

De rerum (incerta) natura

A tentative approach to the concept of quantum-like

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Abstract

In recent years, the term quantum-like has been increasingly used in different disciplines, including neurosciences, psychological and socio-economical disciplines, claiming that some investigated phenomena show “something” in common with quantum processes and, therefore, they can be modeled using a sort of quantum formalism. Therefore, the increasing use of the term quantum-like calls for defining and sharing its meaning in order to properly adopt it and avoid possible misuse.

In our opinion, the concept of quantum-like may be successfully applied to macroscopic phenomena and empirical sciences other than physics when at least two conditions are satisfied: a) the behavior of the investigated phenomena show logical analogies with quantum ones; b) it is possible to find a criterion of truth based on an experiential/scientific approach applied to a probabilistic model of description of the phenomena. This is only a first, small step in the approach to the concept of quantum-like, hopefully helpful to promote further discussion and achieve a better definition.

Truth is born as a paradox

and dies as the obvious

A. Schopenhauer

1. Introduction

Since the birth of Galilean sciences, physics has been considered the most rigorous scientific discipline, relying on mathematics as the essential tool for demonstrations and discovering immutable laws of Nature from a deterministic perspective. This view is embedded in the century-old Western rationalist thought, from Aristotle through Aquinas' rational theology, the 17th-century rationalist revolution, Enlightenment, Empiricism, and Positivism. As a result, one perceives physics as a source of rock-hard certainties, a fact also favored by the naïve optimism and the faith in science permeating the end of the 19th-century. In this climate, the great physicist Lord Kelvin emblematically stated before the British Association for the Advancement of Science, in Bradford, in September 1900 that:

“There is nothing new to be discovered in physics now. All that remains is more and more precise measurement” (quoted by Alexander [1]).

It was only a brief Victorian calm before the quantum storm unleashed by Max Planck: the revolution he introduced on October 8th of the same year is known today as quantum physics.

Quantum physics was not only a new theory. Indeed, it initiated a slow cultural evolution that now, over after 120 years from its introduction, has extended far beyond the boundaries of physics to spread to other disciplines (e.g., biology and neurosciences) and every aspect of life, promising to

yield a shift of paradigm and a change of *Weltbild* (image of the world). Actually, it has led to the foundation and the inflexible certainties of the classic Western thought being dismantled and realizing that knowledge cannot be as rock-hard and immutable as formerly believed, at least if the teaching of Max Plank is not left behind.

The quantum theory stems from the concept of quantum, a term often misunderstood; it is usually perceived as “the smallest”, while it only means “an amount of”, i.e., it indicates a quantity; if this is the case, it calls for defining the thing it refers to. According to the original definition by Plank, the quantized object was energy [2]. Then, according to Einstein’s interpretation of the photoelectric effect [3], it became light (and the quantum of light took the definition of “photon” in 1926), and, following the novelty of the double nature of light, it was also extended to matter (the electron), thanks to the work of De Broglie [4]. In other words, the stuff of the quantum has evolved over time, encompassing different “things”.

2. **From *rei* to *rerum***

The Latin term *res* (from Sanskrit *rāh*, “thing, ownership, wealth”) has been widely used in philosophy to define the nature of reality, from the *De Rerum Natura (The Way Thing Are)* by Titus Lucretius Carus (based on Democritus’ atomism) to the Cartesian concepts of *res cogitans* and *res extensa*. Indeed, ontology is the study of “things” and their nature, of what exists, of universals, of properties of entities, as well as their relationship. Any *res* is generally considered to exist as a separate entity, while, from a linguistic standpoint, the term is used to name an undefined object or entity. Therefore, in this context, one can use the term *res* to deal with physical objects, using it in singular or plural as appropriate. If one introduces the concept of “reference” – namely, describes its features in the attempt to define it – what is dealt with are attributes of the “thing”, justifying the use of the Latin *res* in the genitive, where the singular and the plural form have different meanings. Here, the term *rei* can indicate the object of the quantity initially defined by the word “quantum” – i.e., what properly belongs to quantum physics – while the term *rerum* (like in Lucretius’ poem)

entails a broader meaning encompassing the logic of quantization in other contexts. Therefore, it does not pertain to a single object but involves other entities, including matter, and may also extend to other things belonging to the macroscopic reality when the *rerum* behavior shows some likeness with quantum phenomena in a broader sense.

According to Lucretius, when dealing with the *rerum* definition ‘*without considering the intervention of the gods*’, the aim is the rational explanation of natural phenomena. Since physics (from Greek: φύσις) is the first and fundamental reality – principle and cause of all things – and the pre-Socratic philosophers were considered *physicoi* (physicists), the term “*physics*” has been generally regarded as synonymous of nature. It follows that the meaning of *De Rerum Natura* is the attempt to rationally explain physical phenomena in a broad sense. Since everything is part of nature, virtually every field of knowledge can be included in the description of *rerum*, going beyond the proper definition of *rei* in quantum physics to arrive at the more general definition of *rerum* as any physical object. Thus, it seems appropriate to postpone the term “like” to the definition of “quantum” – viz., quantum-like – when dealing with phenomena in other fields of knowledge showing some likeness with those described by quantum physics.

3. A question of logic

In recent years, the term quantum-like has been increasingly used in different disciplines, including neurosciences, psychological and socio-economical disciplines, claiming that some investigated phenomena show “something” in common with quantum processes and, therefore, they can be modeled using a sort of quantum formalism. Accordingly, several neologisms – such as quantum economics, quantum finance, quantum cognition, quantum hypnosis, quantum psychology, and quantum medicine [5–10] – have been introduced in the literature, leading to the quantum interpretations being involved in an increasingly wide range of *rerum*. This highlights the great appeal of quantum physics despite its ostensible unintelligibility when approached through the prism of classic post-Aristotelian thought, a fact, in turn, revealing an increasing dissatisfaction with

its method of interpretation of reality. Thus, the problem is endowed with substantial epistemological implications; accordingly, there is also a need to shift from the original physical definition of the term quantum to make it compatible with its use in various aspects of the macroscopic world.

All this given, it is necessary to address the point relating to the “logic”, understood as the study of the laws and functions that characterize the structure of thought. While the logic of classical physics has been deterministic, in quantum physics it has become probabilistic and able to admit some contradictions – thanks to its various interpretations, especially the Copenhagen interpretation in 1927 – a fact entailing a shift of paradigm with respect to the ruling Aristotelian logic of the Western classical thought. The latter may work in many instances of everyday life but may not correctly face events looking inevitably probabilistic [e.g., weather forecast [11]]. Therefore, the rationale behind quantum phenomena might be extended to understand other wonders of the macroscopic world where the classical, determinist model may fail to define them properly.

In the climate of post-Enlightenment rationalism, it is not surprising that science adopted a determinist approach; it can be considered the long-lasting result of the claim to know the substance and the essence of phenomena in a *Weltbild* ruled by a principle of causality. This led to the Newtonian universe being conceived as a “big clock” and human beings and animals being reduced to “small clocks” with their machinery immersed in the bigger clock they belong to.

The full expression of scientific determinism has been introduced by Laplace:

“We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set Nature in motion, and all positions of all items of which Nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain, and the future just like the past would be present before its eyes” [12].

Laplace's statement is axiomatic and/or hypothetical at best, since no human being might ever reach such knowledge; it is tantamount to a faith saying that God knows everything, but, even admitting His being, He would anyway be in the dimension of eternity beyond the space-time in which humans live. Accordingly, Popper rejected determinism, defining it as an ideology rather than a theory [13]. Actually, a full determinism is hypothetical rather than real, entailing a conventional approximation – i.e., the threshold above which the effects are considered as the result of the initial conditions, neglecting the variability below the established threshold. As a result, predictability necessarily is approximate: according to Popper et al., “Causality yes. Mathematical causality, or exact causality, no” [13]. Thus, the introduction of a criterion of truth based on an experiential logic applied to a probabilistic model seems more reasonable with respect to an alleged determinism, and a properly defined concept of “quantum-like” might be more flexible in the interpretation of physical phenomena, understood as *De Rerum Natura*.

In our opinion, the concept of quantum-like may be successfully applied to macroscopic phenomena and empirical sciences other than physics when at least two conditions are satisfied: a) the behavior of the investigated phenomena show logical analogies with quantum ones; b) it is possible to find a criterion of truth based on an experiential/scientific approach applied to a probabilistic model of description of the phenomena.

4. Why a concept of quantum-like: epistemological implications

The increasing appeal of the quantum paradigm, justifying the introduction of the term quantum-like, seems to be dependent on the limits of Western classical thought to properly interpret all phenomena of the macroscopic world. Hence, an insight into its limits, besides advantages, is an essential step to properly frame the problem. Its detailed analysis is far beyond the aims of this article, but outlining a few fundamental aspects is necessary to envisage the reasons for the introduction of the quantum-like concept [for a detailed analysis, see [14–16]]

Aristotle has been the philosopher who has contributed more to the development of rational thinking in the West. In fact, in his *Metaphysics* and in *Prior* and *Posterior Analytics*, he funded a rigorous logical strategy aimed to discern the real from the false through a clear distinction of logical and illogical reasoning and, as a result, of facts from fancies. The Western way of reasoning has followed Aristotle's strategy, based on his tripartite logical system – i.e., the principle of identity, the principle of non-contradiction, and the principle of excluded middle (or Third) – and his metaphysical assumptions, also adopted by modern sciences; this entails that both metaphysics and scientific knowledge are logical and closely connected.

Western philosophy has pursued the ἐπιστήμη (*epistème*, from the Greek ἐπι- and ιστάναι, that means what stands above), i.e., a certain, indisputable knowledge overcoming any doubt and negation, seeking for the immutables, the essence, and substance of phenomena. This has led to a static way of reasoning, taking the unchanging for truthful and what seems to be contingent, becoming, swinging between being and not-being as illusory or irrelevant.

Then, the posterity turned the Aristotelian logic into an undiscussed, dogmatic doctrine [14,15,17]. The overestimation of the power of syllogism, induction, definitions, tripartite logic, and the split of reality according to a stiff dichotomous criterion (true vs. false; 1 vs. 0) has led to Nature being a priori constrained within one's mental categories. This, in turn, has led to the relative being taken for absolute and the particular for universal. Given the underestimation of the limits of available knowledge at any given time, one has been inclined to judge truthfulness or falsity according to one's ignorance, besides knowledge. As emphasized by Popper, this also entails the possibility of retransmission of falsity by logic in empirical sciences [18], including the risk of deviation from reality yielded by the closure of investigated phenomena within the limits of selected facts, theories, and mental categories – what Edgar Morin has defined the delusion of abstract conceptual coherence [19].

Unlike Socrates and Democritus, Aristotle – named by Dante as “Who teaches to all who know” – knows to know, while post-Aristotelian thought has been strongly inclined to believe to know, also

taking beliefs for knowledge. In other words, Aristotle has introduced a positive knowledge, while Democritus and Socrates were fully aware of not knowing, “for truth lies in the abyss” (Democritus, fragment DK 68 B 117). Their stance is in line with the Greek concept of ἀλήθεια (*alétheia*, truth) – etymologically stemming from the privative alpha in front of *-lētheia*, in turn deriving from the term λανθάνω (*lanthano*, concealed, hidden, unknown). Therefore, *alétheia* means that knowledge and truth are only truthful fragments grasped from the unknown. Accordingly, they used the *elenchus* (refutation) and *reductio ad absurdum*, rather than the Aristotelian use of induction and syllogisms, to be taken for proofs of positive knowledge.

The century-old Western rationalism paved the way to the outstanding rationalist revolution of the 17th Century and the birth of Galilean sciences. Still, they were based on a political compromise with the Church – claiming the exclusive competence on the soul (consciousness) – rather than a free epistemological reflection. The Cartesian dualism, ontologically splitting the *res cogitans* and *res extensa*, was aimed to favor the compromise by saving the soul for the Church, but made it unfathomable with the scientific method based on Galileo and Descartes’ mathematical-geometrical apriorism. Therefore, it made the *res extensa* and *res cogitans* incommensurable, leading to the observer being excluded from the observed facts [14,15].

In broad terms, the classic Western thought has been inclined to commit a sin of naivety, i.e., the illusion to know the reality as it is in itself and possess the truth by a seemingly foolproof method. Nevertheless, it is neither the only possible method nor the perfect one to be exclusively adopted despite its undeniable value. Especially in empirical sciences, its products remain *dóxa* [as all axiomatic knowledge, as emphasized by Aristotle himself (*Metaphysics* 1005b, 1-5)], providing valuable partial models of the reality at best. Metaphorically, some brittle bricks have been inadvertently used to build up the inflexible Western rational scaffold, leading to it being cracked by the quantum quake of the early 20th Century.

If this is the case, the pre-Socratic thought may help find a *fil rouge* between ancient philosophy and modern physics and help restoring the cracks. In fact, pre-Socratic philosophers were called φυσικοί

(*physicoi*, physicists) for they investigated the Nature, meant as ὅλης φύσεως (*hólēs physeos*, the whole) – including both material and (ostensibly) immaterial realms, viz. body and mind, matter and energy, atom and void – with a non-dualistic paradigm contemplating the complementarity of opposites, a paradigm akin to Taoism [20]. Then, following the parricide of Parmenides by Plato and Aristotle, the rational approach to reality was affected by nihilism (i.e., the idea that what exists is doomed to become nihil) [21] and an increasing dualism, the edge of which is Descartes' thought embedded in an inflexible rationalist stance. Hence, the opposites were ontologized and substantialized, making them incompatible, paying the high price of an irreconcilable split of what in nature is united.

Quantum physicists have introduced an entirely new paradigm in the Western cultural landscape, able to explain the realm of the infinitely small and rejoin what classical thought had unduly split; at the same time, it is old as the hills, reappraising the wisdom of the first *physicoi* and Eastern philosophers. Democritus plays a central role in physics for his theory of atoms and void. Like other pre-Socratics, Democritus' thought has been puzzling and considered paradoxical or self-contradictory – swinging between atomism, empiricism, and skepticism – when analyzed through the prism of post-Aristotelian thought [22]. In his theory of atoms and void, he moves a step forward along with Parmenides' concept of being by defining the elementary basis of the physical world in its appearance, where the void is not tantamount to nihil but exists as an essential component of the appearance of being. Void is the complementary counterpart of matter, without which the latter could not exist and be perceived as such. At the same time, atoms serve as the basic units of the manifold, dynamic, ever-changing appearance of the world emanating from the Being. In other words, Democritus allows merging the concept of Parmenides' Being and Heraclitus' dynamic world of becoming into a whole, where “Opposition unites. From what draws apart results the most beautiful harmony. All things take place by strife” (Heraclitus, Fragment DK 22B8). This also accounts for the coherence of Democritus' proto-empiricist approach to nature. In fact, his analysis starts from what is given, where he holds an epistemically sound and modern view –

compatible with Poppers' fallibilism, the model-dependent realism [23] as well as the Popper and Eccles' Theory of the Three Worlds and its new neurophenomenological version [16,24] – leading him to state:

“...In reality, we know nothing about anything; but for each of us there is a reshaping-belief ... to know in reality what each thing is in character is baffling” (Fragment DK 68 B 7, 8)... We know nothing in reality; for truth lies in the abyss” (DK 68 B 117).

Rather than a skeptic stance, it is a well-founded awareness of the intrinsic limits of rational knowledge of nature, in perfect agreement with Socrates' awareness of not knowing and Kant's “natural illusion” of humankind, taking concept and mental images for the reality in itself [25].

Democritus' enlightened view has not surprisingly made him the great father of modern physics and cosmology [26] and, we argue, of quantum physics. In fact, his intuition of the atomic structure of matter was confirmed by physics in the 19th Century (i.e., 2,300 years later), an epoch when matter's discrete or continuous structure was still debated. The subsequent discovery of the atom as a complex rather than indivisible entity has seemingly overcome Democritus' theory. On the other hand, one should refrain from simply applying to Democritus' concept of atom the meaning it currently has.

The Democritus' ἄτομος indicated the smallest, unperceivable, indivisible unit of the physical world, he established by outstanding intuition. Thus, his a-tom does not necessarily correspond to what we have named atom today and may well fit the elementary subatomic particles at the deepest level of reality; if this is the case, the whole of his atom and void may also fit the concept of virtual particles and quantum vacuum. Since, a), energy is subject to transformation but never becomes anything and, b), matter (being concentration of energy) may disintegrate and disappear but cannot result in an absolute nihil, one can argue that Western nihilism is wrong; it is a result of naïve realism rather than a product of reason, as already established Hippocrates in *De Diaeta* (I, 4, 9). Therefore, the ancient thought was right when establishing that everything in the phenomenal

reality appears and disappears by aggregation and separation from a virtual, unknown, and unobservable part of reality, what in quantum physics has been named *Grid* [27]. As a result, it seems reasonable to liken the Grid to the concept of Tao and Being, as well as the Hindu deity शिव (Śiva), lord of the timeless cosmic dance that is the origin of appearance-disappearance-regeneration of the world, a fact making so evocative the statue of Śiva at CERN in Geneva.

Fortunately, the reason is much more than a given form of rationalism, and science is much more than the inflexible use of a given paradigm; likewise, Nature is much more than any narrow model of it and disregards the clumsy attempts of humans to constrain it within a given set of axioms and theories established a priori. This is the fundamental reason for the scientific and concurrently epistemological revolution introduced by quantum physics.

5. Conclusions

The birth and spread of the prefix quantum to disciplines other than physics and the introduction of the term quantum-like reflect the increasing dissatisfaction with perceived limits and pitfalls of classic Western thought. Of course, the latter remains valuable: what is wrong is its dogmatic use and the claim of its exclusive capacity to comprehend the world. The introduction of paraconsistent logics, like fuzzy logic and dialetheism, is also a clear sign of the need to smooth its inflexibility, entailing the risk of preventing a proper assessment and understanding of some aspects of phenomenal reality.

The increasing use of the term quantum-like calls for defining and sharing its meaning in order to properly adopt it and avoid possible misuse. For example, the term entanglement is becoming more and more fashionable outside the field of quantum physics and may risk being used as an appealing synonymous of a close relationship, while its proper meaning is a non-local connection. If that were the case, there would be no reason to use it instead of other appropriate terms just for its scientific appeal, unless a non-local connection is investigated [e.g., in some studies on consciousness [28]].

Some intriguing cases of non-causal relationships might also fit Pauli's and Jung's concept of synchronicity as a sort of particular case of entanglement in the world of consciousness [29].

One should wonder whether the naïve view of individuals as separated, autonomous, independent entities is correct, or, instead, they should be considered as inseparable, interrelated parts of a single world, as already well defined by both the ancient thought and modern theory of complexity. If this were the case, there would be no need for borrowing the term entanglement from quantum physics, but, rather, a reflection on the classical paradigm would be enough and welcome. At any rate, the use of the term entanglement to indicate a close relationship is not wrong in itself and might be used, should this meaning be endorsed and shared.

In conclusion, the increasing use of the term quantum-like and other related terms borrowed by quantum physics to describe macroscopic phenomena is an interesting fact, endowed with relevant epistemological implications and need to be better defined to avoid improper use and possible unscientific or irrational drifts. Actually, the appeal of quantum-like seems to reflect on the surface a deep unease with the limits of the classic Western thought and a need for moving farther. If 20th century physics has undergone a radical revolution, other disciplines – e.g., medicine and life sciences – have remained anchored to Newtonian physics, for it seems to explain quite well the order of magnitude of the investigated phenomena. Nevertheless, the newborn quantum biology and the quantum theories of consciousness are promising fields of investigation; for instance, some mental processes like making decisions may better be understood using the quantum-like approach [30].

If the above discussion is correct, the quantum-like topic is worth taking seriously and properly defining. We think that it may be legitimately applied to macroscopic phenomena and disciplines other than physics when the conditions mentioned above are met: a) the behavior of the investigated phenomena show logical analogies with quantum ones; b) it is possible to find a criterion of truth based on an experiential/scientific approach applied to a probabilistic model of description of the phenomena.

Of course, this is only our provisional opinion, hopefully, helpful to promote further discussion and achieve a better definition of the topic.

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