a manner similar to that of fractal objects, focusing mainly on recursive elements, i.e. those that refer to their own features. Literary fractal incarnations are innumerable, from tautologies to cyclical stories, from "nested boxes" to space-time games, to the "1001 nights"... If we accept the hypothesis that the literary text is a nonlinear (chaotic) dynamic system, then we must also take into account the last element of chaos theory, namely the strange attractor or the fractal attractor. We know that Edward Lorenz demonstrated in 1963 the importance of the principle of "sensitivity to initial conditions" by introducing the concept of attractor, to which David Ruelle would associate the epithet "strange". We recall quickly that the attractor is applied to any system close to equilibrium, while the strange attractor characterizes a dynamic system, in which it does not correspond to a point or a line, but to a dense set of points found throughout the region, a set which can be assigned a "fractal" dimension. (Ilya Prigogine, Isabelle Stengers, *La nouvelle alliance : métamorphose de la science*, 1986).

But what exactly works as a strange attractor in the novel-system? According to Noëlle Batt, it coincides with the meaning itself, viewed as a trajectory that "crosses at one time or another all levels of the text and is elaborated through internal and external transcoding" (*Dynamique littéraire et non-linéarité*, 1999: 197). Fractality thus allows the modelling of the connection between the various partial similitude ratios disseminated in various levels of the text, referring to a dynamic of its generation, rather than to a static arrangement of isolated features.

There are plenty of examples, but we shall cite only two of the most illustrious in world literature and one in Romanian literature: Franz Kafka, Jorge Luis Borges and Mircea Cărtărescu. Kafka's *Trial* and *Castle* are written under a manifesto fractal dominant. In both works, the inability of the individual to overcome the absurd mechanisms of bureaucratic power makes him take an oblique path in order to solve never-ending problems, repeating himself and wandering around a legal labyrinth. Like Mandelbrot's fractals, we start from a specific point in space and time, the elements generated by the impossibility of overcoming the system being reiterated and multiplied indefinitely. The fractal progression of absurdities determines a complex system whose main feature gave rise to the epithet "Kafkaesque". Kafka is unique and can be formalized as a model precisely because he does not choose the false, easy, territorializing path of criticism, of mimetic representation. In "major" literature (Gilles Deleuze and Félix Guattari, 1975), the fracture of languages is resorbed into symbolic language.

As for Mircea Cărtărescu, the complex novel *Orbitor / Blinding* allows the identification of the butterfly pattern at every step. Thematically and structurally, any tiny wing flap triggers a fabulatory-fractal, seemingly chaotic tumult of memories and projections, and the entire architecture of the novel is based on the almost infinite multiplication of the butterfly effect, each time generating different levels of reality. As in Zhuāng Zhōu's famous parable: the sage dreams that he is a butterfly, and when he wakes up, he wonders if it was a butterfly that dreamed it was Zhuāng Zhōu. And if it flutters its wings as well, it changes the initial conditions of the whole system and can become a perpetual strange attractor.

Among the mechanisms that allow the confirmation of this principle, the *mise-en-abîme* probably most clearly illustrates this equivalence between part and whole. Defined by Lucien Dällenbach as an "internal mirror that reflects the whole story through simple, repeated or specious reduplication" (1977: 52), the , the *mise-en-abîme* is a metaphor with a summary effect that Philippe Daros sees as a "game with specific topological character "(in *Littérature, Modernité, réflexivité*, 2002: 157). Designed as a relationship between the whole and its constituent parts, this topological game forces the reader to reconstruct the relationship between subsystems and the novel-system as a whole, in order to perceive the effect of its meaning, as long as any small change in the subsystem causes changes throughout the text.

Studies on the relationship between literature and fractality have often emphasized the need to consider fractality in its metaphorical sense, that of multiplying the same topic in various ways. Thus, if the fractal object is "the reunion of a (finite) number of copies of itself on a lower scale" (Alain

Boutot, *L'invention des forme: chaos, catastrophes, fractales, structures dissipatives, attracteurs étranges*, 1993: 31), then the novel, as a chaotic system, shares the same principle, because its elements respond to different scales (language, history, utterance, enunciation, style). There are indeed several data regarding the author, the reader, and the text that allow a fractal nature to be attributed to the novel. The author, considered a subject without a stable identity, finds in the literary creation his projective elaboration, because he changes within and according to his creation; the readers, through the act of reading, construct their own textual object starting from the discontinuity of morphemes, semes and various signs; Finally, in the text, the analogies, the *mise-en-abîmes* and the associative phenomena cause the novel to gave a fractal nature and confirm the principle of self-similarity.

Whereas the main forms of identity constructions remain relatively stable in theory, as a concept, identity must always be specified, because it designates a plural and complex principle. And here, the rhizome theory, developed by Deleuze-Guattari in *Mille plateaux* proves to be useful:

> Let us summarize the principal characteristics of a rhizome: unlike trees or their roots, the rhizome connects any point to any other point, and its traits are not necessarily linked to traits of the same nature; it brings into play very different regimes of signs, and even nonsign states. The rhizome is reducible neither to the One nor the multiple. It is composed not of units but of dimensions, or rather directions in motion. It has neither beginning nor end, but always a middle (milieu) from which it grows and which it overspills. It constitutes linear multiplicities. (1980: 31)

Any literature that is worthy of this name does not cultivate genealogies and lineages, but rather networks of intertexts and hypertexts, open or unconsciously activated, fact that essentially changes the perspective on the topology of the ego.

In their own way, each of these writers challenges their own perception of reality and, starting from there, of our personal reality. When, for various reasons, this is difficult to accept, self-fiction as a fractal multiplication of the ego is a handy emergency exit.

"Reality is plastic", stated the transdisciplinary physicist and essayist Basarab Nicolescu, in the volume *Ce este Realitatea*? / *What is Reality?* (2009) The work of Cioran, in its turn, lends itself perfectly to a quantum approach, starting from the idea that the whole reality is an eternal oscillation between actualization and potentialization. Contemporary scientists and epistemologists share this belief: there is no absolute actualization. Heisenberg, for example, in agreement with Husserl, Heidegger, Gadamer and Cassirer, has always stated that this rigid and artificial distinction between subject and object must be suppressed, that the privileged reference to the exterior of the material world must be abandoned and that the only possible way to approach the meaning of reality is to accept a vision - not a binary one, as in classical logic - but a ternary and multiple one, the idea of "levels of reality" being indispensable for the perception of such a complex phenomenon.

A dislocated, staggered identity, as found in Cioran's works, reveals ourselves attached to our avatars, not only because we have created them, but because they give us that immersive illusion of immersion in a in-between, in a non-place, a space of absolute freedom, which the Euclidean and Aristotelian everyday setting forbids us to have. Cioran prefers to slip between labels, to know himself in the impossibility of a global, unitary comprehension, ignoring his fractality in the sense of self-similarity and infinite repetition. With him, we are simultaneously "inside" and "outside" the personal universe, hence a kind of bi- or plurilocation and duplication of the subject, according to a "fissional" logic, as J.-C. Kaufmann calls it (2004). "I become de-individualized as we speak," states Cioran. "Let us be done with this old Self!" (*Cahiers*, 2009: 133) And the frontier of the real world no longer seems to be the final frontier... We can speak of fractal, therefore, as a preservation of the open possibilities of encounter, of "assembly", of enunciation-production that are singular, multiple, unpredictable, non-predictable. But the fractal also refers to the meaning of fracture, of fragmentation, in which, however, each particle contains the key to the structure of the whole. To speak in Deleuze and Guattari's terms, the fracture deterritorializes the self, giving it the appearance of fragmentariness, while the fractal reterritorializes it into the One, in the rare moments when the intuition of totality flashes into view.

Although contemporary generations have laid the scientific foundations for these intuitive perspectives, they have long travelled through the common flow of our imagination, as it is splendidly illustrated by one of the most dense and insightful literary writings, *The Conference of the Birds*, by the Persian Sufi poet Farid Attar (12^{th} century). The title refers to a passage in the Qur'an that indicates that the prophet Solomon was given the privilege of understanding the language of birds, that is, that of the whole creation and of the inner being of the set of living beings that compose it: each of them then became for him an open book that reveals the intimate secret of its being , making it thus possible the deciphering of all symbols and the revelation of the mysteries of creation.

This story is a true mystical epic that recounts the birds' search of their king, Sîmorgh. It should be noted that traditional Persian tales often play with the meaning of the prefix “si-”, which means “thirty”, in order to suggest that this king would be as large as thirty birds together - “morgh” meaning “bird” - or that its plumage would include thirty colours. Iranian legends say that Sîmorgh lived long enough to witness the destruction of the world three times. Besides, his long existence would have allowed him to gain access to the knowledge of all ages and, in certain mystical accounts, to high theosophical knowledge.

So thousands of birds travel for years through almost inaccessible regions. Most die on the way, and only thirty birds reach the end of their search and can contemplate the sublime bird. At this precise moment and through the subtle resumption of the above-mentioned pun, Sîmorgh becomes the mirror of these *sî-morgh* (“thirty birds” in one) who discover that they have, in fact, sought the innermost secret of their own being. At that moment, as Henry Corbin analyzes, “*when they look at Sîmorgh, they really see Sîmorgh. When they contemplate themselves, they again contemplate Sî-morgh, thirty birds. And when they look at both simultaneously, Sîmorgh and Sî-morgh are one and the same reality. Indeed, Sîmorgh appears twice, and yet Sîmorgh is unique. Identity in difference, difference of identity.*” (1991:197)

The multiple birds embody the captive soul, which has lost its memory of its eternal state. Sîmorgh embodies the figure of the Holy Spirit and the angel of humanity, a mesenger of the higher worlds to guide each pilgrim in his search and his understanding of high spiritual truths. Sîmorgh is therefore here the Face or the interface through which the divine manifests itself to man. And we believe that this symbol can be introduced into an open equation, which is suggested to us not only by the meaningful tales of many ancient civilizations, but also by some convergences of artistic representation, thousands of leagues apart (a visibly inconclusive distance): Sîmorgh = The Holy Spirit / Archangel Gabriel (this is how it appears in the works of the Persian mystical philosopher, Attar’s contemporary, Sohrawardî) / Angel of Revelation = Phoenix...

Corbin even draws a parallel between the end of this mystical epic and the thinking of certain great Western mystics, such as Meister Eckhart, who, in the same respect, stated that “The gaze by which I know Him is the gaze by which He knows me”. And the search for Sîmorgh through the seven quantum valleys, in which it is at once day and night, hot and cold, “here” and “there”, is, ultimately, the image of an inner adventure, equally individual and collective, through which we understand, once again, that we are all in One, but also that One is more than the sum of its parts...

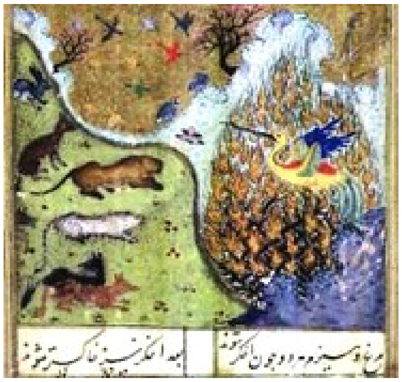



Illustration to *The Conference of the Birds,* Iran, 15^{th} c.
Voroneţ Monastery, Doomsday Judgement, 15^{th} c. (detail)

The fifth valley or the valley of Unity (Tawhîd)

> The Hoopoe continued: "You will next have to cross the Valley of Unity. In this valley everything is broken in pieces and then unified. All who raise their heads here raise them from the same collar. Although you seem to see many beings, in reality there is only one — all make one which is complete in its unity. Again, that which you see as a unity is not different from that which appears as number. And as the Being of whom I speak is beyond unity and numbering, cease to think of eternity as *before* and *after*, and since these two eternities have vanished, cease to speak of them. When all that is *visible* is reduced to nothing, what is there left to contemplate?"
>
> (1999: 180)

Leaping over time - we have learned to do it! -, the most exciting literary exploration of fractality, quantum principles and the spherical One seems to be the creation of Jorge Luis Borges. His entire literary universe subsumes, to varying degrees, to a fractal perspective. In his texts we find immortal characters everywhere, memories that subsist outside the body that generated them, labyrinthine buildings, impossible to comprehend within the Aristotelian logic, cyclical books that end where they begin and come apart in time, areas where the whole cosmos focuses in various configurations of mirrors and reflections, games with time and space - a fractal gaze that recreates a new dimension of reality, changing the canons and conventions of the classical waiting horizon. For example, Borges' story *The Garden of Forking Paths* is based on an old Chinese novel, a metanarrative pretext for a vision of the temporality of history, time itself being the main theme of the story. The fractal interpretation is favoured by the fact that time denies its linearity, spilling into a number of potential universes.

Borges experienced eternity in life. He called it "Feeling-in-death" and it came to him as an immediate intuition of himself out of time (Yankelevitch, 1998: 198) To Russell's paradox of the set of all sets that cannot contain themselves as an element, Borges responds by developing a catalogue that would contain pure singularities of space and time, taken absolutely at random not only from finite sets, but from the continuum. Borges's reaction has to do with the ability of the word to name what has not existed yet, not so much the things that exist before their naming, but rather those whose naming causes them to exist. By proclaiming the supremacy of the unreal over all ranks of reality, he shows that this capacity for reference of words resides neither in us, nor in them, nor in the definitions, uses, and objects that seem to saturate it. There is a constitutive vacuum, argues the Argentine writer, between language and word, which forces us again and again to dig, to carve, in order to give each word a new use, another definition or occurrence. What the poet does with a language brings to the surface a property that belongs to language, but that people, in general, have forgotten. Somewhat similarly, A. De Waelhens wrote: "Through the word, the subject frees himself from the oppression of the thing, distances himself from it and thus elevates it in itself, as it presents itself to itself from it. But the word also concerns the thing and thus makes it present in its absence." (1966: 378.)

Out of a passion for mathematics and the language of numbers and shapes, Jorge Luis Borges thus invented the Babel Library, a space-universe composed of hexagonal pieces projected to infinity, or "Cipher", a kind of code or unit in which the universe can be reduced to a single element that encompasses and explains it, finally transposed in literary terms the principles of the cardinal equivalence of *aleph zero*, thus baptized by the brilliant mathematician Georg Cantor.

In one of his short stories, *The World Congress*, the main character finds that this congress exists, but that it is made up of every individual, of every plot of reality, of every event. In fact, there is no representation of the world that does not require every atom in this world, but at the same time, every atom is a particular form of representation of the whole. The same way the unique book Borges dreams of consists of all the books in the world, but it is contained in every word and in every letter of every word... In all his writings, the narrative framework seems to weave the relation between the same and the other by raining he issue of the one and the multiple.

In *Aleph*, Borges the character is invited to admire a magical object in which space and time are condensed. Aleph is infinite in its content, finite in its external form: the diameter of the Aleph must have been two or three centimetres, but it is "one of the points of space that includes all the other points" (p.160), a point where all points converge, as in a black hole, a point containing the entire universe, the microcosm of alchemists and Kabbalists, *multum in parvo*:

> Mystics, faced with the same problem, fall back on symbols: to signify the godhead, one Persian speaks of a bird that somehow is all birds; Alanus de Insulis, of a sphere whose center is everywhere and circumference is nowhere; Ezekiel, of a four-faced angel who at one and the same time moves east and west, north and south. (...) Really, what I want to do is impossible, for any listing of an endless series is doomed to be infinitesimal. In that single gigantic instant I saw millions of acts both delightful and awful; not one of them occupied the same point in space, without overlapping or transparency. What my eyes beheld was simultaneous, but what I shall now write down will be successive, because language is successive. (...) Each thing (...) was infinite things. (p.164)
>
> In the words of Cantor, the mathematician Borges was fascinated with, "the universe is made up of an infinity of points", and "the most infinitesimal point in the universe is symbolic for the macrocosm". Like all perfect things, Aleph is also round: "a small shimmering sphere, of a dazzling radiance," and "the outer space was whole there" (p.164)

Why Aleph? Borges also explains the reasons for his choice:

> For the Kabbalah that letter signifies the En Soph, the unlimited and pure deity. It is also said that it has the form of a man who points to the heavens and to the earth, indicating that the earth below is the mirror and map of the heavens above. For *Mengenlehre* it is the symbol of the transfinite numbers, in which the whole is not necessarily greater than each of its parts. (p.168)

In the field of the mathematical transfinite, as in the field of the theological transfinite, the part is equal to the whole.

Aleph, the first letter of the Hebrew alphabet, is also a symbol of unity. This object, which, like a library or a book, contains the entire universe in an enclosed space, goes further than the latter. Aleph, unlike the library, has no extension: it is a point, not a structure. This point contains the infinity of space, being at the same time non-spatial (because it is only one point) and also contains eternity, because it contains simultaneously all the points of the universe at any given moment of their evolution (eternity contains all the moments of time, but it is atemporal). This shape is the supreme example of Borges' dream of escaping from the extent of space and from the sequence of time:

> Let us examine the present moment. What is the present moment? It is the moment consisting to a certain extent of both past and future. The present itself is like the finite point in geometry. The present itself does not exist. It is not an immediate given of our consciousness. Well, we have the present, and we see the present gradually turn into the past, into the future. There are two theories of time. One, which appears to me to be accepted by everyone, perceives time as a river. Time flows from a point of origin, an unknowable originating point, and gets to us. We also have another theory, formulated in the metaphysics of the British philosopher James Bradley. Bradley posits that what happens is precisely the opposite: that time flows in the reverse direction, from the future to the present. That this moment in which the future becomes the past is the moment we call the present. We can choose one of these two metaphors. We can place the source of time in the future or in the past. It is all the same. We always have before us the river of time.
>
> (*Time*, 2012: 431)

One of the most surprising approaches to the story is found, however, in Floyd Merrell's original approach, *Jorge Luis Borges, Mathematics and the New Physics* (1991). In this complex study that combines literary analysis with cutting-edge scientific theories, Merrell argues that *Aleph* dramatizes the discovery of what physicists call a space-time singularity: a point in the universe where a star collapses and "the limits of space and time have been reached". In the sixth chapter of his book, "What is Real?", Merrell briefly discusses the development of quantum theory, especially on the subject / object issue. It is the cornerstone of classical physics, which has been virtually eliminated from the new physics. Due to the impossibility of a strong separation between the behaviour of subatomic particles and the interaction with the measuring instruments that serve to define the conditions in which the phenomena occur, the subject / object separation proves to be no longer acceptable. As Merrell points out, this idea began in contemporary science with Ernst Mach and is explicit in Fritz Mauthner's critique of language. Merrell draws parallels between the "idealistic" strain of quantum theory and the "idealism" of the Tlönians in Tlön, between the short story *Uqbar, Orbis Tertius,* as well as between the role of probability in quantum theory and Borges's *Lottery in Babylon.* Merrell later compares the so-called "multi-world interpretation" of quantum mechanics, where the universe constantly forks into an extraordinary number of branches, to the image of Pen's Ts'ui's temporal labyrinth, described in Borges's *Garden.* He also compares the notion of intertextuality in *Pierre Ménard, author of the Quixote* by Borges with the theory of David Bohm, according to which each member of the whole is related to any part of it and to everything else, in fact.

Equally exciting is the comparison of symmetries and asymmetries in Borges's texts with the "broken symmetries" recently discovered at subnuclear level, which, Merrell explains, apparently disturbs the belief in a perfectly harmonious universe. The realist-nominalist controversy seems to take on in Borges's writings "a form of linguistic idealism according to which we are suspended within the limits of language, unable to go beyond the limits with which we must operate" (1991: 209). In Borges's writings, reality becomes a purely mental construction, and language is the mediator through which it approaches reality: the Dream precedes the world, in Borges's vision, and words can only mirror and, at best, reflect us.

Mircea Eliade believed that the principle of the identity of a being with the archetype abolished time as a gesture made by a man, becoming mythical, inscribing man in the same eternity as the gesture. This cyclical philosophy is set forth in Borges's *A History of Eternity.* It is attributed to Nietzsche and is described in these terms: "The number of atoms that make up the universe, although excessively large, is limited and capable [...] of a limited number of combinations (though too large). In an infinite time, a number of possible combinations must be reached and the universe must absolutely repeat itself." (2006: 404)

The notion of archetype derives from the human propensity for using the same form of psychical representation given a priori. The archetype can thus be considered as a "form of thought" that already exists in a human collective, being even a founding principle of its tradition. We could say that the archetype acts as an attractor of any other "form of thought" that approaches it. Throughout the literature that we would call "fractal", acausality occurs, the still-unknown mechanism that tends to synchronize events connected through meaning (archetypal resemblance) rather then through cause.

Theatre is also adapting to the new perspectives. "We have to cultivate our fractal," says Fanny Soriano in the dossier created for the play titled *Fractals*, staged in Marseille in January 2019, inviting viewers to take a fresh look, unrestricted by clichés and conventions, at artistic expression, and providing an extremely rich document on fractals. The dossier states that: "*Fractals* challenges us on the tension between a liberating chaos and the cycles of life ... Obsessive, hypnotic, repetitive, unpredictable [...]. *Fractals* also urges us to rethink the fracture between order and chaos." (2019: 7)

Such questions are taken even further by the remarkable Lebanese writer Wajdi Mouawad, an émigré to Canada and therefore a person deeply concerned with the issue of identity, speaking openly about an "wave-like identity" of the individual, composed of an infinity of fragmentations and defragmentations (*Leçon de Wajdi Mouawad*, 2009). In the play *Incendies*, the main character is a mathematics teacher, Jeanne, who promises her students that this exact science will change the way they look at the world: "Welcome to the world of pure mathematics, that is, to the land of solitude", she tells them. We saw in Chapter 3 that this is not the case. In fact, when Jeanne answers in the affirmative to a student who wanted to know if one plus one can make one, she evokes the Syracuse conjecture and the hypotenuse writing, in which everything leads to one, but a One full of all the multitudes that are within it:

> There is a very strange conjecture in mathematics. A conjecture that has not been proven yet. Pick a number, any number. If it is an even number, we divide it by two. If it is odd, we multiply it by three and add one. We do the same thing with the number we have obtained. This conjecture states that no matter the number you start from, you always arrive at one.
>
> (2009: 121)

*

If we look more closely at this issue, we shall find that the "struggle" of literature with the collapse of the wave function of the word is much more extensive and richer than it appears to be in a superficial examination. Let us recall some of the most striking narrative illustrations, which we have read, perhaps with an obvious bias, convinced that we were dealing with (science-) fantasy, although their semantic reverberations are infinitely more complex.

How many of us have thought, for example, while watching the cult film *Matrix*, about the famous and controversial brothers Igor and Grichka Bogdanov, rebellious scientists and visionary writers, authors, in 1980, of the cult novel *La Mémoire double*, recently republished in France? What if they were right ahead of everyone else? The Bogdanov brothers claim that the directors of the film Matrix plagiarized them, and they have plenty of arguments. In their novel, the main character, Antoine, lives simultaneously in the country, in the Gascony countryside, and in a virtual world - the Matrix. The whole plot takes place under the auspices of quantum physics.

Indeed, Pierre Bayard, a professor of literature at the University of Paris VIII and a psychoanalyst, tries to do them justice - and not just them - in an exciting essay published in 2014, *Il existe d'autres mondes* (*There are other worlds*), dedicated, not coincidentally, to Schrödinger's living-dead cat. The text aims to study the influence of quantum theories on literature and to demonstrate that the hypothesis of parallel universes can prove to be an unexpectedly rich decoder for reading and understanding the world and the self. Bayard is convinced that physicists are not wrong when they say - at least some of them do - that we actually exist in a multitude of copies, in a plurality of universes, and that writers are more sensitive to the idea of alternative worlds, which they translate into art.

He would not be contradicted in any way by Haruki Murakami, the great Japanese writer for whom living in parallel realities runs as a constant throughout his novels. For example, *Hard-Boiled Wonderland and the End of the World* take us simultaneously through two parallel worlds, starting from the idea that each of us shelters, in the depths of our consciousness, a nucleus whose content we ignore. First, we see a city surrounded by thick walls, from which people cannot get out. Only unicorns can, and they vacuum up the ego and personality of the inhabitants, in order to take them out of the city. Meanwhile, in Tokyo, in the underground laboratory of a secret building, someone has to disrupt a computer program at the request of the old scientist who invented it. A seemingly trivial mission, but one that plunges us into abysses haunted by "INKlings" and "nerves." At the same time, in the fortified city, where there are neither tears, nor joys, a man separated from his shadow must read dreams from the skulls of unicorns. Between this hard-boiled wonderland and the place at the end of the world, perfectly antinomic in appearance, circulate fleeting thoughts, but also tangible objects, which seem to indicate that the realities and dreams of the two space-times coexist and that the two people might in fact be only one.

Obviously, theories about parallel worlds have long fed fiction, but until recently, they have led it towards the SF literature aisles of major bookstores. However, things seem to be changing lately, and this subgenus emerges imperceptibly from the narrow cage assigned to it and enters the "great" literature, proving, once again, that the divisions and delimitations in the perception and knowledge of the world are more and more porous, that we are more and more permeable to the once unthinkable thought that we simultaneously live different lives in different places. I have found a beautiful illustration of the contact between the spheres of mathematics and everyday life in Paolo Giordano's novel, mentioned in Chapter 2, and more recently still in 2013, in Philippe Forest's *Le Chat de Schrödinger* (*Schrödinger's Cat*), published by Gallimard, a disturbing metaphysical novel, which unfolds its possibilities and actualizations based on the quantum model.

Furthermore, the academician Jean d'Ormesson begins his essay *Comme un chant d'espérance* (*Like a song of hope*) with a reference to another academician-writer, in turn preoccupied with the invisible, François Cheng: "Containing the promise of Everything, Nothing designates the Non-being, this being nothing but that through which the being happens." (2014: 7) It is true that today, the experience of the Internet and increasingly sophisticated computer games, allow us to adopt all kinds of "avatars" and move freely through parallel worlds, facilitating the acceptance of new perspectives on reality. Our horizon of expectation has shifted rapidly, and therefore quantum theory is almost no longer seen as a virtuality by our imagination, but is instead fully accepted at the table of major truths that shape the mind and the personality.

Interim conclusions

Descartes has oriented scientific research towards plots ("dividing each of the difficulties [...] into as many plots as possible") and towards efficiency ("making us masters and owners of nature"). In this project, the subject and the object, Man and nature, were clearly separated, as were the body and the soul. But for almost four centuries, this project has proven to be extremely fruitful, as evidenced by the technical and scientific achievements of today's civilization. However, this resounding success has created a division in culture and within each individual. Science and technology have gradually become separated from other fields of culture - arts, letters, philosophy, etc. As for the individual, seduced by an immense and fragmented knowledge, driven by the cult of efficiency at all costs, he found himself diverging from his inner life, and the world became meaningless to him, with an evolution that seems doomed to suffer the constraints of chance and necessity.

And yet, the world no longer appears to us as a set of objects, but rather as a network of inseparable relationships. Therefore, the experience of physicists has showed them the limits of the notion of object and that it was better to replace it with the notion of energy model or models. This reality, this network of relationships, is inherently dynamic. Our knowledge has evolved and is branching out spectacularly. But knowledge, be it scientific, mystical, humanistic or artistic, is one and the same.

Carl Sagan, the legendary TV personality, the host of the series "Cosmos", once said:

> There is an idea - strange, haunting, evocative - one of the most exquisite conjectures in science and religion. It is entirely undemonstrated; it may never be proved. But it stirs the blood. There is, we are told, an infinite hierarchy of universes, so that an elementary particle, such as an electron,

> in our universe would, if penetrated, reveal itself to be entire closed universe. Within it, organized into the local equivalent of galaxies and smaller structures, are an immense number of other, much tinier elementary particles, which are themselves universe at the next level, and so on forever - an infinite downward regression, universes within universes, endlessly. And upward as well. Our familiar universe of galaxies and stars, planets and people, would be a single elementary particle in the next universe up, the first step of another infinite regress.

Will we ever find the smallest thing possible? And if yes, what relevance will it have, since by then we would have found also the biggest thing possible and we would have understood that we have returned into the One?

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Chapter 5

From atomism to holism through information

At quantum field level there is nothing
except energy and information.
Deepak Chopra

5.1 Atomism and holism in psychology

In psychology, the atomistic perspective is a very old one. It is based, on the one hand, on the decomposition of the human personality into its component elements and the study of their functioning laws, and on the other, on the identification of the primary element or its fundamental constituent. The atomistic vision is a doctrine of perception, according to which human beings perceive a mosaic of atomic sensations, each being independent and unconnected with some other sensation.

The idea of applying *atomistic* approaches not only to matter but also to phenomena of the psyche is as old as atomism itself. Democritus spoke of the "atoms of the soul". According to the principles of his doctrine, these atoms can differ only quantitatively from those of the body: they are smoother, rounder and finer, hence the idea of the sphere in the perception of the atom, an idea referred to in detail in Chapter 4, and which it allows them to move easily throughout the body. Practically, however, the atoms of the soul are no less material than other atoms.

Later, Leibniz's monadology brought major changes to this view. Leibniz did not begin by viewing atoms as exclusively material, only to then interpret the soul in terms of these atoms. He thought from the beginning of his "atoms", his monads, in terms of analogy with the soul. A monad is much more spiritual than it is material. Monads have no extension, as they do not have, as specified in Chapter 2, spatiality. They are centres of action, but not primarily in the physical sense. Each monad is endowed with a certain degree of perception and each of them mirrors the universe in its own way. However, monads differ from each other in the extent of perception they are capable of.

From the perspective of traditional metaphysical debate, two essential approaches to the structure of reality are worthy of discussion: *atomism* and *fundamentalism*. According to atomism, there exist *mereological atoms*, i.e. minimal elements in the mereological structure of reality (very, very small "things" that have no subcomponents whatsoever). Fundamentalism states that there are fundamental truths, sentences that are true, but which do not owe their truth to any other "more fundamental" truth (Schnieder, 2020).

According to David Hume's early modern empiricism, and also according to the view of Wilhelm Wundt, the father of experimental psychology before World War I, the fact that humans still experience a whole, an ordered accumulation of unordered "atoms" of perception, is caused by the ability the mind to combine them by "association", which gave rise to the so-called theory of associationism.

The obvious reductionism of atomism, so inappropriate in the field of psychology, made it give way, little by little, to the complementary concept of *holism*.

In psychology, holism is an approach in understanding the human mind and behaviour, which focuses on the analysis and interpretation of things as a whole, contrasting, as we have pointed out, with reductionism, which tries to break things down into their smallest parts.

Psychological atomism (or *associationism*) interprets mental activity by summing up some elementary phenomena. It starts from the idea that the activity of the psyche has a material support and explains psychical life through the action of the association as a central and fundamental phenomenon in the formation and manifestation of psychical phenomena. Any systematic approach that is based on the idea that mental processes are constructed of unique elements (e.g., sensations and feelings) that form combinations falls within the visions of atomistic psychology. These unique elements are called *psychical atoms*, by analogy with physical atoms. In other words, in this approach it is necessary to understand the parts in order to be able to understand the whole (the assembly).

This approach suggests that we can understand the parts only when we see them in relation to the whole. In the realm of psychology, the holistic view suggests that it is important to look at the mind as a unit, rather than trying to break it down into its individual parts. Each individual part plays its own important role, but it also operates within an integrated system. In essence, holism states that people are more than just the sum of their parts. To understand how people think, the holistic perspective emphasizes that we need to do more than just focus on how each individual component works in isolation. Psychologists who take this approach believe that it is more important to look at how all the parts work together. Therefore, the key phrase that sums up the idea behind the holistic approach is that *the whole is more than the sum of its parts*.

As an approach to understanding systems, holism is used both in psychology and in other fields, such as medicine, philosophy, ecology, economics. The field of holistic medicine, for example, focuses on treating all aspects of a person's health, both physical symptoms and psychological factors and social influences. In order to understand why people do the things they do and think the way they think, holism suggests that we look at the whole person, instead of focusing on one aspect of the problem, recognizing that various factors interact and influence each other.

One of the reasons why it is so important to consider the whole being is that the whole can have emergent properties, as the human being is what is called a complex system, and we shall refer to these issues in detail in the following sections. Thus, we shall see that emergent properties are qualities or characteristics that are present in the whole, but cannot be observed by analyzing the individual parts.

Then, the question arises, as E. Thompson puts it: Is the brain a "decomposable" or "nondecomposable" system? (2014, 458-459). This question addresses the functional organization of the brain as a cognitive system. In a decomposable system, each subsystem's operation is determined by the subsystem's intrinsic properties independent of the other subsystems, making the system's organization strongly modular. Modularity decreases depending on how strongly the subsystems interact, especially through feedback and reentrant or recursive processes. If the subsystems are only weakly coupled, such that the causal interactions within a subsystem play a stronger role in determining its operation than do the causal interactions between it and other subsystems, then the system is "nearly decomposable". If the subsystems are strongly coupled, then the functional organization of the system becomes less governed by the intrinsic properties of its subsystems and more governed by the ways the subsystems interact, making the system "minimally decomposable". In a "nondecomposable" system, the coupling is such that the subsystems no longer have clearly separable operations apart from the larger context of their interdependent operation. The current debate about whether cognitive functions can be localized to specific brain regions, or whether cognitive functions need to be mapped onto dynamic networks instantiated in shifting coalitions or assemblies of regions, can be regarded also as a debate about the extent to which the brain's cognitive organization is decomposable (modular) or nondecomposable (nonmodular).

Associationism was a dominant psychological conception in the 17th - 18th - 19th centuries in Europe. The basic idea of the associationists is that the psychic activity has a material support and that the psychic life arises from psychic-elementary states caused by objects and by the union in different ways of the simple, irreducible psychic phenomena. This conception is called psychological atomism because it considers all psychic phenomena as made of non-decomposable psychic elements.

Functional decomposition is an important goal in the life sciences, and is central to mechanistic explanation and explanatory reduction.

A growing literature in philosophy of science, however, has challenged decomposition-based notions of explanation. 'Holists' posit that complex systems exhibit context-sensitivity, dynamic interaction, and network dependence, and that these properties undermine decomposition. They then infer from the failure of decomposition to the failure of mechanistic explanation and reduction. Complexity, so construed, argues D.C. Burnston (2019), is only incompatible with one notion of decomposition, called "atomism", and not with decomposition writ large. Atomism posits that function ascriptions must be made to parts with minimal reference to the surrounding system. Complexity does indeed falsify atomism. Contextualism suggests that the function of parts can shift with external context, and that interactions with other parts might help determine their context-appropriate functions.

For example, if we consider the human brain, it contains millions of neurons, but, nevertheless, each individual neuron cannot not tell us what the brain can do. Only if we look at the brain holistically, analyzing how all the pieces work together, can we see how messages are transmitted, how memories are stored and how decisions are made. In fact, one of the first debates in the field of neurology focused on this dilemma: either the brain is homogeneous and cannot be broken down (holism), or certain functions are located in certain cortical areas (reductionism).

Nowadays, researchers recognize that certain parts of the brain act in specific ways, but these individual parts interact and work together to create and influence various functions or even take over functions of other areas, if the latter have been damaged. In recent years, this extraordinary capacity of the brain is known as *neuroplasticity.* Like reality, the brain is plastic.

However, like the reductionist approach to psychology, holism has both advantages and disadvantages. For instance, holism can be helpful when looking at the big picture as a whole allows the psychologists to see things that might otherwise have escaped them. In other cases, however, focusing on the whole might lead them to overlook finer details.

One of the great advantages of the holistic approach is that it allows the evaluation of multiple factors that could contribute to a psychological problem. Thus, instead of focusing on a small part of a problem, researchers can look at all the elements that can play a role. Human behaviour is complex, and therefore explaining it often requires an approach that can account for this complexity. Holism provides a complete answer to difficult questions about how people think, feel, and behave. People are infinitely complex and varied, and holism is able to address all the external and internal factors that influence our past, present, and future.

Gestalt psychology also has deep roots in holism, which considers that it is not enough to look only at human behaviour as a whole, but also to understand how the human mind itself uses a holistic approach in order to make sense of the world.

Unlike psychological atomism, gestaltism considers that the whole is always different (not greater) than the parts of which it is composed and that its attributes are not deductible from the analysis of the parts, taken separately. In this respect, Kurt Koffka, one of the classics of Gestalt psychology, wrote in 1935 that it would be more correct to say that the whole is *something other* than the sum of its parts, because adding the parts up is a meaningless procedure, given that the part-whole relationship is significant.

In order to understand how the human mind is structured and how it operates as a unitary whole, modern theories have been used in recent years - information theory, complex systems theory, network science - and we shall present them in brief in the following.

5.2 Information

Definitions and conceptualization

Every item of the physical world has at bottom -
at a very deep bottom, in most instances - an immaterial source and explanation; (...)
all things physical are information-theoretic in origin and this is a participatory universe.
John Archibald Wheeler

Every physical system, just by existing, can register information.
And (...), just by evolving according to its own peculiar dynamics,
can process that information.
Seth Lloyd

Since the formulation of theories regarding special relativity and quantum mechanics, information has become a central concept in the description and understanding of our physical reality.

In an etymological sense, information comes from the Latin verb *informare*, which means "to give shape" or "to form an idea over something". The perception of information is extremely heterogeneous, the concept of information being a topic of reflection and analysis in information theory, communication theory, knowledge theory, logic, semantics, philosophy, theology, etc.

The term "datum" comes from Latin (*datum*), the past participle of the Latin verb *dare*, "to give". Since ancient times the sentences or deeds considered obviously true were called "data", givens. Unprocessed initial data consist, in the broadest sense, of numbers, letters, images, and other forms of data produced by devices that convert physical quantities into symbols.

In principle, data forms information, and information constitutes knowledge. In reality, the phenomena are not limited to an inclusion of one field in another. Information needs data and processing and storage systems, and knowledge requires an accumulation of information, but also higher mental processes, such as generalization, abstraction, synthesis, correlation and signification. This diversity under which the information is presented causes the difficulty both of defining it, and of understanding its meaning in a unitary manner at different levels of reality.

With the advent of quantum mechanics, the need arose to define information at quantum level. In theories developed in the second half of the twentieth century, such as chaos theory, fractal theory (Mandelbrot, 1983), and the theory of nonlinear dynamics, later reunited in what is called the complex systems theory, the need to define information became even more stringent, all the more so as this theory applies regardless of scale, at all levels of reality.

The science of complexity requires a new approach to information as a defining notion along with energy and substance. Because of this, defining information becomes even more complicated from the perspective of the new paradigms. Traditionally, there are two meanings of the notion of information. One is the Aristotelian one, which designates the structuring of a specific form, of an organization in an initially inhomogeneous matter, and the other designating the transmission of a message. Information can be seen both as a fact in itself, and as a fact of relating, of transmitting facts.

Information theory is related to Shannon and Weaver (1963), who defined information as an entity that is neither true nor false, neither significant nor insignificant, neither credible nor doubtful, neither accepted nor rejected. As a result, it is worth studying only the quantitative component of information, not the qualitative part, which allows the association of information with the second law of thermodynamics, with entropy, information or the amount of information being inversely proportional to it. Thus, Weaver linked Shannon's mathematical theory to the second law of thermodynamics, stating that entropy is what determines the rate of information generation. The information formula is identical to that of entropy developed by Boltzmann, but taken with the minus sign:

$$H = -\sum_{k=1}^{i} p_k \log p_k,$$

where p_k represents the probability of an element or event k within the system.

Information is therefore, in a sense, the quantitative one, entropy. It should be noted that Octav Onicescu (1966) also formulated a hypothesis regarding the fact that the degree of organization of a system can be "measured" with the help of information energy, defined as follows:

$$E = -\sum_{j=1}^{n} p_j^2(A),$$

where p_j represents the probability of occurrence of event A.

This quantitative approach to information is applied in the field of telecommunications and computer science. From this perspective, it is important to establish the amount of information and its true/false character in the transmission of information, to which notions of probability can be linked, in finding at the receivers' end the information transmitted from the source. Even in this technological approach, two aspects of information are highlighted: information as a product, which reflects a static vision, and the approach as a process, which emphasizes the genesis and purpose of information. In fact, the two aspects represent information as potential and information expressed and involved in the dynamics of matter becoming and structuring.

Trying to structure the numerous informational approaches, Lucas Introna distinguishes two archetypes, the informational one and the communicational one. The former was dedicated to the explosive development of information technology and is related to the realization (development) of systems "producing" information. The latter has its origin in Shannon and Weaver's communication scheme, being somewhat less visible in the field of information systems, but more widely accepted in the theories of communication.

Similarly, Stonier (1990) believes that the fundamental aspect of information is that it is not a mental construction, but instead a basic property of the Universe. Any general theory of information must begin with the study of the physical properties of information, as manifested in the universe. This must be done before attempting to understand the varied and much more complex forms of human information. The next step must involve examining the evolution of information systems beyond physical systems, first in the biological sphere, then in the human, cultural sphere.

The scientific approach to information theory starts from the idea that mathematics is the general language of nature. Galileo said it, many said it after him, but also long before him, Pythagoras or the Indian mathematicians did, too. They all believed that the structure of the universe is written in mathematical language, and that its "letters" are geometric shapes, symbols, and mathematical equations. From this perspective, science does nothing but decipher, through physical-mathematical modeling, the information contained in the structure of matter. According to this paradigm, information is found in nature, outside it, beyond the observer and independent of it. Therefore, information must have existed before the emergence of human consciousness.

Information has an objective natural existence; people are the ones who absorb it in their minds and in the memory of the computer, modify it and multiply it by thinking, and bring it into the "middle" of society through language.

At the opposite pole of this materialistic-objective approach to information is the concept that information is something that a person communicates to another person, and the meaning of information can be understood only by considering the presence of living beings endowed with thought, placed in a social-cultural context and analyzed from a historical perspective.

A fundamental feature of information pertains to the subjectivity of its reception. What may be information to one person may be meaningless to others. On the other hand, starting from the same data set, different people can deduce, through different processing, different information. If the data has a physical, tangible existence, the information exists only in the receiver, being intangible. What constitutes information for one person may be data for another person.

Information is therefore a fundamental component of reality, as are substance and energy, as nature is filled with information. More broadly, information pre-dates its observer or interpreter. Thus, the concepts of matter (substance and energy) and information, together, can explain the emergence, formation, structure and dynamics of the mind and knowledge, but also of the entire structure of the universe.

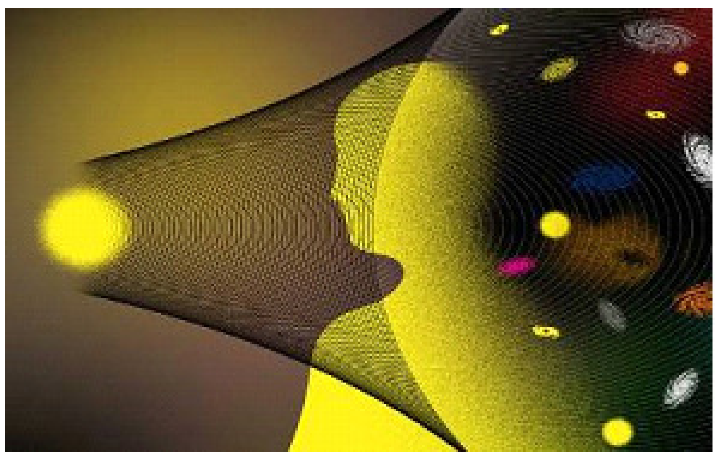
5.3 The importance of axiomatic systems in cognitive perception of reality

In this section we shall highlight the role of axiomatic systems, as a mechanism involved in the perception and cognition of reality. The use of axiomatic systems from different physico-mathematical models underlying epistemology can then be extrapolated to psychological mechanisms and concepts involved in human perception and cognition (Hazewinkel, 2001; Whitehead and Russell, 1963).

Starting from an evaluation of the axiomatic systems of antiquity, insisting on Pythagoras's numerical system of and Euclid's geometric system, continuing with the tendency of axiomatization of mathematics experimented by Hilbert and with Gödel's incompleteness theory, but also with the paradoxes of quantum physics and of the wave-corpuscle duality, we find the same need for axiomatization in various psychological theories, as well as in the new discoveries in neuroscience. We thus underline an axiomatic unity as a gnoseological principle, both in the evolution of knowledge over time, but also along the levels of reality in various paradigms.

All these point to the importance of the multidisciplinary, interdisciplinary and even transdisciplinary approach, in order to showcase the axiomatic paradigms that unite reality with the subject, the object with the observer, the mind with the body, in a naturalistic vision that can generate new hypotheses in knowledge (Cilliers and Nicolescu, 2012; Nicolescu, 2014; Crumpei, Gavriluţ, Crumpei Tanasă and Agop, 2016).

The need for axiomatic systems in the rational understanding of reality appeared in antiquity, if only as rough sketches, Pythagoras being the one who built a true axiomatic system based on numbers. The greatest reach in science and knowledge has had the Euclidean axiomatic system, which is still in use to this day, being completed by the axioms of non-Euclidean geometry. In this respect, Hilbert proposed a complete axiomatization of mathematics, being stopped in his drive by the incompleteness theory formulated by Gödel, which, through the paradox he built, triggered what was called a crisis of sciences. Richard Feynman seems to have the last word when he states: "*... paradox is just a conflict between reality and what we believe reality should be*".



Arguments related to a topological mechanism for processing information that would lead to an axiomatic system based on which information is processed have been brought by Gestalt psychology, which we have already referred to in the first section. This axiomatic system builds what psychologists call the "core of beliefs, convictions, and certainties", which underpins knowledge and the understanding of reality. This nucleus differs from one historical stage to another, from one culture to another, from one community to another and even from one individual to another.

The paradoxes raised by quantum physics a century ago can be understood from this axiomatic perspective, which starts from a coherence between mental representations and therefore our expectations, and the physical system of reality, which, from an infinity of versions, reveals that with which our mind achieves coherence. Thus one can understand the paradoxical aspects offered by the famous double-slit experiment and, in general, by the wave-corpuscle duality, which has aroused so much controversy.

It takes an axiomatic shift in our minds to discover reality afterwards from the perspective of these new axioms. As long as humans expanded their range only to the distance they could cover on foot or with the help of animals, the axiom of the flat Earth was the one that naturally prevailed. It was only the great voyages of the great explorers that revealed the reality of a round Earth (although the ancient Egyptians, but especially the ancient Greeks had this intuition; some of them, like Eratosthenes, had even calculated its circumference more than two thousand years ago). Geocentrism was the dominant concept for hundreds of years. It was only when doubts arose over the discovery of new instruments (Copernicus' calculations or Galileo's telescopes) that new paradigms gradually formed in the minds of the scholars of the time, leading to the heliocentric conception, with corrections made by Kepler on orbits and culminating in Newton's coherent theory of physical reality.

The emergence of new paradoxes in the late nineteenth century, based on both experiments - in the case of electromagnetism, for example - and new mathematical concepts, such as non-Euclidean geometries, led to the construction of new axioms that allowed the development of the special and general relativity theory and of quantum mechanics.

All these examples are not only specific to scientific knowledge (whether mathematical, physical or logical), but also to other forms of knowledge (philosophical, religious, artistic), which leads to the conclusion that the multidisciplinary and transdisciplinary methodology is the most appropriate approach in understanding reality, in all its axiomatic aspects.

From the perspective of computer systems, things are clear. If the right software is not found in the computer system, then the program is not recognized, so it cannot be processed, and in conclusion it does not exist. The situation is similar to the case in anthropology, in which a tribe of Amazonian natives was shown films depicting aspects of the modern world: the natives noticed and understood only the flocks of pigeons in St. Mark's Square, as birds were the only item the two worlds shared.

This also explains, from the perspective of different axiomatic systems, the great misunderstandings and lack of acceptance in today's clashes, in the era of globalization and emigration, between different cultures and religions.

5.4 Information and network science

Networks are essentially systems made up of connected elements. In recent decades, the development of computing infrastructure and access to large digitized databases on various social, natural and artificial systems have led to a new vision of networks. It has become clear that networks are present in all complex systems, from the microscopic level to Earth-size scales. In social networks, knots (or agencies) correspond to individuals, and the links (or hyperlinks) represent the various interactions among them.

The study of social networks focuses on investigating the interconnection of individuals and the position of said individuals in these networks. The first studies in this field were conducted in the field of social sciences, as the investigation of the structure and dynamics of human interactions was a current topic of interdisciplinary research. The investigated systems gradually evolved from small groups of people to large-scale social systems.

As a rule, social networks are self-organized, emergent and complex, and therefore a coherent global pattern emerges from the local interaction of the elements that make up the system. These patterns become more apparent as the size of the network increases. But a global network analysis, for example of all interpersonal relationships in the world, is not feasible and may contain so much information that it is uninformative. The practical limitations of computing power, ethics, and the recruitment and payment of participants also limit the scope of social network analysis. The nuances of a local system can be lost in a large network analysis. Therefore, in order to understand the properties of the network, the quality of the information may be more important than the scale. Thus, social networks are analyzed on a scale relevant to the theoretical questions of the researchers. Although the levels of analysis are not necessarily mutually exclusive, there are three general levels in which networks can be included: micro, medium and macro level.

Most social networks at the macro level are complex networks, which involve nontrivial, substantial elements, from the network topology, with complex patterns of connections among elements, which are neither purely regular nor purely random, in a manner similar to that of biological and technological networks.

The study of networks aims at analyzing and modeling their structure, evolution and dynamics, in order to reveal the relevant statistical properties and to propose models that would predict their future behaviour.

To understand the behaviour of complex systems, it is necessary to study the network topology that underlies them. *Network topology* is an important tool for visualizing the system and analyzing the evolution over time of their characteristics. Networks developed from graph theory.

The foundations of graph theory were laid by Leonhard Euler in the 18^{th} century. Since then, graph theory has evolved greatly, so that in the twentieth century research has focused on the study of random graphs. At that time it was believed that in a complex system, the connection of the elements occurs randomly. The theory of random graphs was founded by Paul Erdős and Alfred Rényi. Numerous theorems have concluded that probabilistic methods are effective in various problems related to graph theory, and thus for many years researchers have been convinced that all complex systems were driven by random processes.

The preliminary steps in investigating the behaviour of complex systems consist in studying the structure and dynamics of the network. Currently, numerous studies in this field aim to find as many answers as possible regarding the general features of complex systems and their behaviour, in the desire to effectively treat currently incurable diseases, by directing treatments to the key elements in the network of proteins and neuronal cells. At the same time, they aim to stop the spread of viruses and prevent it through targeted vaccinations, to annihilate organized crime groups and control many other complex systems that influence our lives.

Statistical physics provides efficient techniques in studying the dynamics of the evolution of complex systems, providing models that help to study transition phases, synchronization properties and critical points in the network. At the same time, it contributes to the identification of the basic elements in the system and analyzes clustering properties and organization principles. Scientists have become interested in the dynamic processes present in networks, which can only be studied using statistical physics. For example, in complex social systems, some major issues are those of the spread of diseases, of rumours, the flow of information, the shaping of unanimous opinion, etc.

The development of the modern study of social networks and its transformation into a true science of networks, which also included artificial networks, was carried out since the 2000s by Albert-Laszlo Barabási, who contributed significantly to the development of network sciences and the statistical physics of complex systems (Barabási, 2010).

His major contribution consisted in the fact that he highlighted the lack of scale in biological systems, more precisely in metabolic networks and in protein interaction networks. A free-scale network is a network whose degree of distribution follows a powerlaw, at least asymptotic, a random network, with a degree of distribution that reveals that particular dimensional component. An important feature is the relative triviality of the knots, with a degree that far exceeds the average. The knots with the highest degrees are called *hubs* and have specific purposes in the network. Another feature is the distribution of the clustering coefficient, which decreases as the degree of the hub increases.

Barabási's contributions to network biology and network medicine include the introduction of a specific concept, which describes the connections between diseases, through the genes that are shared between them. He was also the pioneer of using *BigData* in the context of patient data, in order to explore the comorbidities of some diseases, by superposing them with information about molecular networks.

In biology, a biological neural network is composed of a group or groups of chemically connected or functionally associated neurons. A single neuron can be connected to many other neurons and the total number of neurons and connections in a network can be expanded. Connections, called synapses, are usually formed from axons to dendrites, although dendrite-dendrite synapses and other connections are possible. In addition to electrical signals, there are other forms of signalling that arise from the diffusion of neurotransmitters.

Artificial intelligence, cognitive modeling, and neural networks are information processing paradigms inspired by the way biological neural systems process data. Artificial intelligence and cognitive modeling try to simulate certain properties of biological neural networks. In the field of artificial intelligence, artificial neural networks have been successfully applied to speech recognition, image analysis and adaptive control, in order to build software agents (in computers and video games) and autonomous robots.

Neural network theory has served both to better identify how neurons in the brain work, and to provide the basis for efforts to create artificial intelligence. Artificial neural networks can be described as computational models with particular properties, such as adaptability, the ability to learn, generalize or classify information, these operations being based on parallel processing.

From a functional point of view, a neural network is a system that receives input data, corresponding to the initial data of a problem, and produces output data, which can be interpreted as answers to the analyzed problem. An essential feature of neural networks is the ability to adapt to the information medium corresponding to a concrete problem through a learning process. This way, the network extracts the problem pattern starting from examples. It can be said that a neural network builds its own algorithm for solving a problem, if it is provided with a representative set of particular cases (training examples).

From a structural point of view, a neural network is a set of interconnected units, each characterized by simple operation. The operation of the units is influenced by a number of adaptable parameters. Thus, a neural network is an extremely flexible system. The structure of the functional units, the presence of connections and adaptive parameters, as well as the way they operate are inspired by the human brain. Each functional unit receives several input signals that it processes and then produces an output signal.

Such a system learns by changing the connection intensity between elements, that is by changing the weights associated to these connections. The initial knowledge that is provided to the system is represented by the characteristics of the considered objects, and by an initial configuration of the network. The system learns and constructs a symbolic representation of a given set of concepts, by analyzing the concepts and the counterexamples of these concepts.

An artificial neural network is a set of functional units, located in the knots of an oriented graph and between which signals flow along the arcs of the graph. Artificial neural networks are networks of neural models connected through adjustable synapses. All neural network models are based on the interconnection of simple computational elements in a dense network of connections.

The defining elements of a neural network are its *architecture*, which specifies how functional units are located and interconnected, and which determines the flow of information within the network, and its *operation*, which specifies how each unit and the network as a whole transform input signals into output signals. The operation is influenced by the architecture, especially by the way the units are interconnected.

5.5 Information as ontological entity, together with substance and energy

The everyday reality of the impact of information technology, computer networks, virtual reality and artificial intelligence requires questions and answers about the role of information in the gnoseological approach. The preponderance of a reductionist logical positivism in scientific research, the exaggerated emphasis on particle physics and high energies, as well as a certain axiomatic blockage related to the existence of the immaterial, have caused the issue of information to be, until recently, almost completely eluded.

Shannon and Weaver's information theory examines information only quantitatively and only in relation to entropy and the second law of thermodynamics. Developments in the last decades of the twentieth century in the fields of nonlinear dynamics, chaos theory and fractal geometry, but especially the advances of computer science in the last three decades require a systematic approach for defining information and its importance in structuring reality together with energy and substance (Barabási, 2010).

From this perspective, all our concepts, from physical reality to mental imaginary reality, can be understood coherently using the same paradigm, whether it is the conservation law, the fractal, Euclidean and topological dimension, or the mechanism of multidimensional processing through the syntactic, semantic and pragmatic treatment of human knowledge.

This new paradigm is *the informational paradigm*, which presupposes the existence of a functional, phenomenological, potential substratum, represented by information.

In computational technology, we are obliged to give information its rightful place in the ontological context, namely, in the substance - energy - information triad. The beginning of the twentieth century opened, through the relativity theory, the way of knowing the dynamics between energy and substance, as quantum physics brought new elements regarding the constituents of reality.

From the perspective offered today by the evolution of scientific knowledge, it seems difficult to understand the insistence on the wave-corpuscle duality (Heisenberg, 1949), which has provoked so many interpretations, eluding however the issue of information. A certain inertia in changing the axiomatic structure, in epistemology, means that even today, most researchers do not involve information in the physical-mathematical models they work with.

It is becoming increasingly clear that the hundred-year-old assumptions regarding hidden variables, subquantum potential, quantum potential or fractal potential actually describe information, involved in all the structural and dynamic phenomena of matter; the wave-corpuscle duality shows that at the level of the corpuscle, all the information of the particle (the properties of the particle) is also present in the wave, which, by collapsing the wave formula, structures the particle.

From the point of view of information technology, things are very clear. You can receive an email from Australia, with an attachment that allows you to build a vase with a 3D printer, as a gift from that overseas friend. It is obvious that the information sent through the electromagnetic field have generated the object you hold in your hand. Undoubtedly, the software contains all the instructions for the computer and printer to build a body with the same configuration as the one originally designed. It is only partially teleportation, because the configuration of the atoms and constituent molecules of the vase is not transmitted, but only the three-dimensional configuration using the material provided by the printer. In fact, even the teleportation experiments attempted today address simple structures (photons, atoms or molecules) for the time being, but even in this case we start from the *entanglement* mechanism, which involves an informational link between two particles that have interacted at some point in time and have remained informationally connected. However, intuitively, information technology thus manages to transmit, regardless of distance, not only information expressed through texts, algorithmic instructions or images, but also three-dimensional bodies as a whole.

5.6 Complex systems. The emergence process

A complex system is a system composed of many components that can interact with each other. The science of complex systems is a general way of representing and understanding reality, as a complex system presents a complex structure at multiple scales. This structure can be seen as the totality of the relations between the components of the system, and information theory can quantify these relations.

Therefore, holistic science or holism in science is an approach that emphasizes the study of complex systems. From this perspective, complex systems are viewed as coherent integers, whose component parts are best understood in the context and in the relationships between themselves and those between them and the whole.

A complex system cannot be analyzed in terms of principles by fragmenting it into parts, since it is composed of elements that make sense only inside the system. It has an unpredictable evolution, it can undergo sudden transformations, no matter how large, without obvious external causes, and it has various aspects, depending on the scale of analysis.

A complex system differs in principle from a complicated system in that the difficulty of prediction lies not in the inability of the observer to take into account all the variables that would influence its dynamics, but in the sensitivity of the system to initial conditions (slightly different initial conditions lead to extremely different evolutions), with the added effect of a process of self-organization (a process determined by the interactions between the component subsystems, which has as effect the spontaneous occurrence - unpredictable in principle - of order relations).

A complex system can be modelled and studied in an equivalent topological space, called the phase space, in which specific notions are defined, such as attractors and repulsors, basins of attraction, trajectories, limit cycles, etc. In this context, we can speak of a functional modeling, much more abstract and more "detached" from the constraints imposed by an "anatomy" and a concrete "physiology". While classical modeling starts by approximating what is "seen", functional modeling involves identifying an equivalent dynamic system, whose behaviour can be analyzed through specific methods, with an extremely high degree of generalization.

Emergence plays a central role in the theories of integrative levels and complex systems. For example, the phenomenon of life, studied in biology, is an emerging property of chemistry, and psychological phenomena arise from the neurobiological phenomena of living things. Through emergence, new systemic levels appear, which usually results in a leap in the operation of systems, as well as the emergence of new properties, which arise from a new form of organization.

In philosophy, in systems theory, in science and art, emergence occurs when *the whole is greater than the sum of the parts*, that is, the whole has additional properties, which the parts do not possess. These properties are due to the interactions between the parts.

An emerging property of a system is therefore a property that cannot be explained through the features of its parts. In any system or biosystem, its parts and elements generate new properties, establishing, through interaction, new dynamic relationships, both the first and the second category of which do not exist initially, since they are not predictable prior to systemic integrations.

On the other hand, in philosophy, reductionism is related to the associations between phenomena that can be described in terms of other, simpler or more fundamental phenomena. Reductionism does not deny the existence of phenomena, but instead explains them in terms of a different reality. Reductionism does not exclude the existence of what might be called an *emergent phenomenon*, but instead implies the ability to understand these phenomena only in terms of the processes that compose them. The reductionist conception is very different from emergence, which considers that what emerges is always more than the sum of the processes from which it emerges.

Emergence can be revealed, depending on the system approached, through a series of mechanisms, in processes characterized by non-computability, non-localization, non-linearity in evolution, large number of elements, areas of chaoticity, and in which the direction of evolution of the system is given by the competition of attractors in the phase basin. All these processes are found in the complex systems theory (or complexity theory), which includes fractal geometry, nonlinearity, topology and chaos theory (Gavriluţ and Agop, 2013; Radu and Agop, 2013):

The impossibility of reducing the whole to parts, as well as the rejection of physical reductionism (there is also a mathematical reductionism, through which mathematics can be reduced to classical logic, as an understanding), element interactions (cancelling differences - through combination), hierarchical levels (sometimes obtained by the transformation of quantity into quality), the existence of the chaotic state (deriving, in a general framework, from an initially stable state, by the appearance of bifurcations), and the estimation of its limits, the transition from discontinuous (microscopic) to continuous (macroscopic) form (which, in turn, may represent a certain form of discontinuity for other higher levels of knowledge and perception) generates a "causality fracture". (Sorin Băiculescu, 2015)

In systems composed of a large number of elements, the properties of the systems are not found in the sum of the properties of the constituent elements. The emergence property is therefore the one that creates a connection between the set of components and the properties of the complex system. However, research in the field of complex systems has so far failed to formulate a unitary theory to explain emerging properties, as well as the relationship between the dynamics of the components of the systems and the properties of the system as a whole.

5.7 The place of information in the wave-corpuscle duality

The complex systems theory requires a reassessment of the wave-corpuscle duality, from the perspective of fractal geometry and nonlinear dynamics, which also needs the involvement of information as the third element in the wave-corpuscle duality.

In the scale relativity theory, the dynamics of any physical system is described by quantities expressible by fractal functions, i.e. functions dependent on both coordinates and time, as well as resolution scales. Moreover, any quantity can be written as the sum of a differentiable part, which is dependent only on coordinates and time, and a fractal part, which is dependent on both coordinates and time, as well as on the resolution scales. In such a context, the differentiable part proves to be compatible only with the predictable states of the physical system, while the fractal part is compatible only with the unpredictable states of the same physical system.

The analysis of the wave-corpuscle duality in the sense of de Broglie's theory implies the simultaneous existence of two types of motion: a deterministic, predictable motion, associated with a continuous hydrodynamic type of motion along a continuous line, which is specific to the corpuscular character, and a zigzag, random, unpredictable motion, which is specific to the wave-like character.

De Broglie's model introduces the two types of motions only as hypotheses, but the real problem is the ratio between existence as wave and existence as corpuscle, as well as the wave-corpuscle structural compatibility, meaning that the wave structure must be compatible (coherent) with that of the corpuscle.

A new way of approaching the issues implied in the wave-corpus duality consists, in our opinion, in the assumption that the motion of a particle takes place on continuous and non-differentiable curves. This means a transition from a classical approach to motion in a Euclidean space to an unconventional, non-standard approach, involving motion in a fractal space-time. Thus, de Broglie's difficult problem – his inability to justify the uniform motion of the particle in the wave field (hence the incompatibility with the linear, uniform motion of the wave-corpuscle duality) – can also be solved.

The postulate through which the motions are introduced on continuous and non-differentiable curves solves this problem of linear and uniform motion, in the sense that on the new fractal manifold, the motion is free, that is, it takes place on geodesics.

Accepting such a postulate, based on the model of the scale relativity theory, it results that the geodesics of a fractal space-time can have a double representation, on the one hand a stochastic, unpredictable representation, described by Schrödinger type equations, specific to the wave-like character, and, on the other hand, a deterministic, predictable representation, made by the fractal hydrodynamic model, specific to the corpuscular character.

The unpredictable part must be directly correlated with non-differentiability and is manifested through the existence of a potential, called fractal potential. The maximum principle of the informational energy gives the concrete form of the potential, and this, introduced in the fractal potential, results in the complete form of the force field. Therefore, informational energy not only stores and transmits information through interaction, but thus links it directly to the deterministic part. So, practically, those who possess all the "secrets" are the fractal potential, which imposes the fractal, intelligent medium, and the informational energy, which lends force.

The movement between increasingly complex structures is based on the correlation between corpuscle and the corresponding wave. From here, this phenomenon present in the wave-corpuscle duality includes the information, which alternates between the spatio-temporal structured information in the corpuscle and the same information distributed in the "structure (contents)" of the wave.

Thus, the topological nuancing of the information is realized between the two poles, that of the fragmentary, the discrete, the digital on the one hand, and that of the holistic, continuous and wave analogical on the other side. Signification is achieved by relating informational content from less complex levels to more complex levels, achieving unity in terms of information between digital and analogue, between discrete and continuous, between fragmentary and holistic.

While corpuscles retain individual properties that lead to explicit bonds (strong forces, weak forces, electromagnetic forces, quantum gravity), the waves corresponding to these particles overlap by modulation into waves that contain all the continuously dispersed information. This aspect, which derives from the properties of waves on the one hand and those of corpuscles on the other, as well as the aspect of the wave-corpuscle duality, lead to the conclusion that all corpuscular structures, from nuclear to atomic, molecular and macromolecular, hold the information both in the content of the structure of these corpuscular formations, and in the corresponding waves, where the information is found in the modulation of the waves, as the spatio-temporal structures are constituted.

In conclusion, any corpuscular structure in the three-dimensional space-time has an informational equivalent, dispersed in modulated waves, correlated with the spatio-temporal corpuscular structure. The correlation between wave and corpuscle is maintained throughout the constitution of the corpuscular structures and participates in their realization. This is due precisely to the discrete, fragmentary structural information, which correlates with the continuous, ensemble information dispersed in the modulated wave resulting from the integration of all the waves corresponding to the respective corpuscles.

As we have noticed, a complex system has the ability to adapt to the external constraints generated by other complex systems or by all the systems which it relates with, which leads to emergent properties.

The final meaning and significance that lend a teleological aspect are always the preservation of the coherence of reality and its unity, at any scale and level. This objective can only be achieved through a permanent correlation between the corpuscular and spectral network, in parallel with a correlation within the corpuscular networks through the relationships and connections between the various structures in informational correspondence with the information of the whole that is in the spectral space. Thus, the permanent connection between discrete and continuous, between digital and analogue, fragmentary and holistic, is achieved, generating the coherence and unity of reality.

From this perspective, we infer that the notion of *field* is essential. Through the informational corollary that it presupposes, both at quantum level and at the other levels of reality, up to the cosmic one, the electromagnetic field is the domain of informational interrelation. It is present in the horizontal plane at the level of each scale in the relations between various forms of matter and energy structuring, but also in the vertical, transversal plane, through the emergent informational connection between various scales and levels of reality.

The movement, dynamics, transformation of matter are based on this informational balance between the corpuscular component (nuclei, atoms, molecules, macromolecules, etc.) and the wave component represented by the information modulated in the waves corresponding to those corpuscles and located in the corresponding electromagnetic field.

Information is actually coded energy, which is expressed in the shape of patterns, structure blueprints, which are initiated by attractors that operate in the phase space, between the chaotic and the structured part. The information is stored in the spectral space and expresses the patterns in the structuring of atoms, molecules, macromolecules, cells. It has a potential existence that is expressed through substance and energy under certain conditions of local coherence.

Therefore, from the quantum microcosm to our Newtonian reality, we encounter information under the same topological forms at each scale. As a field of mathematics, topology was born by formalizing the continuous transformations of geometric bodies, but then it extended to structural transformations. Topological transformations are not scale dependent; they have the same qualitative significance regardless of the level of reality, which has as a consequence the ubiquity of information, such as substance and energy, both at the level of the microcosm and at the level of the macrocosm.

It is known that atoms form molecules and macromolecules, whose spatial configuration undergoes topological changes that cause them to have certain properties. Organic macromolecules in the shape of proteins and enzymes carry information to cellular receptors in the shape of topological structures. Any modified radical determines a reconfiguration of the spatial structures, which generates a certain necessary property in the chain of metabolic transformations which, in this way, are topologically equivalent, since they have been obtained through topological transformations.

Each biochemical structure is a graph, each cellular structure is a network that forms knots and whose dynamics can be described by the network topology, which explicitly specifies the neighbourhoods of each point. All this information comes, without a doubt, from the structure of DNA. DNA itself, apart from the sequence of nitrogenous bases that form the genes, has a topologically complex structure, in agglomerations that form chromosomes, but which also influence its coding functions. The same mechanisms of information transmission from DNA to messenger RNA and ribosomal RNA and the constitution of proteins and neurotransmitters can be found in the structure and operation of the nervous system. Here also we find networks, knots, graphs, therefore topological transformations. All these are is only one part of reality, because atoms, molecules, macromolecules, etc. are the corpuscular aspects of the wave-corpuscle duality. All these structures also have a wave part, they are practically doubled by a spectral reality, of electromagnetic field.

Since the middle of the last century, Shannon and Weaver's information theory has captured solely the *quantitative* aspect, by associating information with entropy and the second law of thermodynamics. Only artificial languages and information technology have showcased the *qualitative* aspect of information.

The string theory, developed in the last four or five decades, undertakes the effort of describing, through physical-mathematical modeling, the structure of reality, at dimensions smaller than the Planck scale. Also, principles related to network topology, knot topology and multidimensional topology can be found in the field of biochemistry and biology, including that of nucleic acids, whose topological configurations and multidimensional structures actually hide informational topology, as a form of application of informational logic in the dynamics of reality.

All these fields of science and technology start from the assumption that everything that exists, from elementary particles to the cosmos, is based on information, which can be formalized in symbolic, mathematical logic. These formalizations capture both the dynamics of the information between the wave and the corpuscle, and the dynamics of the transformation of matter in the three-dimensional space, but also in the multidimensional one.

The performances of information technology and the principles on which they are based, lead to the conclusion that information is the basis of reality, in other words, the topology of information, i.e. its configuration and expression, determines the structure and dynamics of matter, of everything that exists.

5.8 Different levels of reality. New hypotheses in psychism

If we accept that topological transformations are scale invariant and that these topological transformations represent energy patterns, configurations through which information is expressed, regardless of the level of reality and scale, information should have as a substrate said topological transformations.

Obviously, there exists structural information, which, together with energy and substance, structures matter at various scales and in various states of aggregation. It is a structural information, which is realized through topological transformations in the fractal and even Euclidean dynamics, and through which information acquires diversity, and energy - a qualitative character. Qualitative variations of energy appear here: informational energy or psychical energy at mental level.

Thus, Carl Gustav Jung, in his research on the unconscious and archetypes, considers that psychical energy is a form of energy, described by qualitative features, rather than quantitative ones, as physical energy was described. Together with Wolfgang Pauli, he explored throughout their long friendship, which produced a rich body of correspondence, the parallels between space and the psyche, the atomic nucleus and the Self (C.G. Jung, *Atom and Archetype: The Pauli / Jung Letters*; D. Lindorff, 2004; Jung, 2013).

Starting from Pauli's interest in the analysis of dreams, their conversations and correspondence raised fundamental questions about the nature of reality, viewed through the double lens of physics and psychology. Each of them used the tools of their own expertise to explore the boundary between the known and the unknown, and together they found common ground in the analogy between the atom, with its orbiting nucleus and electrons, and the Self, with its conscious central ego and unconscious medium. In his posthumously published work, Jung wrote:

> We do not know whether what we on the empirical plane regard as physical may not, in the Unknown beyond our experience, be identical with what on this side of the border we distinguish from the physical as psychic. Though we know from experience that psychic processes are related to material ones, we are not in a position to say in what this relationship consists or how

> it is possible at all. Precisely because the psychic and the physical are mutually dependent it has often been conjectured that they may be identical somewhere beyond our present experience, though this certainly does not justify the arbitrary hypothesis of either materialism or spiritualism (2013).

Four decades before the physicist John Archibald Wheeler (who coined the term "black hole") made the statement "this is a participatory universe and the participation of observers gives rise to information", Pauli planted the seed of a great question:

> Modern microphysics turns the observer once again into a little lord of creation in his microcosm, with the ability (at least partially) of freedom of choice and fundamentally uncontrollable effects on that which is being observed. But if these phenomena are dependent on how (with what experimental system) they are observed, then is it not possible that they are also phenomena (extra corpus) that depend on who observes them (i.e., on the nature of the psyche of the observer)? And if natural science, in pursuit of the ideal of determinism since Newton, has finally arrived at the stage of the fundamental "perhaps" of the statistical character of natural laws ... then should there not be enough room for all those oddities that ultimately rob the distinction between "physics" and "psyche" of all its meaning...?

Thus, Pauli and Jung arrived at the concept of *synchronicity*, which constitutes the final dependence between the observer and the observee, pitting it against synchronism. Jung was the one who gave the final form of the definition of synchronicity:

> Synchronicity could be understood as an ordering system by means of which "similar" things coincide, without there being any apparent cause [...]
>
> Modern physics, having advanced into another world beyond conceivability, cannot dispense with the concept of a space-time continuum. Insofar as psychology penetrates into the unconscious, it probably has no alternative but to acknowledge the "indistinctness" or the impossibility of distinguishing between time and space, as well as their psychic relativity. The world of classical physics has not ceased to exist, and by the same token, the world of consciousness has not lost its validity against the unconscious... "Causality" (...) formulates the connection between events and illustrates them as cause and effect. Another (incommensurable) approach that does the same thing in a different way is synchronicity. Both are identical in the higher sense of the term "connection" or "attachment". But on the empirical and practical level (i.e., in the real world), they are incommensurable and antithetical, like space and time [...]
>
> I would now like to propose that instead of "causality" we have "(relatively) constant connection through effect," and instead of synchronicity we have (relatively) constant connection through contingency, equivalence, or "meaning".

Pauli relied by introducing the crucial concept of *scale* in thee considerations on synchronicity:

> Synchronicity should be defined in a narrower sense so as to comprise effects that only appear when there is a small number of individual cases but disappear when there is a larger number (...) not only is the term "meaning" not the right one here (...) but also the concept of the (psychic or psychoid) archetype cannot be used so lightly in the acausalities of microphysics...

Starting from these crucial observations, new paradigms have gradually emerged in scientific research regarding the nonlinear approach to reality, the reconsideration of the cause-effect relationship, the local-global relationship, which highlight the dependence on the scale of observation of phenomena.

*

In closing, we would like to highlight the following conclusions, which refer to the application of the complex systems theory, which can lead to new hypotheses on the structure of psychism and its operation. Thus, the dynamics between the two components, namely the structured, acausal, differentiable, Newtonian component on the one hand and the potential component, unstructured, causal, on the other hand, is found in the psychoanalytic conception of the psychic system, later reformulated in various forms in the theories of psychism, namely the *unconscious* (id), the *subconscious* (superego) and the *conscious* (ego), as we find them defined in Freud's psychoanalysis.

According to him, the superego is considered to be partially conscious, partially unconscious and to contain, in Freud's view, the totality of norms, rules, social and moral laws, which are built in the mental space through education, and representing elements of law and faith, practically the core of beliefs through which information from the medium is processed.

From the perspective of complexity theory, this superego could be associated with the space of phases, where these beliefs and values help to process information into conscious mental structures. Unlike Freudian theory, complexity theory would assume that this (superego) level contains not only social and moral values and norms, but also patterns of processing of Newtonian laws, related to space, time, motion, as well as other rational precepts that science has given to modern man in order to help him adapt to the medium.

The current trend of associating neural networks in the wider expanse of network science, also allows a physical-mathematical formalization of the phenomenology of neural networks, as well as the construction of information-symbol models. The extrapolation of the emergence to physical systems, to biological systems and to the systems of psychism can generate new models that can be applied also to the concept of consciousness.

Advances in neuroscience have left an unanswered central question of psychism: what is consciousness? Modeling the psyche from a computational perspective has helped the development of cognitive neurosciences, but has also shown their limitations, of which the definition, description and operation of consciousness remain essential. From René Descartes, who presented the problem of psychism in the form of brain-mind dualism, to David Chalmers, who defined *qualia* as the hard, weighty problem of neuroscience research, numerous hypotheses and theories have been issued in order to comprehend the phenomenon of consciousness. Specialists in neuroscience, such as Giulio Tononi or David Eagleman, ultimately consider consciousness as an emergent phenomenon of all processes that take place in the brain (Massimini and Tononi, 2018; Eagleman, 2018).

Nobel laureate Roger Sperry also claims that the "mysterious" features of consciousness are immaterial, strongly emerging features of the brain:

> [...] consciousness was viewed as a dynamic emergence of brain activity, neither identical with nor reducible to the neural events of which it is composed primarily. Moreover, consciousness was not viewed as an epiphenomenon, inner aspect, or other passive correlate of brain processing, but rather as an active integral part of the brain process itself, exerting strong causal effects in the interaction of brain operations. In a leading position at the highest levels in the hierarchy of brain organization, subjective properties have been known to exercise control over biophysical and chemical activities at subordinate levels.

Black hole physics and the astrophysics of recent years, as well as the Big Bang theory, have argued in support of the idea that the basic principles of quantum mechanics are found in the structure of the universe. Moreover, according to some recent theories, the phenomenon of gravity itself would be, in itself, an emergent process (Verlinde, 2017).

Therefore, the meaning of structuring the nature of consciousness is found in the shape of the direction of evolution and teleological purpose, of integration in the ensemble of systems and in any complex system, at all scales. The fractal geometry of reality confirms the older intuitions related to the structuring of the universe, which would have the same principles of operation and constitution, regardless of scale.

The phrase *"In every grain of sand the whole universe is found"*, so often encountered in various contexts, probably hides a deep truth, because the fractal structure of the universe, with the fractal property of self-similarity, seems to lead to the holographic universe hypothesis of David Bohm (1989), which would turn this phrase into a general ontological principle.

In fact, it has been more than half a century since neuroscience researchers arrived at the conclusion that the manner of transmission of signals from analyzers is spectral. Thus, at the level of the visual analyzer perception, the signal is transmitted to the occipital cerebral cortex in a spectral manner. Tactile transmission is also spectral (de Valois and de Valois, 1993). All these data have provided arguments in support of a theory of the holographic or holonomic brain, according to which, in the spectral space associated with brain structures, there are conditions for structuring a holographic system, which explains both the enigma of memory structuring and the connection with cognition and affectivity (Pribram, 1986). The description of fractals and of their role in structuring reality came to support this fractal approach, especially since the very architecture of the brain, brain blood vessels and of the entire body is based on a fractal algorithm and a fractal geometry.

Complex systems can be identified at various scales, and the method can also be applied to the imaginary space. In the imaginary space, time has a property of spatial dimension, which allows it to move in both directions on its axis. The brain can imagine contexts that we do not encounter in physical reality, such as mathematical concepts that were initially imagined, dreamed, then demonstrated in reality - or at least some of them were, such as quantum theory, relativity theory, fractal theory. All this was first imagined, then described, before being revealed with the help of the computer in the physical reality. This is why, as seen in the previous chapter, the role of creators, be they writers, painters, or musicians, is essential - due to the boldness of the imagination and the breadth of visions that, more than once, foreshadowed tangible discoveries.

As we have already pointed out, the unpredictable, causal, unstructured, potential part of the structure of complex systems is found in the structure of the spectral field associated with the corpuscle in the structured, causal, Newtonian, predictable part. The discontinuity of reality described by Max Planck as the quantum of energy, and by Dennis Gabor (1946) as the quantum of information, the non-differentiability specific to fractal dynamics, as well as the property of complex systems, with deterministic chaos, all due to a continuous interference between physical and complex reality, through the spectral field. Depending on the conditions of the local field, of the forces and of the structure, of the scale, under the action of the attractors the information is taken over, information being basically patterns of qualitative energy, diversified by topological transformations.

In the structure of complex systems there is a potential part with a chaotic aspect and a structured, causal, Newtonian part, as well as different intermediate phases. It follows that a certain uncertainty exists in the entire structure of reality. Moreover, we find the uncertainty principle (Heisenberg, 1949) in the communication theory (quantum of information) (Gabor, 1946).

We can state that the nonlinear, potential, seemingly chaotic part corresponds to the unconscious, that the structured, causal part corresponds to the conscious, and that the intermediate phases, as well as the structures that process information from both reality and the unconscious, are represented by what Freud called superego. This is not just a court of censorship of the impulses and desires, with only moral significance, but we find therein the processing structures of the representation of physical reality, such as three-dimensional vision, synesthesias, i.e. the processing that structures imaginary reality according to our analyzers ability to perceive reality.

In complex systems, the chaotic part is structured through attractors, depending on the constraints of the system. As an example we could take the manner in which certain physiological needs generate during dreaming a certain dream structure (thirst, hunger, sexual abstinence, etc.).

These mechanisms are also evident in the daydreaming, when fantasies are much more adapted to the conditions of reality. Thus, the violation of the physical laws and of causality no longer occurs, but they are modified in the direction of the subject's desire-aspiration. During wakefulness there is also a dynamic, with the chaotic part potentially unconscious in the background, which allows access to information, memories and logical connections.

Recent studies on the role of the unconscious in wakefulness and in monitoring cognitive and motor activity show that there is a permanent involvement of the unconscious through various basal reactions, such as defensive reactions to a potential danger or the involvement of psychotraumas through the unconscious in current activity (such as blind sight, verbal slips, failed acts, compulsive neurotic behaviours).

The whole cosmological and biological evolution boils down to a dynamic link between chance and necessity, between diversity (or random mutation) and selection, between chaos and structuring, similar to what takes place in the human body (in which the permanent renewal of cells and tissues occurs, as well as the dynamics between inflammation (disorder) and structuring). Thus, old age, disease, epilepsy, heart rhythm disorders, can be interpreted as losses of fractal character, by the reduction of chaoticity.

Virtual projections in optics or in projective geometry can be associated so that the entire physical reality (Newtonian) to which we have access through the sensory organs, through perception, is a projection in the imaginary space. A virtual, Newtonian reality, as a projection of physical reality, is complemented by an unstructured, acausal, seemingly chaotic component: imagination, dreams, failed acts, subliminal mechanisms, the unconscious, etc., which can be associated with the acausal, potential, unstructured and non-differentiable component of complex systems, the source of inspiration, creation and access to non-Euclidean realities, to holospace.

These potentialities can be realized through patterns, such as, for example, Jung's archetypes and collective unconscious, and can be found in a logical, algorithmic, organized, systematized form in everything that means creation, from the construction of a speech, conversation, improvisation, to the construction of new musical, artistic, scientific creations.

The chaotic, unpredictable part contains not only the Newtonian reality to which we have access, but much more, perhaps even the structure of the entire universe, at a potential informational level. The brain has access to the implicit part (hence the implicit reality of David Bohm), if we associate this part with what the classics called the unconscious. One can thus explain the capacity for mathematical, physical thinking, of reality in n-dimensional spaces, in timeless, a-spatial realities.

5.9 The brain's semantic map

The existence on the cerebral cortex of projections of the sensory and motor structure of the body of what, classically, we call the sensory homunculus and the motor homunculus, has been known for almost a century. Research on psychopathological situations, such as the phantom limb syndrome, provides arguments for a spatial projection of each body segment in the brain. The fact that, after the loss of a segment, this cerebral representation of the segment remains functional for a longer or shorter period, denotes both the existence and the persistence of these representations.

The mirror therapy applied for cases of persistent, painful and spasmodic phantom limb problems shows that the representations of body segments have a spatial character, since they can be influenced by the illusion of topological changes outside the imaginary space (Ramachandran and Rogers-Ramachandran, 2008). The fact that the brain image of the lost limb segment persists beyond the normal period after an amputation shows that certain circular reverberant circuits maintained by memories marked by pain, contracture and suffering are involved in the persistence of this cerebral spatial structure. This experimental evidence leads to the conclusion that, in the imaginary space, there is a projection of the spatial structure of our body, in which the affective processes, positive or negative, participate along with the senses and motricity, and the corresponding neuromotor plaque. Moreover, affectivity is involved in all cognitive processes, including the projection of the body and of the entire reality, at the level of the imaginary space (Davidson, 2003).

On the other hand, at a glance, the phenomena of suggestion and suggestibility as modern theories view them, are involved in Ramachandran's technique (Ramachandran and Rogers-Ramachandran, 2008) of remedying residual or complicated phantom limb syndrome. A number of studies have shown that we are willing to accept and believe, as long as there is a motivation, be it affective-emotional, or even logical, rational. In order to be able to reconstruct the action of a book or a movie, of a speech or a lecture, a virtual, imaginary reality must be built in our brain, actually describing what we call *imaginary space*.

About 30 years ago, so-called *mirror neurons* were mentioned, and they were then scientifically validated by functional MRI research, providing objective evidence for the existence of a virtual or imaginary projection of the Newtonian geometric space in which we live. The excitation of these neurons in the motor or sensory area to the actions and behaviour of others comes to support the older so-called theory of mind, which tried to explain our ability to "intuit", to feel the feelings and thoughts of others. Mirror neurons come as objective arguments in support of this theory, which psychologists have placed for many years as the basis of our relationships, communication, and of our specificity as social beings. However, they also represent a proof of the existence of spatio-temporal structures in our imaginary.

The presence in the brain of the two networks, the corpuscular network consisting of neurons, and the spectral network, consisting of the modulated waves of those neurons, structured in a spectral field, can generate new hypotheses and explanations for the operation of the brain and mind.

From the start, we have a physical description of the neural network, as a corpuscular structure that represents the brain and contains neural information (built on genetic patterns as a result of evolution), and a description of the mind, represented by the spectral field in which information is found, structured in programs, assimilated from birth by adapting to the medium, through education and culture. Thus we can describe from a new perspective concepts such as personality, which, in the classical vision, consists of two components: temperament, with which we are born, and character, which we acquire through education. The neural network built from birth on genetic patterns lend stability and specificity to personality, while the topological patterns in the spectral field lend adaptability and diversity, depending on the family, community and cultural context.

The hypothesis of the two networks and the dynamics between them may provide answers to certain puzzles highlighted by neuroscience so far. Thus, the existence of a body self-model proposed by Thomas Metzinger (2009), the phantom limb phenomena investigated by Ramachandran (Ramachandran and Rogers-Ramachandran, 2008), as well as those evidenced by experiments with rubber limbs or the phenomena of suggestion, suggestibility and hypnosis, as well as the way and the place of memory storage, all can find coherent explanations from the perspective of the hypothesis of the existence of the two networks, the neural one and the spectral one.

The state of consciousness is the result of the dynamics between the two networks that manage to integrate the various components of the brain, with information from the analyzers in the vision of the whole, that the spectral network offers. Loss of consciousness results from the loss of this connection, which is reached as a result of traumatic, thermal, electrical or magnetic shocks, etc., but also in special situations, such as seizures or anaesthesia. In the case of epilepsy, the neural network loses its chaotic component specific to any complex system, through the expansion in both hemispheres of the regular cycles generated by the epileptogenic centre (as in the case of electroconvulsive therapy). The recovery of chaoticity allows the resumption of consciousness. In the case of anaesthesia, the dynamics between the two networks is affected by the change in protein topology under the influence of aesthetic substances, the result being an altered state of consciousness depending on the place of action and the doses of anaesthetic substance used.

Whereas the connection between our terminals (computers, telephones, etc.) and the electromagnetic network is built through binary codes, at the level of the double network of the brain, the coding is represented by the three-dimensional topology of proteins. This disconnect between the two networks in localized territories, through changes in the topology (i.e. configuration) of proteins, may be involved in some diseases, such as Alzheimer's dementia, in the case of which in the early stages there are no alterations of the neural network (informational alterations in the structure of proteins could be highlighted from the perspective of an informational pathology).

Today's information technology has outlined a semantic and informational network (integrated telephony, internet and data communication system), which uses a network of millions of servers and terminals, a network backed up by a spectral, electromagnetic network, using land stations and satellites. This is a technological information model for what we are beginning to discover in the brain.

Over the last century, research has caused the science of the meanings of signs to be used in many fields of the social sciences and of humanities, as well as in natural sciences and in the information technology. Today we talk about the semantic web, semantic algorithms and semantic logic, with the aim of building programs and systems pertaining to artificial intelligence. At the same time, semantic information is a field of research of human cognition, starting from the fact that language is the expression of thought, and the study of the meaning of language is an of specifically human process analysis.

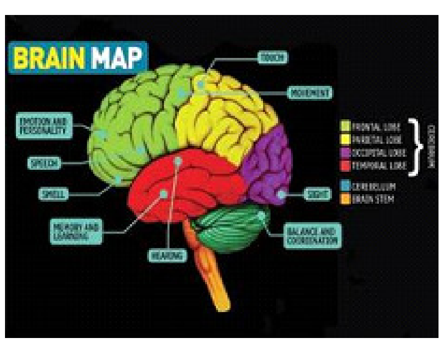
Syntax, semantics, pragmatics, as well as the hermeneutic and holistic approach are logical mechanisms that can explain higher mental processes, such as abstraction, conceptualization, generalization, symbolization and metaphor. All these have long been used in the narrative process, but they have not been analyzed in a holistic perspective related to the structuring of reality, both of the physical and of the mental reality.

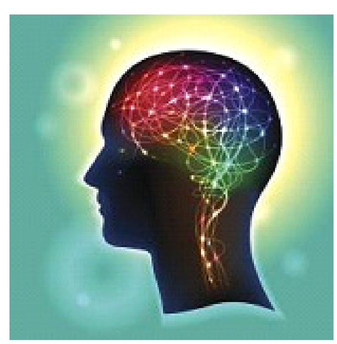
New approaches in cognitive psychology, and in neuroscience in general, focus on information and on how, starting from data, information becomes a body of knowledge able to describe reality. Beyond the quantitative aspect that information has, as shown in Shannon and Weaver's information theory, from a psychological point of view, its qualitative component is important. This qualitative component is given by its significance. Therefore, semiology and semiotics, meaning and significance are notions reexamined today from another perspective, not just the linguistic one.

Today, semantic information is a phrase analyzed by both philosophers and computer scientists (semantic information, semantic web, ontologies). The semantic aspects of information also become very important for psychologists because the structure and the way the nervous system works require this approach. Nerve structures, from the periphery to the cerebral cortex, contain overlapping nerve nuclei of increasing complexity, from the spinal cord to the bulb (medulla oblongata) and the brainstem, then to the diencephalon and the subcortical centres. Information undergoes additions, from simple binary data, combined into frequencies and amplitudes, to increasingly complex information structures, which, at the level of the cerebral cortex, create images through mapping, which are then used for our representations of reality. The meaning of language is represented in certain regions of the cerebral cortex, commonly called the *semantic system*. So far, a small part of the semantic system has been mapped, the semantic selectivity of most regions remaining unknown.

In 2016, Jack Gallant of the University of Berkeley conducted a study published in the journal *Nature*, in which he systematically mapped semantic selectivity in various regions of the cortex using "voxel-wise" in functional MRI research. The subjects were exposed to narratives that they listened to for several hours, and the organization of the semantic system in stable patterns from one individual to another was highlighted. Generative narrative models were then used to create a detailed semantic atlas. The results suggest that many areas of the semantic system represent information related to specific semantic domains or groups of related concepts, which are positioned in brain areas related to the multiple meanings that the notions and concepts can have.

The aim of the study was to structure the way in which the brain represents the "semantic content" of language. Most previous studies of language and the brain had been based on isolated words and sentences. Gallant used narrative scenario stimuli because he wanted to outline the full range of semantic concepts in a single study. This made it possible to make a semantic map for each individual, in order to highlight which specific areas of the brain react to words that are similar in meaning or semantic content. Another aim of this study was to create a semantic atlas by combining data from multiple subjects, showing which parts of the brain represented similar information, but in different contexts / thematic areas. The study did not aim to test just a single hypothesis or ask a simple question. The purpose was to have an exhaustive image of the representation of meaning, or of semantic information in narrative language, across the entire cerebral cortex. The resulting maps show that semantic information is represented in complex patterns distributed across several broad regions of the cortex. Moreover, each of these regions contains many distinct areas that are selective for special types of semantic information, for example people, numbers, visual properties, or places. It has also been discovered that these cortical maps are relatively similar in different people, down to the smallest detail.





These semantic maps provide for the first time a detailed map of the manner in which significance is represented on the entire surface of the human cortex. We find that language, instead of being limited to a number of areas of the brain, activates fairly large areas of the brain. We also find that these representations are bilateral: the reactions in the right cerebral hemisphere are about as strong and varied as the reactions in the left hemisphere.

The discovery of this semantic system of the brain, with the simultaneous stimulation of many different areas of both cerebral hemispheres (in the case of polysemantic notions) implies, in our opinion, the existence of a spectral network that allows the simultaneous activation of these loci. In fact, information technology is also working to build semantic networks necessary for translation software, but also for search engines. By designing today the global location of the servers where the semantic variants of some words are found, a very similar image to the one obtained by Gallant by visualizing the semantic system of the brain can be obtained.

From this perspective, schizophrenia could be understood not only as a phenomenon in which the imbalance of membrane phospholipid metabolism takes place, but also as an informational phenomenon in which the so-called semantic processor is altered, thus resulting in the phenomenon of verbigeration, which is a major impairment of thought and speech and consists in the stereotypical repetition of phrases, often meaningless, a situation that occurs frequently in schizophrenia.

The discovery of the semantic system of the brain is evidence of processing based on semantic logic and can explain how the narrative dimension, stories, metaphors, symbols and language and literature in general can build images that translate reality into the psychical system.

We could speak, therefore, of an “emerging semantic logic”, highlighted at the level of the wave-corpuscle duality and formulated in an increasingly more complex manner at the level of atomic, molecular and macromolecular structures. In our opinion, the continuation of research in this field, as well as the approach related to semantic logic can result in new theories related to the operation of the mental component of the psychical system.

This could solve the age-old mind-brain duality, which represents nothing but the two aspects of the same physical and informational phenomenon, if we take into account the existence of the two networks, neural and spectral, and the emergent and semantic nature of informational dynamics, which are nothing but different degrees of informational complexity.

Instead of conclusions...

In modern science in recent decades, along with the development of information technology, the role of information in the structuring and dynamics of reality is increasingly emerging. The first ideas related to the primordial role of information appeared in almost all cultures of Antiquity, being picked up over the centuries, in the creations of artists, theologians and philosophers. Due to the reductionist materialism, specific to scientific methodology, in the last three centuries this paradigm has been circumvented, without taking into account the fact that all the properties of systems, related to their structure and dynamics, were nothing but information.

Information permeates the entire physical reality and is present even beyond it, in what science calls *virtual / potential reality*, *multiverse*, or even *imaginary reality.*

Information technology, apart the progress it makes available for other technologies, has brought information to the firmament of knowledge, this being today the main concept used both in science and in everyday life. Conferences, symposia, colloquia dedicated to information have begun to be organized, with the aim to debate its role, from the quantum level to the cosmic level, with special attention paid to the human brain.

Around the year 2000, the foundations of network science were laid, which has allowed the development of artificial data networks and information globalization, but at the same time has brought a revolutionary perspective on reality, according to which, as the father of network science, Laszlo Barabási, reveals, the entire reality is a complex network of networks. These are, in fact, an expression of the structure and informational dynamics of reality and a new stage in the approach of knowledge is expected from this vision, leading to new hypotheses, new technologies, a true revival in science and, in general, in knowledge.

In the last decade, special programs for the study of the brain have begun on all continents, in an interdisciplinary approach, which aims both for a deeper knowledge of brain function, and for a revolution in information technology, by creating quantum computers, developing robotics and enhancing human performance through technology.

One conclusion gains increasingly more ground: that, in fact, the basic element of reality, the primordial atom sought by entire generations, is nothing else but information, with its basic unit, the bit, since, as John Wheeler was saying, "*it from bit* symbolyzes the idea that every item of the physical world has at bottom - at a very deep bottom, in most instances - an immaterial source and explanation; that what we call *reality arises in the last* *analysis from the posing of yes-no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and this is a participatory universe*". (1989)

This is a revolutionary conclusion for the science of the twentieth century, and, apparently, a necessary one of the science of the twenty-first. However, we must not overlook the fact that the sacred texts contain, in their essence, this truth.

> *In the beginning was the Word, and the Word was with God, and the Word was God. He was with God in the beginning. Through him all things were made; without him nothing was made that has been made. In him was life, and that life was the light of all mankind...*
>
> (John 1:1-14)

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Chapter 6

Knowledge - discovery or revelation?

The only true wisdom is in knowing you know nothing.
Socrates

To know that you do not know is the best.
To think you know when you do not is a disease.
Recognizing this disease as a disease is to be free of it.
Lao Tzu

Robert Reid, *Knowledge* (1896)

6.1 On knowledge... or, from lightning to DNA and, maybe, *beyond...*

Knowledge - is that discovery or revelation?

Perhaps, considering things at a higher level of "reality", this paradox disappears? Or, on the contrary, perhaps we shall accept that the human brain will not evolve enough to discover its own origins. Who gives us access to knowledge? Intellect, imagination or intuition? All of these together, in a still undefined concept?

What is the way in which the imaginary can be involved in the process of knowledge? Can the reason/spirit disjunction be taken to another level, through the spiritual-imaginary-rational triad, in which the imaginary, initially a gap between the intuitive approach and science, functions as a bridge between them? Man is creating more and more new things, but unfortunately he has fewer and fewer new thoughts...

In his 1983 reference book, *The Modularity of Mind*, the philosopher Jerry Fodor stated that there exist "thoughts that are beyond our comprehension". How can we ask ourselves such questions, though?

Philosopher Colin McGinn believes that the reason why some philosophical problems (such as the relationship between mind and matter, or how the physical processes in our brains lead to the emergence of consciousness) prove unsolvable, is that the answers are simply inaccessible to the human mind. McGinn is convinced that, in fact, there is a solution to such problems, including the relationship between mind and matter or body, except the human brain will never find it. Some researchers claim that this is already true of theories such as quantum mechanics. Richard Feynman states: "I can say with certainty that no one understands quantum mechanics." Does it appear that we are "cognitively closed" to the quantum world?

On the other hand, psychologist Steven Pinker argues that, "if our ancestors did not need to understand the universe to spread their genes, why would natural selection have given us a brain capable of doing this?"

The human mind, implicitly the brain and consciousness, is the greatest mystery of the Universe, of humanity and of each of us. The brain is the only organ that studies itself, the only organ that raises the problem of its functioning... In the area of neurosciences and transpersonal psychology, the ability of the matter to mirror itself through the human brain is considered today to be the most challenging subject in the world of science.

We can trust that the way we think, the way we represent and perceive reality represents reality itself, but this is, as Plato described it, only an apparent reality, because we are limited by senses, prejudices, finitude... Do we thus enter in a vicious circle, or do we filter everything through an endless series of mirrors? For instance, Schopenhauer's idealism was expressed in his famous formula: "The world is my representation", and his belief that all objects of experience are dependent, for their existence, on the brain, or on a knowing subject, was influenced by Kant and by George Berkeley:

> *"... if accordingly we attempt to imagine an objective world without a knowing subject, then we become aware that what we are imagining at that moment is in truth the opposite of what we intended, namely nothing but just the process in the intellect of a knowing being who perceives an objective world, that is to say, precisely that which we had sought to exclude. For this perceptible and real world is obviously a phenomenon of the brain; and so in the assumption that the world as such might exist independently of all brains there lies a contradiction."*
>
> (Schopenhauer, *The World as Will and Representation*)

So, why do we think the way we think? What exactly generates the ideas of the beginning and of the end, of 0 and 1, of everything and nothing, of irreducibility, indivisibility, of minimality... of atomicity? Is it because of our tendency to fragment, to parcel, to divide?

> "Here I stand, atoms with consciousness, matter with curiosity. An universe of atoms, an atom in the universe."
>
> Richard Feynman

But how many types and forms of knowledge and truth do we "know"? Knowledge can be common, scientific, philosophical, political, legal, etc. We can also talk about empirical knowledge and theoretical knowledge, direct (immediate) knowledge and intermediate knowledge, tacit knowledge and explicit knowledge, a priori and a posteriori knowledge, etc.

Is the way our brain is built responsible for all these divisions, or is there something else beyond this level, something that gives us the impetus, the desire, the aspiration, the need to finally integrate things, after having initially fragmented them? This seems to be the purpose of transdisciplinarity that we are going to evoke again in this chapter and without which we consider that knowledge cannot be conceived.

6.2 On self-knowledge

He who conquers himself is the mightiest warrior.
Confucius

The awareness of being alive, as the first manifestation of knowledge, triggered the history of man and his world, the entire civilization and culture. Unfortunately, however, human culture, when based on appearances - as Yuval Harari observes in *Sapiens - A Brief History of Humankind* and in *Homo Deus: A Brief History of Tomorrow*, can be confusingly artificial.

The sensible-latent distinction was the starting point for contemporary psychology. Thus, in the myth of Plato's cave, to which we referred above, we find as *sensitive* - the shadows on the walls of the cave, and as *latent* - what they deduced as existing in the real outside world. In the psychoanalytical method developed by Freud, based on the myth of the cave, we also find the *sensitive* - the dream, as we remember it in the morning, and the *latent*, which represents the meaning of the dream...

The philosopher Plato famously pointed out the need for a distinction between knowledge and true belief in the *Theaetetus*, leading many to attribute to him a definition of knowledge as "justified true belief". In the process of knowledge, an important part is represented by the self-knowledge, which usually refers to a person's knowledge of their own sensations, thoughts, beliefs, and other mental states.

From a mental and moral point of view, self-knowledge is the first step in knowing the world at large. Not coincidentally, Eastern and Western cultures claim essentially the same thing, namely that the purpose of life is self-discovery, self-knowledge. This is also because knowing the other and the world in general begins with self-knowledge. Although we are separate individuals, we are (inter)connected with everyone else, in a vast network in which, for each of us, the external, concrete world is a reflection of our own inner universe. This allows knowledge, but also recognition in others, or of the others in us..., a vast network of "mirrors" to the inside and outside. Is it a coincidence that these are key concepts in mereology, a subject we approached in previous chapters?

In the history of psychology, the method of introspection has long dominated, introspective psychology being a way of knowing the self, which starts from the idea that man can have direct access to the knowledge of his own psyche. David Hume famously expressed skepticism about whether we could ever have self-knowledge over and above our immediate awareness of a "bundle of perceptions", which was part of his broader skepticism about personal identity. Or, from another perspective, what does it mean to know yourself, is it you being the subject of your own subjectivity?

Each of us has, along with positive aspects, a characteristic negative aspect, an inner tendency, called "specific compulsion". This is rooted in the idea, in the false image we have of ourselves and which greatly influences our behavior. Thus, the specific compulsion prevents us from understanding ourselves, from being aware of our deep motivations, so that we can objectively evaluate the tensions of our own personality.

It is given by the presence of a dominant psychic tendency, by an irresistible force, especially when it remains hidden, unconscious. This is not a mere obsession or a fixed idea or conscious concern, but rather the dominant force of a certain behavior. The identification of this personality compulsion consists in bringing to light a defensive mechanism, generally hidden, subconscious. Its roots are in layers of the personality so deep that they are almost imperceptible. Based on a strategy of self-defense and self-protection, compulsion is fundamentally a way to avoid, to hide a certain unwanted state we face. Thus, unconsciously, everyone comes to believe that it is his compulsive mechanism that makes him superior to the others.

Authentic inner knowledge is transformative, it changes our perceptions of everything, it opens the way to consciousness. It is our evolution to finally get to know what *I am* means. It is a fascinating journey inside the being, towards our wholeness, in search of the true inner self, with all its meanders, with immense consequences on the self-image, on others, on the world, on spirituality.

Unlike all other types of knowledge, spiritual knowledge is, the *actual* knowledge, in a "reality" where time - without which our existence cannot be conceived - does not exist. But how can we *know* such knowledge? And of what is it the knowledge? We should not expect an answer. The important thing is, as Nicu Gavriluţă says in his Afterword, the road, the state of travelling to (in) a "reality" that frees us from limits, closure, finitude, time and space. These are the apparent paradox, the apparent tautology. Bounded by our own finitude, we travel along an infinite path to ourselves and to the essence, towards the... One, because the essence of man is beyond time and space...

6.3 External knowledge On scientific knowledge and the necessity of a transdisciplinary thinking

In his work, *On the Trinity*, St. Augustine distinguishes between *scientia* and *sapientia*, science and wisdom. Science (*scientia*) is knowledge of the outside world, while wisdom (*sapientia*) is knowledge of the inner world and the eternal reality. Hence two diametrically opposed ways: in the first case we reach reality through the *senses*; in the second, by *contemplation*. Through the Fall, man lost his *sapientia* and was left with *scientia* alone...

The term "knowledge" is difficult to understand when we want to define it. This is why "knowledge" has been reconstructed as a cluster concept that points out relevant features but that is not adequately captured by any definition. Ludwig Wittgenstein sought to bypass the difficulty of definition by looking to the way "knowledge" is used in natural languages. He also observed, following Moore's paradox, that one can say "He believes it, but it isn't so", but not "He knows it, but it isn't so". He goes on arguing that these do not correspond to distinct mental states, but rather to distinct ways of talking about conviction. What is different here is not the mental state of the speakers, but the activity in which they are engaged.

As long as knowledge can only be situated in forms of time, it is doomed to remain truncated and to manifest disjointly. Knowledge's lack of unity is expressed into different forms of knowledge. Fragmented by the cutouts that allowed its manifestation, knowledge is - whatever type of knowledge we talk about - incomplete, subjective, limited and fragmentary and, in most cases, it is not possible to understand exhaustively a specific domain.

Scientific knowledge, especially in the field of physics, has reached an increasingly obvious stalemate, as noticed, very disappointed by the state of affairs in fundamental physics (especially in elementary particles physics and in cosmology), Sabine Hossenfelder, in her book *Lost in Math: How Beauty Leads Physics Astray*. Thus, in the last half century, a number of tempting ideas have appeared in fundamental physics (such as supersymmetry theory, string theory, etc.). Unfortunately, none has been experimentally confirmed so far, as there is a lack of experimental data, the obtaining of which would require very high energies.

Once again, one sees, paradoxically, how subjective scientists can actually be, in the desire to obtain "beautiful" theories, perfect, unitary, even ultimate, and how human science is, despite the image we usually have of it. In modern thinking, in the disciplinary approach of scientific research, the space between disciplines and outside the disciplines can be likened to the vacuum in classical physics, which is lacking, as we know, or believe, in content.

Transdisciplinarity, as a form of integrated learning, aims precisely at exploring space not only inside, but also between and outside disciplines, a space that, like the vacuum in quantum physics, unlike in classical physics, is shown to be dense, and therefore potentially investigable.

As Basarab Nicolescu stated, transdisciplinarity "will be the era of translators - of those who translate into our macrophysical language what is happening at another level of Reality". Stephen Hawking said: "I think the next century will be the century of complexity", while Fritjof Capra speaks, in the same context, about the simplistic way in which man configures his existence, referring to the deterministic concepts of Cartesian-Newtonian thinking, while quantum mechanics, the anthropic principle and the holographic paradigm open a new vision of the world, man and knowledge, the discovery of the small infinity, of Planck's quantum causing the most complex mutations since Copernicus. Reductionist simplicity is nullified by multidisciplinary complexity. "A complex multischizophrenic reality seems to replace the simple one-dimensional reality of classical thinking."

Therefore, at least in scientific knowledge, beyond the study of each scientific discipline, the interdisciplinary and transdisciplinary approach can provide a more complete and integrative vision of reality, or more precisely, of our projection on reality. We will refer to these aspects in the following, thus resuming, and completing, in some places, the issues discussed in the first chapter. So far, the development of the scientific method has made a significant contribution to how knowledge of the physical world and its phenomena is acquired.

Contemporary research paradigms have shown significant changes dictated by the evolution of the theory of knowledge, as well as by the new techniques and technologies. The hyperspecialization developed in the late 19^{th} century and in the early 20^{th} century was a stage when scientific disciplines crystallized. This allowed a positivist and analytical approach, which in the end proved to be too restrictive and simplifying. A holistic approach to the knowledge of reality from the Renaissance encyclopedists' point of view has proven to be increasingly necessary, which has led to the emergence of interdisciplinary approaches among research disciplines, allowing the integration of knowledge into a complex epistemology, which is closer to reality.

Interdisciplinary approaches have increasingly evolved into a broad coverage uniting different disciplines, but that needs to be seen together, in order to integrate knowledge of reality. In the last half of the 20^{th} century, certain theories and concepts were developed (such as fractals, chaos, nonlinear dynamics, etc.), which are recently found in the complex systems theory. This enables a holistic approach from the atom to the cosmos, including brain structure and human brain functions.

The need for an interdisciplinary approach emerged some decades ago, as it has been functioning since the time of the great discoveries at the beginning of the 20^{th} century, between physics and mathematics, then between physics and chemistry, chemistry and biology, etc. In the second half of the 20^{th} century, interdisciplinary approaches appeared in all fields, with different scientific disciplines, but also between science and art or science and philosophy.

Nowadays, physics together with quantum mechanics, biochemistry, cell biology, meteorology and cosmos can be addressed by theories that describe the essential mechanisms of functioning. There still remain phenomena of reality that cannot be covered by the scientific methodology. Art, religion and culture, in general, represent forms of knowledge that have been circumvented by science. Transdisciplinarity aims to include all of them (Nicolescu, 2002, 2012, 2014; Cilliers and Nicolescu, 2012; Russell *et al.*, 2008).

From theoretical discussions, transdisciplinarity starts to have practical consequences in the development of programs that include consortia of universities, bringing together professionals from a large variety of fields. In this chapter, we pursue a transdisciplinary exercise, involving science and religion, and an interdisciplinary one, involving disciplines and theories which appeared in the second half of the 20^{th} century (topology, chaos theory, fractal geometry, nonlinear dynamics, all of which can be found in the complex systems theory). The latter required the reformulation of quantum mechanics theories starting with the beginning of the century, based on fractality and the substance-energy-information triad.

6.4 The change of knowledge paradigms in the last century

In recent decades, research has evolved from the study focused on disciplines, to an interdisciplinary study. Thus, the notion of interdisciplinarity emerged in a much broader sense, linking different disciplines of fields of knowledge. Starting with the great discoveries at the beginning of the 20^{th} century in physics, a whole series of hypotheses and developments emerged in the fields of chemistry, mathematics, cosmology etc., but especially in technology.

Many fields of science have shown resistance to the relativistic, quantum or nonlinear approach, that physics, together with mathematics had previously theoretically described even before the 20th century.

The evolution of science in the second half of the 20th century lead to the development of fractals and fractal geometry, of topology, of the chaos theory as well as of nonlinear dynamics, which started to provide better explanations to the phenomena in various fields, previously only explained by Newtonian physics.

All these theories were grouped under what, over the last decades, has been called the science of complexity or the complex systems theory. The principles of this theory can be applied via specific properties at any scale or reality level, from the theory of strings to cosmologic models and to meteorology.

In the last decade, numerous works have been published where the attempt is to apply this theory also to biological systems, on the human body and the human mind. The evolution of research in the field of studying the brain and its functioning underwent a series of stages throughout the 20th century, 35 from the age of the great anatomical discoveries, through phrenology, to the behaviourist and now cognitivist stage, so that in the last decades neurosciences have attempted to encompass the phenomenology of psychological reality, within an interdisciplinary approach.

However, in the last years neurosciences have had to extend interdisciplinarity and also transdisciplinarity, to include specialists in quantum physics, information technology and even cosmology, along with traditional specialists in psychology, neurology and psychopathology.

This widely interdisciplinary necessity comes from the need to apply the principles of complex systems to brain activity as well. In order to do this we need to overcome the paradigm according to which psychological activities are solely the product of neuron activity, and by a detailed understanding of the functioning of the main types of neurons we will understand the functioning of the brain (the mental aspects).

The complex systems theory comes with totally different assumptions. In the complex systems formed by a great number of elements, the properties of the systems are not to be found in the sum of the properties of their constitutive elements. The property of emergence creates a link between the multitude of components and the properties of the complex system. As a result, even if we were to describe all the properties of all neurons, we will not be any closer to understanding the mental aspects of the brain.

On the other hand, an approach to science from the perspective of theology was a less used solution, even though a series of authors, with both scientific and theological training, attempted to bring both fields to a common, non-contradictory line; this attempt takes also an institutionalized form, as the Vatican has theologians who are specialized in exact sciences.

The apparent contradiction and competition between theology and science is due to the two currents of opinion: deism, which considers that everything is explained through an omnipresent and all powerful Creator, God the Creator Who, by divine mercy, maintains and upholds nature, and the other opinion, atheism, which appeared in the 19^{th} century and is determined by the mechanist way of thinking, that was specific to the then scientific theories, marked by Newton and Kepler's views, in which the Universe is a great autonomous mechanism in its functioning. The same causality principles, determinism and linearity, were to be searched and discovered in all empirical fields, man himself being a complicated mechanism, yet a wonderful one (the man-machine).

At the beginning of the 20^{th} century, the atheist current gradually underwent, through discoveries in physics, great fractures. The clear and deterministic world of Newtonian physics was replaced by unpredictability, nonlinear dynamics, a-causality and a series of nonintuitive concepts, not only for the common person, but also for scientists.

The theories of the second part of the 20^{th} century, chaos theory, fractal theory, the theory of nonlinear dynamics, which constituted the science of complexity, all come with a model of reality, at all its scales, that is completely different from the model of the classical period of science.

In this model, unpredictability, acausality, aspatial and atemporal realities are found in nonlinear dynamics, with the structured, causal part, with the type of information that we customarily saw described by Newtonian theories and which represent the so-called objective, conventional and current reality. Though the process was not too obvious, in less than a century, the certainties that science had been accustomed to offer people came to be so relative that the empirical phenomena studied always needed interpretations from different gnosiological perspectives.

These new ontological problems raise epistemological questions, and they require the understanding of phenomena to have more and more interpretations of a metaphysical nature, as it was the case with the ancient Greek philosophy or in the German classical philosophy, as well as in oriental philosophical-religious views, in Taoism, Buddhism, for instance. Not accidentally, specialists from quantum physics (among whom the first was Fritjof Capra, 1975, with his Tao Physics) directed their search towards the approach of these conceptions in order to understand the phenomena of quantum physics.

Phenomena such as complementarity, non-localization, Heisenberg uncertainty relations from quantum physics, which are to be found under equivalent forms in the unpredictability and nonlinear dynamics of the complex systems, have forced the way to interpretations which should provide them with coherence. In spite of conceptual difficulties and of their character, which is non-intuitive for the human intellect, they can acquire coherence from a metaphysical interpretation and, why not, from a theological one.

We get back, in the following, to some considerations to which we have also referred in Chapter 5, and which emphasize the importance of axiomatic systems in the process of scientific knowledge, and not only.

6.5 The axiomatic systems in the scientific knowledge and in the cognitive perception of reality

Generally speaking, axiomatization appears like an *ars inveniendi*, a crucial stage in the knowledge process. The axiomatization guarantees the abstraction, the generality, the systematicity and the exhaustivity of this process.

Based on logic, an axiom, or postulate, is essentially a statement considered to be obvious. Axioms and postulates are supposed to be true without any proof or proof. Basically, something that is obvious or stated to be true and accepted, but that has no evidence for it, is called an axiom or a postulate. Axioms and postulates serve as a basis for deducing other truths.

However, there are some differences in the nuance between the two concepts, captured from the beginning by the ancient Greeks. While axioms are independent hypotheses common to all branches of science, the postulates are strictly related to private science. Unlike axioms, postulates capture what is special about a particular structure. For axioms it is impossible to derive from other axioms, but the postulates are probable in axioms. Axiomatization, as a process in itself, is therefore essential to scientific knowledge, while in the case of other types of knowledge it may prove to be irrelevant, even undesirable. Thus, in psychology for example, the concept of axioms is not very relevant, since axioms arise in formal systems that employ proofs. Psychology is not a formal system and the only real formal systems are mathematics, logic and computer science, which are all closely related.

Initially, the term axiom was used in the sense of "to evaluate, to appreciate, with reference to a commodity", or, in another context, "to judge with dignity, to value someone for his dignity". Aristotle is the one who outlines in Metaphysics the meaning we recognize and use today, especially in mathematics: "obvious principle in itself, the basis in a demonstration".

The greatest impact on science and knowledge is attributed to the Euclidean axiomatic system, which is still used nowadays, although it is completed by the non-Euclidean geometrical axioms. Hilbert set himself a goal to build a complete system of axioms in mathematics, but was stopped in his endeavor by the incompleteness theory formulated by Gödel.

In mathematics, an axiomatic system is a set of axioms from which some (or all) axioms can be used in conjunction to logically derive theorems. A mathematical theory consists of an axiomatic system and all its derived theorems. An axiomatic system is called consistent if it lacks contradiction, i.e., the ability to derive both a statement and its denial from the system's axioms. In an axiomatic system, an axiom is called independent if it is not a theorem that can be derived from other axioms in the system. A system is called independent if each of its underlying axioms is independent. An axiomatic system is called complete if for every statement, either itself or its negation is derivable.

Let us observe that not every consistent body of propositions can be captured by a describable collection of axioms. A set of axioms is called recursive if a computer program can recognize whether a given proposition in the language is an axiom. According to Gödel's First Incompleteness Theorem, there are certain consistent bodies of propositions with no recursive axiomatization. Typically, the computer can recognize the axioms and logical rules for deriving theorems, and the computer can recognize whether a proof is valid, but to determine whether a proof exists for a statement is only soluble by "waiting" for the proof or disproof to be generated. The result is that one will not know which propositions are theorems and the axiomatic method breaks down. An example of such a body of propositions is the theory of the natural numbers. Stating definitions and propositions such that each new term can be formally eliminated by the priorly introduced terms requires primitive notions (i.e., axioms) to avoid infinite regress. This is called the axiomatic method (Hazewinkel, 2001). A common attitude towards the axiomatic method is logicism. In Whitehead and Russell, 1963, it is shown that all mathematical theory could be reduced to some set of axioms.

Mathematical methods developed to some degree of sophistication in ancient Egypt, Babylon, India, and China, apparently without employing the axiomatic method. Euclid of Alexandria authored the earliest extant axiomatic presentation of Euclidean geometry and number theory.

Many axiomatic systems were developed in the 19^{th} century, including non-Euclidean geometry, the foundations of real analysis, Cantor's set theory, Frege's work on foundations, and Hilbert's "new" use of axiomatic method as a research tool. For example, group theory was first put on an axiomatic basis towards the end of that century. Once the axioms were clarified (that inverse elements should be required, for example), the subject could proceed autonomously, without reference to the transformation group origins of those studies.

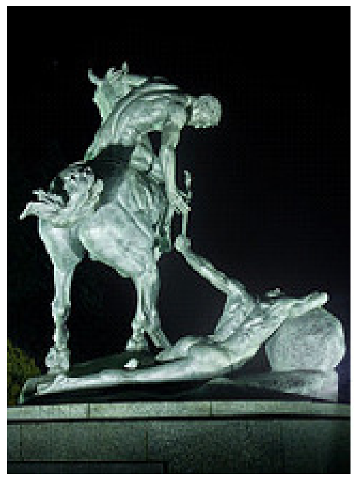
Classical physics is generally concerned with matter and energy on the normal scale of observation, while much of modern physics is concerned with the behaviour of matter and energy under extreme conditions or on a very large or very small scale. For example, atomic and nuclear physics studies matter on the smallest scale at which chemical elements can be identified. The physics of elementary particles is on an even smaller scale since it is concerned with the most basic units of matter; this branch of physics is also known as high-energy physics because of the extremely high energies necessary to produce many types of particles in particle accelerators. On this scale, ordinary, common sense notions of space, time, matter, and energy are no longer valid. The two chief theories of modern physics present a different picture of the concepts of space, time, and matter from that presented by classical physics.

6.6 Open conclusions

The transdisciplinary approach appears as a necessity related to the compartmented and unilateral character, specific to scientific knowledge, with the multitude of disciplines that have emerged over the years. The cross-cultural approach is necessary in order to underline the presence of the same themes, concepts and ideas, found in practically most major cultures, from ancient times to the present day. What is specific to Western culture and has generated the culture of modernity is the character of scientific knowledge, based on mathematization and experimental verification.

Mathematics, seen as a form of knowledge, was promoted by Renaissance encyclopedic intellectuals, but its premises can be found as far as the ancient world, especially in Greek culture, which imposed axioms and theorems, facilitating calculation in practical problems. Thus, it was possible to separate fictionalization from reality, through verification by mathematical logic and experimental tests. In this manner, the way for a certain type of knowledge was opened, which was the basis for the development of technology and which allowed the construction of tools that extended and enhanced our capacities to know Reality. But scientific advances in recent centuries have led to the neglect of other forms of knowledge.

Cross-cultural analysis demonstrates however that, at human level, there are similar forms of understanding various concepts and notions, with definitions and descriptions that are similar in essence, even if they are expressed in different narrative ensembles. Many of the ancient views are rediscovered by modern science, thus raising the issue of the form of intuitive knowledge or of knowledge outside of science.



Los portadores de la antorcha (The Torch-Bearers) - Sculpture by Anna Hyatt Huntington, symbolizing the transmission of knowledge from one generation to the next

Science has corrected and specified more precisely an entire series of representations about the world of Antiquity (the shape of the Earth, the Universe, geocentrism, atomism, etc.). However, some principles are found in modern models of Reality (the Big Bang, the theory of everything, the wave-corpuscle duality, the ontological role of information). It remains a challenge to understand how intuitive knowledge works, as well as what its role may be.

Many of the great researchers of science, as well as the great creators of other fields, claim that their revolutionary ideas or creations apparently came out of nowhere, unexpectedly, after certain moments of "enlightenment", during a dream or a conversation, etc..

Unlike the religious, philosophical or artistic field, scientific methodology takes these intuitions in the shape of hypotheses, based on which, in the context of other knowledge, it builds theories, which are then verified using a physical-mathematical or computer model, to have them validated or invalidates experimentally.

Beyond these methodological aspects, some of the basic principles of modern science are found, in an intuitive shape, as having been inspired or revealed by various ancient philosophical-religious concepts. The idea of the immortal soul, for example, appeared practically with the human being development both on the plane of various religions and beliefs, and on that of (proto) scientific research, since the soul cannot be destructured, as it is not composed. One such experimentally obtained structure is the hologram, hence the holographic principle.

One of the mysteries of Christianity is represented by the dual nature of the Saviour, in whom the two hypostases coexist, God and man.

In many expressions of Christianity, knowledge is considered to be one of the seven gifts of the Holy Spirit. The Old Testament's tree of the knowledge of good and evil contained the knowledge that separated Man from God:

> "And the LORD God said, Behold, the man is become as one of us, to know good and evil..."
>
> (Genesis 3:22)

The transformation of God, eternal and infinite, into man, with a finite spatio-temporal existence, represents the essential aspect in Christian dogmas, an aspect that underlies the notions of Resurrection and transcendence, as well as the possibility of the connection between man and God. We find this principle in de Broglie's view of the wave-corpuscle duality, which underlies field theories and, in general, those of quantum physics.

Another mystery of Christianity is the Holy Trinity, in which the one God exists under three hypostases: God the Father, God the Son and the Holy Spirit. The science of the last decades highlights, in a scientific narrative this time, the primordial role of information, within the *information-substance-energy* triad.

While in terms of physical reality, epistemology has shown its usefulness and importance, things become much more complicated and difficult in the knowledge of the psychical reality, that of the soul. The difficulty stems from a number of prejudices about the nature of the psyche, which seems to be something other than what we observe in the surrounding reality.

The dual conception of the mind established by René Descartes through the differentiation between *res cogitans* and *res extensa* is preserved to this day in the vision of many researchers.

The immaterial nature of information and of the various programs we find in information technology has been an impediment to approaching psychism from a scientific perspective. While the brain is an organ made up of biological, biochemical, and physical levels, and the laws specific to each level can be applied to it, the mind was considered to be something outside of physics, something ineffable, beyond our knowledge ability.

Information technology has proven in recent years that these data packets, algorithmically structured in programs, are the functional source of various artificial structures in very complex dynamics.

The network science born from the observation of physical reality, but also of artificial computer networks has led to a current representation in which networks represent the general scaffolding of reality, which is nothing but a complex network of networks. The Internet and data networks are thus a true experimental model, useful for researching the properties, operation and dynamics of networks.

Many neuroscientists did not accept the comparison of the brain to a computer, but they currently adhere to the view that the brain, like reality as a whole, is a complex network of networks. Like any network, the brain has, in computer terms, a physical topology (hardware) and a logical topology (software). It also has the ability to reconfigure the network, store, process and learn, as evidenced by artificial computer networks. Even though the brain and the mind (hardware and software) seem to be of maximum complexity, and a whole number of phenomena specific to neural networks and, in general, to the biological ones, are still to be clarified, in principle, the mind does not seem to be something other than a computer program attached to the neural network and thus to the whole body and the whole physical reality.

This representation already manages to explain a whole series of psychological and psychopathological phenomena, but the field is just in its early days. It is possible that intuitive knowledge can be better understood and elucidated from this perspective.

We already know that genetic information contains programs that at the level of the neural network generate behavioural patterns manifested in what we call instincts, but also a number of very complex behaviours, observed and highlighted by ethologists over time, behaviours related to fight-or-flight reactions, pro-social behaviours, mating and nesting rituals, which are also present in humans, in a culturally modulated and sublimated form. Man is more or less aware of them, since the thoughts and actions that determine said behaviours seem to come from somewhere inside us, somehow intuitively.

According to the same principle, new ideas, inspiration or hypotheses in the field of science may be nothing more than the expression of the patterns of structure and functioning of our brain, the same as those encountered in physical reality.

Topology, fractality, the complex systems theory, along with the network science, are fields that emerged or developed in the second part of the twentieth century; they will allow, perhaps, the evolution of knowledge in the field of mind and psyche.

Fractal geometry and topology, with the property of scale invariance, represent expressions of energy patterns that structure reality from an informational point of view. They are found in the description and operation of networks, as basic properties, in a causal chain that crosses through the levels of reality.

Quantum agitation and the wave-corpuscle dual nature determine, in our opinion, the fractal character, which is expressed in various topological forms and configurations, within network structures. The increase in the complexity of the networks ultimately leads to the holographic (holonomic) structure, characterized by the fact that each point concentrates in itself all the information of the whole (see also Bohm, 1993). Thus, science can bring supporting arguments for man's millennial intuition about atomicity and holonomy, often expressed in the phrase "in every grain of sand the whole universe can be found".

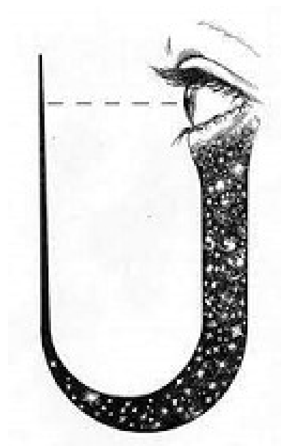
This is the ontic point of singularity, in which their existence and non-existence, their potentialities and their explicit expression overlap, here 0 is confused with 1, yin with yang, the beginning with the end.

From an epistemological point of view, everything we have discovered about physical reality and the Universe first appeared in someone's mind in the form of an idea, a challenge, a question, a hypothesis. Subsequently, verification with the help of experiments did or did not validate those hypotheses.

The issue of the connection between subject and object raised by the experiment of double-slit in quantum physics showed the participatory character of the subject, whose perception of reality presupposes the existence of a program, a software (the hypothesis, theory), which can then be found or not in reality (the experimental method).

Information technology, increasingly present in today's world, shows how important is coding, informational coherence - which allows the link between sender and receiver - for connection. The entire reality is in a permanent and total connection, all the systems are in an emerging integration, all the points of the Universe being connected to each other. Man is part of the Universe, he is connected to it, which allows him to know the Universe.

Today's informational paradigm today facilitates the understanding and confirmation of these ancient intuitions, which already existed in various cultures. But it is very well expressed today by the diagram of the physicist John Archibald Wheeler, a diagram in which man, as a constitutive and conscious part of the Universe, is able to reflect it, to know it, to integrate it and to signify it, giving it thus a teleological purpose.



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Instead of conclusions, or... opening boundaries

There are more things in heaven and earth, Horatio,
than are dreams of in your philosophy.
Hamlet, W. Shakespeare

The story of the atom, circumscribed to the few main directions proposed in this book, with innumerable bifurcations, meanders, and temporary interruptions, but which coagulates, nevertheless, into a fundamentally unitary perspective, has reached an end - as far as this book is concerned, because, as we have already pointed out in the subtitle of the book, this story does not have and cannot have an end as long as there is someone to think about it.

Questions like *Where do we come from? Where are we going? What is the point of our existence?* have always been a constant of philosophical - and not only - reflections. But an understanding of the minimal structures of reality, a representation of our composition – that would holistically traverse the existential planes, from the first "bubbles" of the vacuum to the functioning of the mind and its articulation with individual, collective, universal consciousness – and a perspective on networks of significant information have been addressed insufficiently so far. The reasons for this lack of integrative vision are numerous, but it is clear that one reason above all is the overwhelming mass of data, discoveries, interpretations from all fields of science. Equally discouraging is the number of specializations, often of infinitesimal scale, that cut up and fragment our knowledge until the big picture is completely dissolved.

No one denies, much less the authors of this volume, the legitimacy of detailed analyzes and experiments required in order to build a viable hermeneutic structure. It is just that, in order to articulate coherently and legitimately the enormous amount of information from various sources, it is equally necessary to have a certain critical distancing and an acuity of gaze that, paradoxically, would be able penetrate details and nuances in order to acquire a clarity that is rational, emotional and spiritual alike, allowing the reconstitution, albeit intuitive, of the original unit.

For thousands and thousands of years, man has believed that he was standing alone and helpless in the face of the universe and nature. An absolute loneliness, of a galactic coldness. An fear of the unknown that gradually led him to try to gather as much knowledge as possible about as few things as possible, in order to give himself the illusion of understanding and control, losing sight of *knowledge*, in its multiple singularity. Today, however, we can say that the intuitions of the great creators, the myths and symbols that span the civilizations of all times join not only hypotheses, but also the most advanced experimental scientific results in saying, fundamentally, the same thing. Our destiny as creatures prevents us from tearing apart the prime veil of the mystery of the beginning, but working together, imagination and scientific theories can lead us to that threshold. Therefore, that fragile being, apparently lost in the great infinity, as in the small infinity, can raise his forehead, fearless. Because it is not alone. Or, more precisely, because now it knows it is not alone. The explosion of that initial seed, the energetic and informational matrix of all possible worlds, led to a huge unfolding in creation, but not through segmentation and rupture, but instead through an ever-expanding network in which, from the atom to the galaxies, everything there is operates in a system of connections, interactions and interdependencies that are visible or non-visible, conscious or not, spatialized or superimposed, in a continuum whose implications at all levels we are just beginning to discern.

It is what this book is trying to shine a light on, despite its imperfection and incompleteness. An open, fluid, plastic dialogue like reality, a way out of the boundaries we build ourselves, a look that encompasses history and philosophy and physics and mathematics and literature and art and medicine in the same search for meaning, fascinating in its innumerable incarnations that communicate with each other much more and much farther than we imagine. You will not find here any definitive solution or unequivocal answer, and this is why there are no conclusions at the end of each chapter. But if these pages have at least managed to arouse dormant curiosities and generate unsuspected connections, then their purpose has been achieved. Because we all have questions and because a multi- and transdisciplinary view of reality in all its forms is not the prerogative of an isolated elite and it does not lie solely in modelling methods that are inaccessible to the many. As Stephen Hawking once said, "If we do discover a theory of everything, it will have to be largely understood by everyone, not by just a handful of scientists. And then we all, philosophers, scientists and even lay people shall be able to take part in the discussion about the reason for our existence and the Universe's. And if we do find the answer to this question it would be the ultimate triumph of human reason - for then we would truly know the mind of God".

The inefficiency of a concept is recognized, first of all, by the fact that its preservation constatly requires new definitions. This is also the case with the concept of *atomicity.* At some point, the development of any theory based on this concept (either in the form of quantum theory of measure in mathematics or in the form of quantum mechanics in physics, etc.) involves "agglomerations" of definitions and axioms (in the case of mathematics), or of definitions and principles (in the case of physics), which seem to have no other purpose than to be the topic of debate. So it was with atomicity. The apparent "revolution" on several of its levels - the view of measure, the view of the atom, the view on light, etc., and all that derived from them - the quantum theory of measure, quantum theory, etc., began to fade, remaining stranded in pure mathematical theories. The explanation lies in the fact that atomicity had especially the appearance of a "revolution", both socially and philosophically, whose effects fade as time passes: the basic structure remains in fact the same, namely that pre-dating the "revolution", and only those who represent that structure change.

We have shown in this book that nothing that the "revolution" of atomicity has brought to science (mathematics, physics, etc.) was missing from the original concept, either in what concerns light, or in what concerns the atom, or, finally, in what concerns quantification itself, which it is, in fact, a completely natural law. For instance, the only "revolution" produced by the concept of *quantum* in human thought would be, perhaps, to grant concepts their natural freedom, protecting them from distortions. That is why nature has agreed to operate both structurally and functionally, with variational principles - those of the optimal (Fermat's principle in the case of light, Maupertuis's principle in the case of classical dynamics, the principle of maximum informational energy in the case of the dynamics of biological structures, etc.).

On the other hand, taking into account certain philosophical considerations, it is said that biblical stories and parables have nothing to do with atomicity, only because they are not falsifiable, while any theory of atomicity must be falsifiable. This is the phenomenon that divides the world today: atomicity, as a "science", with its own/ vs / the Bible with its own! A disjunction that seems to be total and final. Fortunately, it is not. In other words, we raise here the question of whether atomicity as a "science" can be used as the sole guarantor for the ratification of Truth.

For atomicity, like any theory of human origin, expresses a limited truth. This is the assertion based on the historical experience of humanity, from which we have proceeded in writing this book.

The authors

An atomic story

In *A History of Religious Ideas*, Mircea Eliade offers a surprising and refreshing interpretation of Isaac Newton's personality. The famous British scientist dreamed of a *renovatio* of European culture through a unique synthesis of Christianity, hermeticism, alchemy and astrology with medicine, astronomy, mechanics and all the experimental sciences of his time. Newton (re) discovered gravity - the force that keeps planets in orbit - after the Indian scholar Bhaskaracharya had immortalized it in writing in *Surya Siddhanta*, an astronomy treatise written 1,200 years before Newton's birth. In order to homologate his cosmological system, Sir Isaac Newton also sought to discover the forces that hold very small bodies together, that is the microuniverse, by carrying out intensive and secret alchemical research in this regard. They became known to the general public much later, after the exegetes published their research on Newton.

Therefore, the founder of modern mechanics did not rule out the idea of a *secret primordial revelation*, granted by God only to a small circle of initiates. Over time, this occult teaching would have become de-sacralised, surviving under camouflage in fairy tales, legends and myths. Mircea Eliade rightly describes Isaac Newton's eighteenth-century cultural project as "the last enterprise of Christian Europe with the aim of obtaining a *total knowledge*".

Well, the atomic book of this academic quartet - Simona Modreanu, Alina Gavriluţ, Maricel Agop and Gabriel Crumpei - reminds me of such an attempt to "renew" a classical cultural theme: ***the atom***. This paper presents various perspectives in understanding and interpreting the atom (physical, mathematical, psychological, mythological, symbolic, literary, etc.).

Thus, Simona Modreanu, a literature professor, begins by ingeniously deciphering, straight from the first chapter, the presence of the ancient hermetic principle of the micro / macrocosm correspondence in the quantum interconnection and in the existence of the holographic universe. Here, the part encompasses the whole and is, in turn, encompassed by it. Then comes a scholarly foray into the atomism of the ancient Greeks of the fifth century BCE (Leucippus, Epicurus, Democritus, Lucretius) and into Eastern philosophy. There, the atom is present in the *Vedas* and the *Upanishads* - the sacred writings of Hinduism. The theme of the ultimate essence of man and reality is interpreted in specific mythological and philosophical terms: Brahman, Purusha, Ego, Self, etc.

Without playing into the hands of the current Woke "religion", Simona Modreanu points out in an inspired, bold and nonconformist manner certain little-known spiritual and cultural truths. For example, the author restores his rightful place to the Indian sage Kashyap, who clearly formulated the theory of atoms about 2,500 years before the official discoverer - the Englishman John Dalton. She also appreciates the cultural nod given by Dimitri Mendeleev to the Indian philosopher and logician Panini, who provided him with the principles of organizing the grammar of chemical elements.

Very interesting and provocative are the parallels laid out by Simona Modreanu between the Vedic *akaşa* and the theory of vacuum in contemporary physics; between Buddhist / Taoist emptiness, ether / prana and Nikola Tesla's Zero Point; between the ideas of Indian philosophy and the profane representations of these notions in the contemporary Western social mind. The ideas about *vacuum* and *ether* in the Middle Ages and the disavowal of the principles of Aristotelian logic by alchemical philosophy, etc. are then pursued. The cultural heritage of ancient Greece is invoked here, especially that of Aristotle - an author to the liking of the Catholic Church. Documented references are made to classical authors such as Aurelius, Augustine and Thomas Aquinas, Blaise Pascal and Isaac Newton. The author constantly shows a refined pleasure in deconstructing the taboos and commonplaces of textbook science.

As they are so well written, Simona Modreanu's texts offer the reader an intellectual delight that is difficult to match. Here is a prejudice-challenging phrase from the first chapter of the book: "The term quantum mechanics itself was coined in the early 1920's by a group of physicists at the University of Göttingen, three giant minds, all three Nobel Prize winners: Werner Heisenberg, Niels Bohr and Erwin Schrödinger, who were also united by one, perhaps surprising, passion. All three were avid readers of the *Vedas*; moreover, we could say that they elaborated upon these ancient books of wisdom in their own language, with modern mathematical formulas, in an attempt to understand those complex concepts that ancient Sanskrit called "Brahman", "Paramatma", "Akasha", "Atman", "Anu". "I wonder: how many of the physics teachers in Romania have heard about the *Vedas*? Hom many of them have read them or at least about them? More importantly, how many of them, while teaching physics, speak to their students about the fascinating and mysterious analogies between physics and mythology, philosophy, alchemy and hermeticism?

In order to understand more complexly, subtly and deeply the mysteries of the atom, Simona Modreanu puts them through a number of epistemological filters: holograms and fractals, transdisciplinarity and levels of reality, the logic of the included third and systemic visions, circular causality and complex thinking.

The mathematician Alina Gavriluţ, the author of the second chapter of this book, bravely tackles the atom from the perspective of "mathematical reality". She invokes, based on documentation, cosmological theories on the atom, with references to ancient cultures (Greece and India) and practices a refined and clear analysis of the structure of the atom (matter or energy?), with references to the writings of leading authors (Planck, Einstein, Leibniz, Mandelbrot). The classical theories about the atom (atomism and holism) are presented, as well as the new ones (epistemological emergence, synchronicity, *Unus Mundus*, explicit / implicit order, developed / wrapped order, entanglement, space-time continuum, holon, mereology).

The specialists will enjoy (also) the pages about the mathematical "atom", the one that preserves in formal language "the essential indestructible, indivisible, irreducible, minimal and self-similar unity". The novelty brought by Alina Gavriluţ is related to the fact that it comes with new mathematical interpretations for what we call the atom. The types of atoms in mathematical sense, the relations between these typologies and their meanings are presented. There is emphasis on the idea of the self-similarity of the atom (the part reflects the whole), a property that we also encounter in the case of fractals. In this respect, Alina Gavriluţ proposes the introduction in the specialized literature of the notions of *fractal atom* and *minimal atom*, the latter reflecting the properties of *indivisibility* and *non-decomposability.*

In his turn, the well-known physicist Maricel Agop investigate the atom of physical "reality" or the essentiality of the vacuum. Cultural references to ancient Greek beliefs and Eastern cosmogonies refer to the *ether*, this fifth element represented by all the materials that make up the universe. The essential question that concerns Agop here is *whether the ether must remain a fundamental notion in physics.* The answers given by specialists differ, and the Iaşi physicist insists on these differences. All ultimately lead to the *universal informational matrix.*

This information settles in what the authors call *general* or *individual informational pattern*, in the classical sense of *archetype.* Both contain implicit and explicit information that enters interactions. Maricel Agop's vision of the ether is profound and bold: "Matter is not primordial, there is something beyond it, so our senses do not help us in obtaining the truth!" Having a suprasensory reality, the perception of the ether requires the reactivation of pure reason. The ether must be described through a common inference, "leaving reality behind".

The *vacuum* or the *void* in the philosophies of the East is equivalent to the *whole*. Westerners are educated to represent the ether, vacuum, or Nothing in an exclusively negative register. Nothing could be more false. At most, says Agop, Nothing coincides with Everything. This thesis is of Buddhist origin. The author takes it up by formulating an assumption as interesting as it is provocative: nothingness "is extremely complex and contains mysteries that must be deciphered if we are to understand the whole universe".

In the fourth chapter of the book, Simona Modreanu returns and analyzes the social representations of the atom, often manipulated by common sense to make them fit the realm of the intelligible. This becomes possible thanks, among other things, to *objectivation* and *anchoring*. Very ingenious and suggestive are the social representations of the atom, more or less camouflaged in everyday life. Simona Modreanu's precise references are to spheres and "balls"; to the Atomium in Brussels and to the surprising figurative presence of the "atom" on the northern wall of the narthex at... Voroneţ; to art, music and the media, in various expressions and manifestations, such as the doodle Google offers Niels Bohr on every anniversary of birth (October 7), an electronic signature "that somehow resembles its atomic model". Quite unexpectedly, the author writes, is the presence of the atom in... the Quran. The holy book of Islam contains the term *dharra*, which has been translated by *atom* in the English and French versions of the Quranic text.

The same chapter contains an argumentative excursion into the world of the *linguistic atom*, with references to the mythology, religion and philosophy of ancient India. Simona Modreanu's special merit is to have noticed the *recurrence of the spherical* in the social and artistic representations of the atom (point, circle, sphere, loop, the artistic style *tondo* from 14^{th} century Florence, the painting "Salvator Mundi" by Leonardo da Vinci, Kandinsky's works and certain types of architecture). It is known, the round shape is the quintessential symbol of perfection. (The hermeneutics of the round shape is really fascinating. It can begin with the representations of the androgyne from ancient cultures and end with the camouflaged presence of this symbol in everyday occurrences).

In the final part of her study, Simona Modreanu achieves an admirable cultural foray into the *symbolism of the spherical* (point, centre) in the great literature of the world, with references to Dante's Paradise and Maurice Scève's philosophical poem *Microcosme*; to *The Other World* by Cyrano de Bergerac and to the *First Epistle* by Mihai Eminescu; to what is called *fractal literature*, with its exciting idea of parallel worlds (Franz Kafka, Jorge Luis Borges, Mircea Cărtărescu, Igor and Grichka Bogdanov, etc.). Simona Modreanu's conclusion is really subtle. Maybe one day we shall find *the smallest* thing possible (the atom?). Only then will we understand that it is *the largest* thing possible ... Or maybe not even then ... In the eyes of the divine One, opposites cancel each other out.

In the last chapters of the book, the psychiatrist Gabriel Crumpei analyzes *atomism* and *holism*, with clear and documented references to the field of psychology. After invoking Democritus' *atomism* and then Leibniz's *monadism*, he meticulously details *psychological atomism, associationism*, and *gestaltism*, before presenting with confidence and hermeneutical accuracy modern theories regarding the operation of the human mind: *information theory*, the theory of *axiomatic systems*, of *complex systems*, and of *networks*.

We know that nowadays there are new paradigms of information processing, and Gabriel Crumpei and Alina Gavriluţ pay attention to them in these last chapters of the book (artificial intelligence, cognitive modeling, neural networks).

The authors obviously assign greater importance to the *informational paradigm* within the famous substance-energy-information triad. I especially notice (also) the idea, typical of *complex systems* (fractal geometry, nonlinear dynamics), of adding to the well-known wave-corpuscle duality the element called *information*. The novelty proposed is to approach the classic wave-corpuscle issue "assuming that the motion of a particle takes place on continuous and non-differentiable curves". The movement would take place in a fractal-type space-time where the *topology of information* (its configuration and expression) is essential. The last pages of the study about *levels of reality* and the theories of *synchronicity* and of *scale*, with Jung and Pauli as protagonists, are also very provocative.

Besides, Gabriel Crumpei is convinced that *the complex systems theory* can lead to new approaches to the structure and functioning of the human psyche, reconfiguring and reinterpreting, for example, the Freudian triad - unconscious (id), subconscious (superego) and conscious (ego). However, an simple and complex question remains unanswered: What is consciousness? The possible answers are related (also) to *the brain's semantic map*, in particular to *our imaginary space* equipped with its own spatio-temporal structures.

One other idea that stands out in Gabriel Crumpei's text is that of *corpuscular network* (consisting of neurons, including mirror-type neurons) and of *spectral network* (formed by the neurons' modulated waves). Both networks are able to offer "new hypotheses and explanations of the functioning of the brain and mind", of the human personality in general. This is of decisive importance for the future. We already know that there is a "revolution in information technology, by creating quantum computers, developing robotics and enhancing human performance through technology".

In the end, the conclusion is that the primordial atom - the main topic in this book - is nothing but information, with its basic unit, the *bit*. It structures the "participatory universe" (John Wheeler) in which we all live. According to the four authors of this book, we need today a unitary, holistic, integrative vision in order to understand reality.

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The fruitful and serious academic struggle of the four professors and researchers has yielded a really interesting and stimulating result: a new and spectacular book about the atom. Their "gleeful restlessness" and the "splitting of ideas" have put them in a position to tell us, in another manner, something about the endless history of the atom. After all, it is the story that matters, not its end. As Paracelsus put it, the Philosopher's Stone is in every one of your steps. If you have not understood that, then you have not begun to understand anything yet. The story of the search for the atom is the fascinating part, not finding it. Here, quantum physics meets philosophy and alchemy. The atom exists exactly where you are prepared to perceive it. It exists precisely for *you* to perceive. It is in every one of your steps...

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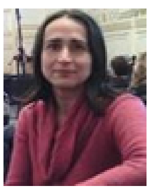

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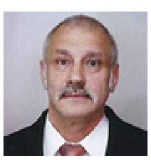

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