"To Be, To Be, What Does it Mean to Be?" : On Quantum-Like Literary Models

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Abstract. This paper discusses a particular type of quantum-like literary models, which are conceptual, rather than mathematical, in character. These models share with quantum mechanics the difficulties of applying the concepts of reality and causality at the ultimately ontological levels they consider, analogous to the level of quantum objects and processes in quantum mechanics. They respond to this difficulty by suspending and even precluding the application of both concepts, as do certain interpretations of quantum mechanics. I call such models and such interpretations "nonclassical," in juxtaposition to "classical" models, which retain realism and causality at the ultimate level of description, even when considering random events. While I offer a sketch of Western thinking concerning the subject, I focus on certain philosophical and literary quantum-like thinking of the late-eighteenth and early-nineteenth centuries, associated with Romantic literature, which shows particular affinities with quantum-theoretical thinking later on. I also consider, in closing, the literary model, found in Beckett's plays, that was developed after quantum mechanics and that shares with it features that earlier literary quantum-like models do not possess.
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1. QUANTUM-LIKE MODELS, CLASSICAL AND NONCLASSICAL

This paper considers a particular type of quantum-like models, found in literature, although such models also exist elsewhere. These models do not involve the mathematics used in quantum mechanics and other quantum theories, which is customary in quantum-like models in mathematical or scientific fields, such as biology, neuroscience, or economics, where the very language of "*quantum*-like" usually applies to such mathematical models (e.g., [1], [2]).[1] Indeed, the models to be considered here do not contain any mathematics at all. They offer conceptual configurations by means of which we can relate to the world either by describing, at least ideally, some of its aspects or by making predictions concerning certain events.[2] Accordingly, such models may be seen as conceptual or philosophical, because even when they occur in literature, they are essentially philosophical in character. A literary quantum-like

[1] In this paper, I shall only be concerned with the standard version of quantum mechanics, discovered independently by Heisenberg and Schrödinger in 1925-1926, and now customarily presented by using Hilbert-space formalism. I shall not address alternative accounts of quantum phenomena, such as those along Bohmian lines (e.g., [3]). I shall also bypass quantum field theory, which introduces additional dimensions into the problematic in question.

[2] Mathematical models used in physics or elsewhere in science also, generally, establish only idealized relations to the objects and behaviors they model.

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model is a philosophical quantum-like model offered in a literary work. [3] These models share with quantum mechanics the difficulties of applying the concepts of reality and causality at the ultimately ontological levels they consider, analogous to the level of quantum objects and processes in quantum mechanics, which is of course a mathematical theory. These difficulties are due to the random or, sometimes, statistically correlated character of the phenomena or events associated with these objects and processes, analogously to the situation that obtains in quantum mechanics. It is a well-confirmed experimental fact that identically prepared quantum experiments, in general, lead to different outcomes, although some of quantum phenomena or events are statistically correlated. These correlations are specific to quantum phenomena and are not exhibited by classical phenomena. Hence, any theory correctly accounting for quantum phenomena is bound to be probabilistic in its predictions, and cannot be deterministic. It can, however, be causal as concerns the underlying behavior of the systems that leads to these phenomena, insofar as the state of such a system at a given point determines its state at all points. (I shall explain the terms causality and determinism below.)

The factors just mentioned allow for a spectrum of quantum-like models, based on different possible interpretations of quantum mechanics or alternative theories of quantum phenomena. This spectrum may also contain, as I shall call them, "classical" models, which have been dominant in considering chance and probability in various domains throughout Western intellectual history and remain dominant now. These models presume that the ultimate constitution of nature is causal and that, to begin with, it is open, at least ideally and in principle, to a realist description, which a given classical model can approximate. In this view, random or statistically correlated phenomena appear as surface effects of one or another causal dynamics, and the recourse to probability becomes essentially a practical, rather than fundamental, matter, due to the difficulties of adequately tracking the underlying processes responsible for these effects. Not all realist models are causal and, thus, classical. Some atomistic models of nature, such as those of Epicurean and Lucretian atomism, are realist but not causal, in contrast to the model of classical statistical physics, which is, at bottom, causal as concerns the behavior of individual constituents of the systems considered. Classical models are common in and define classical physics, beginning with classical mechanics, in which case we generally do not deal with randomness and probability, in the way we do in classical statistical physics or chaos theory. There are also classical (realist *and* causal) mathematical models of quantum objects and their behavior, either linked to the corresponding interpretations of standard quantum mechanics or to alternative theories of quantum phenomena, for example, along Bohmian lines.[4] By contrast, the characteristic feature of the models to be considered here is that they suspend and even preclude the application of both concepts, reality and causality, at the ultimate level, as do certain interpretations of quantum mechanics at the level of quantum objects and processes. In other words, such models preclude any description or even conception of the ultimate ontology underlying the events considered by them. Under these conditions the suspension of causality becomes automatic, since causality would be a feature of a realist description, in principle precluded by nonclassical thinking or models grounded in it. As E. Schrödinger noted, in commenting, disparagingly, on quantum mechanics itself, if the classical-like state of a system is not

[3] By literary quantum-like models I mean a representation of quantum-like configurations in literary works, rather than models describing creative literary practices, such as particular ways of composing literary works, that respond to quantum-like situations, for example, the role of chance there, an interesting but separate subject.

[4] Given that I am mainly concerned with nonclassical interpretations of standard quantum mechanics or nonclassical models elsewhere, I shall bypass the debates concerning realism and causality in quantum physics, more recently in relation to Bell's theorem and related findings, which also bring into play the question of locality. For a discussion of these subjects from the present perspective, see [5].

assumed to exist, "it can hardly be assumed to change causally" [4, p. 154]. In other words, while phenomena and events in question can be seen as "effects" brought about by certain processes, these processes cannot be seen in causal terms: these effects are effect without (classical) causes. I shall call such models or the corresponding theories, or ways of thinking, "nonclassical." In this view, things of nature or mind (since this view can also apply to mind) do exist, but it may not be possible to form a conception of how they ultimately exist. There are, thus, three kinds of models that deal with randomness and probability—classical models, which are *both* realist *and* causal; the intermediate type of models, which are realist *but not* causal; and nonclassical models, which are *neither*.

It would not be difficult to find examples of conceptual quantum-like models of various types *after* quantum mechanics was introduced and its famously strange features became the subject of considerable interest and fascination in philosophy, literature, and art, although nonclassical quantum-like models are uncommon. I shall, by contrast, primarily consider quantum-like models or ways of thinking, primarily in literature, that have preceded quantum theory. I shall in closing this paper also discuss the literary model, found in S. Beckett's works, that was developed after quantum mechanics and that shares with it features that earlier quantum-like models do not possess, which is my primary reason for considering this model. I shall offer a sketch of Western thinking concerning the difficulties of maintaining the realist and causal view of nature and mind, and of different ways of responding to these difficulties. I shall, however, particularly focus on Romantic poetry of the early-nineteenth century and the nonclassical quantum-like models found there. P. B. Shelley's poetry will serve as my main example, although some of both J. Keats's and H. von Kleist's works could also be used here. While this Romantic "anticipation" of quantum thinking may appear remarkable, there is no mystery to it, and it would be more accurate to speak of affinities than of anticipation. There are two clearly discernable reasons for these affinities.

The first is that the period in question coincides with three major developments that posed new questions concerning reality and causality for science, philosophy, and literature. The first is the advent of a new type of philosophical thinking, in particular reflecting a more skeptical attitude toward causality, in D. Hume's and then I. Kant's philosophy. The second is the emergence of probability theory, which had major implications for mathematics, science, philosophy, and the culture of modernity. The third has to do with the eighteenth-century optics, as the site of the major debate concerning the corpuscular vs. wave nature of light. It may be added that the philosophy of Hume and Kant, their followers, and Romantic literature had influenced the thought of such scientific figures as C. Darwin, J. C. Maxwell, and L. Bolzman. Maxwell and Bolzman were responsible for key developments that eventually led to quantum-theoretical thinking, via Planck's law, which was formulated at the intersection of thermodynamics, electrodynamics, and, for the first time, quantum theory, and which was statistical. Prior to his work on quantum theory, Planck made major contributions to thermodynamics. Quantum theory revived the debates concerning the wave vs. particle nature of light—it is true, in a hitherto unprecedented form, but not without philosophical affinities with some earlier stages of these debates, and specifically with the way the problem was seen by Romantic poets, such as Shelley. In sum, one can clearly establish several historical factors that ground the affinities in question between Romantic thought and quantum theory.

The second and more important reason for these affinities is the shared nature of certain problems that one confronts in different fields and, as a result, of *some* responses to these problems (for one can of course respond differently to the same problem). N. Bohr commented on these types of affinities as follows: "We are not dealing here with more or less vague analogies, but with an investigation of the conditions for the proper use of our conceptual means of expression. Such considerations not only aim at making us familiar with the novel situation in physical science, but might … be helpful in clarifying the conditions for objective description in wider fields" [6, v. 2, pp. 1-2]. The questions of reality and causality, clearly on Bohr's mind here, have often been as much at stake in certain philosophical and literary works as they are in quantum theory. These questions were sometimes also posed more radically in literature than in philosophy, although there are important philosophical exceptions, such as F. Nietzsche, whose ideas might have influenced Bohr [5, p. xxii]. I would argue that this was because literature, confronted certain troubling questions concerning human life more directly than philosophy did, questions often linked to the difficulty or even impossibility of relying on the ideas of reality and causality. Philosophy has been more reluctant to doubt that some underlying causal ontology ultimately governs nature and mind, although most philosophers have recognized practical difficulties of capturing the actual character of this ontology. With thermodynamics, evolutionary biology, and most radically, quantum physics, nature posed the questions of reality and causality anew for science and philosophy, even if still in the face of the continuing resistance to parting with either idea.

At the same time, however, even leaving mathematics aside, there are limits to philosophical parallels, invoked by Bohr, between quantum mechanics and other fields. Quantum phenomena and quantum mechanics have their specific, even unique features, some of which would have been difficult and even impossible to imagine if nature itself did not show them to us. In J. A. Wheeler's words, "What could one have dreamed up out of pure imagination more magic—and more fitting—than this?" [7, p. 189] Our thought, I argue here, might not be able to do give a physical and philosophical meaning to this magic without making the unthinkable part of this meaning, without thinking with the unthinkable, as happened in Heisenberg's discovery of quantum mechanics. While, however, this epistemology was envisioned earlier, as, I argue, by some Romantic authors and, especially rigorously, by Nietzsche, quantum-like models that are philosophically isomorphic, *considered in all of its specificity*, were unlikely to emerge before quantum mechanics. It is for that reason that I shall, in closing, consider the nonclassical quantum-like model found in Beckett's work, which was introduced after quantum mechanics and has a greater proximity to it than earlier quantum-like models considered in this paper.

2. A BRIEF HISTORY OF CAUSALITY AND CHANCE

The relationships between causality and chance have played a major role in Western thought from the pre-Socratics on. These relationships are important even in classical models, where causality is assumed to govern the ultimate workings of nature or mind, because randomness or chance still need to be accounted for even in this case. They are also important in quantum-like nonclassical models or nonclassical interpretations of quantum mechanics. This is because, reversing the classical situation, one finds in these cases not only randomness but also forms of correlational order, even if not causality, at the level of observation, although the processes responsible these observed phenomena and events cannot be thought in terms of either randomness or causality, or their interplay, any more than in any other terms. It is crucial that quantum phenomena are characterized not only by their individual randomness but also by statistical correlations (such as the EPR-Bell correlations) between certain phenomena, correlations specific to quantum phenomena and distinguishing them from classical phenomena. Correlations found in nonclassical models elsewhere are not defined as sharply (or numerically), but they are significant, nevertheless.

This section offers a sketch of the relationships between causality and chance, and of the key forms of ontology on which these relationships are based, apart from the question of probability, which will be discussed in the next section. This sketch is not aimed to be comprehensive, and is designed primarily in order to situate more firmly nonclassical quantum-like models in historical and conceptual terms. On the other hand, there is a history to nonclassical models, and this history is important. Every model has a history, although this history is often, certainly in the present case, complex, with many detours and switches between its trajectories, and sometimes with quantum-like jumps, which cannot be filled.

Before I proceed, I would like to define my main terms. By "randomness" or "chance" I refer to a manifestation of the unpredictable. A random event is an unpredictable event. It may not be possible to estimate when such an event would occur and to anticipate it. Probability, by contrast, deals, theoretically or practically, with providing estimates, possibly numerical, of occurrences of certain individual or collective events, sometimes, especially in science, in accordance with mathematical probability theories. Thus, while chance introduces the element of chaos into order and reveals the character of world, or of our interactions with the world, as the interplay of order and chaos, or in James Joyce's coinage, a "chaosmos," probability introduces an element of order into situations defined by the role of chance, and allows us to handle such situations better.

I understand "causality" as an ontological category that relates to systems whose evolution is defined by the fact that the state of a given system is exactly determined at all points by their state at a particular point. A closely related category is that of "necessity," which implies causality, but is not identical to the latter and reflects the presence of stronger (enforcing) causal mechanisms. Causality is, however, my primary category here, and when I refer, for historical reasons, to necessity, it is the causal aspects of necessity that are most essential for my argument. Classical mechanics is a paradigmatic example of causal theory in science, and it has been one of the primary models of causal thinking for philosophy, from J. Locke on.

I understand "determinism" as an epistemological category that denotes our ability, at least in principle, to accurately predict the state of a system at any point once we know its state at a given point. A system may be causal without allowing us to predict its behavior exactly, even in ideal terms. This is the case, for example, in classical statistical physics, which deals with a very large number of individual systems behaving classically, or in chaos theory, which deals with classical mechanical systems whose behavior is highly non-linear and, thus, disables our capacity to predict it exactly. In both of these cases, however, the underlying ontology is assumed to be classical. The behavior of quantum systems is, as explained earlier, manifestly indeterministic regardless of interpretation, because quantum predictions are, in general, probabilistic, which in itself still allows for an underlying causal dynamics responsible for this indeterminism. In the nonclassical view, this behavior is also not causal, even at the level of ultimate individual objects, such as electrons, photons, quarks, etc., objects that do not possess any constitutional complexity, at least as things stand now.

In general, a random event may or may not hide some underlying causal dynamics, which may or may not be available to us. In the view defined here as classical, chance is always a product of some causal dynamics, of which we may or may not be cognizant, or which we may or may not be able to describe. The classical view has been dominant throughout Western history, and it retains its dominance now, and I shall comment on some of the reasons for this dominance presently. The main reason for the language of "classical" is that, while this view itself has been around since at least the pre-Socratics, classical mechanics is, as I said, a paradigmatic model of causal dynamics that underlies random or probable events in physics (as in classical statistical physics) and beyond. Indeed, "classical physics" is a later term, introduced in the early-twentieth century in the wake of relativity and quantum theory.

Classical ontology was dominant well beyond physics during the eighteenth-century Enlightenment, sometimes also known and the age of reason. Such an ontology was assumed by Kant, who was inspired by Newton's physics and who was largely responsible for the term "Enlightenment," apparently introduced in his famous essay "Answering the Question: What is the Enlightenment?" [8]. It appears (there is some debate on this point) that it was also assumed by Hume, who was generally more skeptical concerning causality. What they denied was that the human mind could have a full access to this causality and that it could establish definitive *causal* connections between events, rather than only surmise *probable* connections between them. The classical view of chance and causality has been dominant throughout the history of Western thought, from the pre-Socratics to our own time. Exceptions are rare, even those of a realist kind, whereby the underlying ultimately ontology, while (in contrast to nonclassical models), in principle allowing for a representation, is not causal. As noted from the outset, realist ontology need not be causal and, hence, classical: it may, for example, be defined by some form of the interplay of randomness and causality, or, in Democritus's terms, of chance and necessity (which, as I said, is not quite the same as causality but is not essentially different). In the twentieth century, the classical view found its arguably greatest advocate in Einstein, who expressed it by his famous pronouncement "God does not play dice." He never wavered in his belief in a classical-like approach to physical reality, although he held a complex position on how an access to this reality is possible. Specifically, he thought, closer to Kant and G. W. F. Hegel, that it is only possible by means of a free choice of concepts, rather than on the basis of observations alone, along empiricist lines, à la Mach. Appeals to Einstein's authority on this point are ubiquitous. This is not to say that these appeals do not correspond to beliefs in this view: they often do. According to S. J. Gould:

> I confess that, after 30 years of teaching at a major university, I remain surprised by the unquestioned acceptance of this [classical] view of science—which, by the way, I strongly reject …—both among students headed for a life in this profession, and among intellectually inclined people in general. If, as a teacher, I suggest to students that they might wish to construe probability and contingency as ontological properties of nature, they often become confused, and even angry, and almost invariably respond with some version of the old Laplacean claim. In short, they insist that our use of probabilistic inference can only, and in principle, be an epistemological consequence of our mental limitations, and simply cannot represent an irreducible property of nature, which must, if science works at all, be truly deterministic [causal, in the present definition]. [9, p.1333]

One should not be too surprised, given the prevalence of the classical view throughout Western intellectual history. The dominance of classical thinking should not be unexpected either, even apart from its extraordinary effectiveness in philosophy and science throughout Western history. It may be argued that, as against nonclassical thinking, classical thinking reflects the essential workings of our neurological machinery born in our evolutionary emergence as human animals and possibly helping our survival. In other words, our thinking in general, as the product of this machinery, appears to be classical, and specifically causal, which may explain why Kant was compelled to assign to causality, along with space and time, an a priori nature. This is true even in nonclassical situations because that which defines them as nonclassical is literally unthinkable. We are compelled to infer the existence of this unthinkable from certain configurations of its effects (such as traces left, on silver-bromide photographic plates, by quantum objects) on what we can think and know, in part, unavoidably, through classical thinking. This inference is, accordingly, always theoretical. Nonclassical theoretical thinking is reached via classical thinking, because the nonclassical underpinnings of a given situation make their existence apparent only in certain classical features as effects of these nonclassical underpinnings. The particular character of these effects defies the possibility of a classical understanding of their emergence and compels us to think of this emergence in nonclassical terms. Given the evolutionary origin of classical thinking, it is hardly surprising that it was so pervasive in mathematics, science, philosophy, and literature, and in Western thought and culture, that it has become a form of ideology. By advocating nonclassical thinking and models, I am not suggesting that classical ones should be abandoned. This would be impossible in any event, if classical thinking reflects our biological and neurological nature. Equally importantly, classical thinking retains its positive role in nonclassical thinking, which arises from classical configurations of thought and knowledge.

Beginning with the pre-Socratics or even Homer, there emerged three main *types* of ontology or three ontological *hypotheses*. The *first* ontology is classical ontology, which defines chance as only apparent or illusory, while at the ultimate level order and causality (and indeed necessity) rule. Like the God of Einstein, Homer's Zeus does not play dice, but decides human fate, by "playing" with scales:

> As long as morning rose and the blessed day grew stronger,
> The weapons hurtled side-to-side and men kept falling.
> But once the sun stood striding at high noon, so
> Then Father Zeus held out his sacred golden scales:
> In them he placed two fates of death that lays men low—
> One for the Trojan horsemen, one for Argives armed in bronze—
> And gripping the beam mid-haft the Father raised it high
> And down went Achaea's day of doom, Achaea's fate
> Settling down on the earth that feeds us all
> As the Trojans' fate went lifting towards the sky.
> [10, pp. 234-234, Book VIII, 78-87]

The ancient Greeks complicated the management of fate beyond Zeus's power, given that Moiras, the goddesses of fate, were primarily responsible for the apportioning of fate ("Moira" means "apportioning"), apportioning intricately distributed among three of them. In Orphic cosmogony, the mother of Moiras is *Ananke*, necessity, which would define the causality behind a given sequence of events. In some cases, Zeus could override the Moiras' apportioning and reapportion the fate of an individual or a community, which may be what he is doing in this passage. Even a human being can on occasion influence fate within some versions of the ancient Greek scheme of fate. In sum, causal mechanisms behind fate were quite complex in ancient Greek thought, and sometimes they shift to the interplay of chance and causality, or necessity, to be discussed below. The models of these mechanisms also depend on a given author and on an interpretation of this author: thus, there are differences between Homer's, Hesiod's, and Herodotus's versions of these mechanisms. Still, classical ontology is dominant: the mechanism of fate is ultimately governed by necessity and is causal, and all chance is appearance due to our lack of our knowledge of the functioning of this mechanism. A famous and spectacular example is Sophocles's *Oedipus the King*, where the apparently chance events are ultimately determined by the inescapable necessity of fate, no matter how one tries to circumvent it.

The *second* ontology is defined, conversely, by the rule or misrule of chance, which makes causality, necessity, and order apparent or illusory. This ontology, too, is found in *Oedipus the King*. It may be called "the Jocasta ontology," since it was assumed and was dramatically expressed by Jocasta, Oedipus's mother and wife: "Fear? What should a man fear? It's all chance, chance rules our lives. Not a man on earth can see a day ahead, groping through the dark. Better to live at random, best we can" [11, p. 146, ll. 1068-1072]. Not surprisingly, no appeal to probability is made or is possible under these conditions: next to nothing can be estimated with any degree of belief. This view is proven illusory in the play, since the lives of the characters are ultimately ruled by fate and, thus, by classical ontology. It does not appear that the ancient Greeks had a literary model *based* in this view. Indeed, while this type of ontological view is mentioned sometimes in literary works throughout Western history, the works based on this ontology and the corresponding literary models do not appear until the advent of literary modernism in the twentieth century, sometimes under the impact of quantum theory. One such work is T. Stoppard's *Rosencrantz and Guildenstern are Dead* (1966).

The *third* ontology found in ancient Greek thought can also be traced at least to the pre-Socratics. It was introduced in the fifth century BC in several forms, in particular, as the materialist atomistic ontology of nature by Leucippus and his student Democritus, with whom it is usually associated, and it was developed by Epicurus and then Lucretius. Lucretius's *De*

Rerum Natura [*On The Nature of Things*] may remain its greatest literary and philosophical model, based on an element of absolute randomness or chance, defined as "clinamen," the swerve of atoms, a concept not found in Democritus.[5] Such swerves occur at uncertain times and in uncertain places [*incerto tempore, incertisque loci*] and "if they were not apt to swerve, all would fall down through the unfathomable void like drops of rain; no collisions between primary elements [atoms] would occur, and no blows would be effected, with the result that nature would never have created anything" [12, p. 41, ll. 219-227].

Although clinamen plays a crucial role in Lucretius's universe, the *overall* ontology envisioned by him is different from the Jocasta ontology, because Lucretius's universe allows for causal processes and ordered structures. However, in the absence of God, such structures are the results of the emergent causal process of self-organization, once a sufficiently large number of atoms are brought together, which was a highly innovative conception. The universe itself has emerged through combining atoms (assumed to be infinite in number) in accordance with natural laws. This organization is, however, never guaranteed to be stable, since it can be disordered by swerves. In Lucretius's universe only atoms themselves are eternal, but not any given formation of atoms. Lucretius also suggests that, given the infinite universe, the existence of other worlds than ours is *probable*. He does not appear, however, to invoke probability in relation to atomic behavior as such, perhaps because atomic chance events cannot be assigned meaningful probability in his universe.

While Leucippus and Democritus appear to have been the first to advance this type of ontology as a materialist atomistic ontology, the idea of the world as the interplay of chance and necessity is found in other pre-Socratics. Thus, Heraclitus, a famous contemporary and counterpart of Democritus (anda target of a strong attack by Lucretius), pursued this idea apart from atomism, and by a very different way of philosophical thinking in general. As Nietzsche put it, for Heraclitus, a great philosopher of becoming, "the world is the game Zeus plays," the play, and the interplay, of chance and necessity [13, p. 58]. The word "game" or "play" (the ancient Greek for both is *paidea*) already suggests phenomena defined, as most games are, by the interplay of chance and necessity. Nietzsche extrapolates from Heraclitus's Fragment XCIV (in one possible arrangement), which says (to give one of many possible translations, which are always interpretations): "[Time] (*aion*) is a child at play (*pais paidzon*), moving pieces in a game" [14, p. 71; translation modified]. Nietzsche also refers to other fragments, and he adds that "[it is the play] 'of the fire [the original substance in Heraclitus] with itself. This is the only sense in which the one is at the same time the many'" [13, p. 58].[6]

[5] Lucretius does not use the Greek loan-term "atom" or any a single term to designate the ultimate constituents of matter, but, following Epicurus, he clearly has in mind the existence of such "atomic" constituents.

[6] Plato, in *Timaeus*, developed a contrasting mathematical (rather than physical, mechanical) "atomic" theory of the unchangeable eternal primary mathematical elements (more primordial than physical ones), defined as regular (Platonic) geometrical solids, out of which God created the world. Plato's view of the ultimate reality, which follows that of Parmenides, another key pre-Socratic, was based on the idea of permanent mathematical forms. On the other hand, one of the reasons for Democritus's recourse to atomism were paradoxes brought about by considering continuous mathematical figures, such as triangles, as corresponding to reality, paradoxes that disappear if one abandons continuity. If one wants to retain continuity, these paradoxes ultimately require calculus to be properly addressed mathematically. Heisenberg was famously fascinated with Plato's ideas in *Timaeus*, which had apparently played a role (not clear how significant) in the genesis of quantum mechanics, but on account of the role of mathematics in our understanding of the world, rather than Plato's argument as such. Aristotle, a physicist and a thinker of continuity and plenum, rejected atomism. But he appears to have been more critical of Plato's attempt to derive physical substances from mathematical abstractions than of Democritus's physical atomism, where the main problems were discontinuity and the void between atoms, which were in conflict with Aristotle's principle that nature avoids emptiness. As just

The Lucretian atomistic vision has manifested similarities with both classical statistical physics and chaos theory, and it has been invoked in the philosophical discussions of both theories, although these theories are at bottom causal, classical. The idea of a swerve of an atom in an uncertain place at uncertain time also has a quantum-mechanical flavor, and references to Lucretius have recurred in the discussions of quantum mechanics [e.g., 15]. There are, however, crucial differences between this picture and the nonclassical view of quantum events. In both views, such events occur in an uncertain place in an uncertain type and hence without a known or knowable, or even conceivable, mechanism for this change. This point was emphasized by Bohr in his first paper on the atomic constitution of matter, where Bohr's theory does not yet offer a properly nonclassical view of quantum phenomena, developed by him only following quantum mechanics [16]. However, the Lucretian swerve is part of a continuous process, a shift, random though it is, from one trajectory to another, still apparently based on the idea of continuous motion, inapplicable in quantum physics, where we deal quantum discontinuity, "quantum jumps."[7] Moreover, in nonclassical quantum and quantum-like models, the Democtritean idea of atoms, as indivisible entities of a given (small) size, is inapplicable to elementary quantum objects, elementary particles, of the present-day quantum physics, anymore than any other concept, continuous or discontinuous. In virtually all versions of present-day quantum theory, particles are treated mathematically as dimensionless points, without assuming that this mathematical idealization corresponds to what elementary particles physically are. In nonclassical interpretations of quantum mechanics and in nonclassical models elsewhere, discontinuity is transferred to the level of quantum phenomena observed in measuring instruments. This transfer dispenses with the description of motion or other forms of behavior of the ultimate objects considered by a given model. Instead, one only deals with probabilities of future events, always discontinuous with a point at which this probabilistic assessment is made, on the basis of this and other past events, again, discontinuous with each other.

The nonclassical view goes beyond Kant (or Democritus, who held similar views on this point), for whom the ultimate nature of things, while unknowable, is still thinkable. In Kant, it is not a matter of an arbitrary hypothesis, and in addition to being free from contradiction, any such hypothesis needs to be properly justified, either theoretically or practically [17, p. 115]. In the nonclassical view, the ultimate constitution of objects considered by a given model is not only unknowable, but is also un-thinkable, is beyond thought. In this case, too, it is not a matter of an arbitrary decision: any specific hypothesis concerning this constitution is difficult, if not impossible, to justify, either theoretically or practically, given the nature of the phenomena in question, such as quantum phenomena in quantum mechanics.

It would seem that, once one is thinking in terms of the interplay of chance and necessity, and given other considerations just outlined, it is only a small step to considering ontology of a nonclassical type, at least as a possibility. This step, however, proved to be difficult, and it took literally over two thousand years to make it, in the wake of Hume's and Kant's philosophy, probability theory, and the eighteenth-century debate concerning the wave vs. particle nature of light, which, as explained earlier, were arguably the most decisive developments in preparing this step. The difficulty of this step is, again, not surprising given

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explained, however, discontinuity need not accompany an ontological view defined by the interplay of chance and necessity. Such ontology may be continuous, as in Heraclitus, of whom Aristotle was, however, critical as well, deeming Heraclitus's view that *everything* is in perpetual flux to be too extreme. He saw this view as disabling the possibility of knowledge, which, so Aristotle argued, requires, at least some, permanence.

[7] Radioactivity was the first quantum phenomena resonant with the idea of clinamen. However, it is quite different because a radioactive emission is not an event of a "swerve" but of the creation of new particles, new "atoms."

the pervasiveness and power of classical thinking and perhaps its evolutionary origins, as discussed above. This power compelled most, including Hume and Kant, to look for classical answers to the problems that might have required a nonclassical approach to them. If anything, it is more surprising that nonclassical or near nonclassical views were entertained before quantum physics, which provided a more manifest impetus for such views. On the other hand, this is a testimony to the critical power of philosophical thought, also pursued by means of literature, as able to perceive nonclassical situations in nature and mind, and to respond to them accordingly under the pressure of the problems at hand, just as quantum theory did later.

Consider, for example, the significance of chance events in Shakespeare's plays, events that are never explained or motivated by any hidden necessity, in contrast to Sophocles's tragedies, such as *Oedipus the King*. One can think especially of *accidents* or *hazards* (also in the literal sense of chance both words carry as well) occurring at sea, as in *Hamlet* or *The Tempest*, literally "a sea of troubles" (*Hamlet*, Act III.i.59), the image that also frames the events of *King Lear* and other Shakespeare plays.[8] Not that it is impossible to fight chance and even to win against it, although it is sometimes difficult to say whether one wins or loses. One must, in any event, be ready to face chance. As Nestor says in *Troilus and Cressida*:

> … In the reproof of chance
> Lies the true proof of men. The sea being smooth,
> How many shallow bauble boats dare sail
> Upon her gentle breast, making their way
> With those of nobler bulk!
> But let the ruffian Boreas once enrage
> The gentle Thetis, and anon behold
> The strong-ribb'd bark through liquid mountains cut,
> Bounding between the two most elements,
> Like Perseus's horse. Where's then the saucy boat
> Whose weak untimber'd sides but even now
> Coeval greatness? Either to harbor fled,
> Or made a toast for Neptune. Even so
> Doth valor's show and valor's worth divide
> In storms of fortune. For in her ray and brightness
> The herd has more annoyance by the breeze
> Than by the tiger; but when the splitting wind
> Makes flexible the knees of knotted oaks,
> And flies fled under shade, why, then the thing of courage,
> As rous'd with rage, with rage does sympathize,
> And with an accent tun'd in selfsame key
> Retorts to chiding fortune.
> (Act I.iii.33-54).

Shakespeare's music is the music of the sea, the music of chance, and its complex, chaosmic harmonies, as opposed to the music of the spheres, that of Pythagoras or that of Kepler (another contemporary of Shakespeare). On the other hand, the appearance of Thetis is not by chance: she is the mother of Achilles, the greatest of heroes; it is the rage of Achilles and his concern for the lack of virtue where *The Iliad* begins. While the chance to kill Achilles is small, it is bound to happen at some point with probability one hundred per cent, but it is difficult to predict when, although the Trojan War increases the probability of this event.

Closer to physics, and with echoes of an ancient atomist (as in "embryon atoms"), is Milton's remarkable description of chaos in *Paradise Lost*:

> Before their eye [Satan's, Sin's, and Death's] in sudden view appear
> The secrets of the hoary deep, a dark
> Illimitable ocean without bound,

[8] English poetry will be cited by line numbers, rather than by a reference to particular editions.

Without dimension, where length, breadth, and height,
And time and place are lost; where eldest Night
And Chaos, ancestors of Nature, hold
Eternal Anarchy, amidst the noise
Of endless wars, and by confusion stand.
For Hot, Cold, Moist, and Dry, four champions fierce
Strive here for maistry, and to battle bring
Their embryon atoms; they around the flag
Of each his faction, in their several clans,
Light-armed or heavy, sharp, smooth, swift or slow,
Swarm populous, unnumbered as the sands
Of Barca or Cyrene's torrid soil,
Levied to side with warring winds, and poise
Their lighter wings. To whom these most adhere,
He rules a moment; Chaos umpire sits,
And by decision more embroils the fray
By which he Reigns: next him high arbiter
Chance governs all. Into this wild Abyss,
The Womb of Nature, and perhaps her Grave,
Of neither Sea, nor Shore, not Air, nor Fire,
But all of these in their pregnant causes mixed
Confus'dly, and which thus must ever fight,
Unless th' Almighty Maker them ordain
His dark materials to create more worlds,
(*Paradise Lost*, Book II, 890-916)

This description presents a literary model with arguably the greatest proximity to quantum-like nonclassical thinking prior to quantum mechanics, except for Romantic nonclassical models. This is a strong claim, and it needs to be explained further. In particular, it might be countered that the passage and the poem as whole are unambiguous as concerns God's shaping power in creating order, "more Worlds," out of chaos. (Milton's plural is worth registering here.) This would bring this passage closer to classical ontology, and one might safely presume than Milton's God does not play dice. In this respect, while Milton's universe echoes that of Lucretius, via a brilliant metaphor of "embryon atoms" (defining these atoms' "genetic" potential to become something definite when circumstances are right), the ordered worlds in Milton's universe are not self-organizing in the way they are in Lucretius, whose universe has no God to shape it. The worlds in Milton's universe are created by God, and are defined by order and harmony, albeit not perceived by humans or even some among lesser immortals, such as the rebellious Satan and his crew, with the group initially given a chance to appreciate this harmony better, a chance ultimately not taken.

This is true. Nevertheless, Milton's description of the primordial chaos, especially as at its abyssal, bottomless bottom indescribable—"length, breadth, and height,/ And time and place are lost;" "neither Sea, nor Shore, not Air, nor Fire,/ But all of these in their pregnant causes mixed/ Confus'dly"—is close to a nonclassical view, except that, in the latter view even such attributes as chance would be replaced with neither chance nor order, or some mixture of both at the ultimate level. Milton's passage is, however, in accord with nonclassical understanding of the ultimate (quantum) constitution of nature, insofar as the character of these constituents and their behavior are "dark" beyond our knowledge or even conception. And yet, these "dark materials" allow *nature* and, by experimenting with nature and with its help, ourselves to create new *configurations* of technology and even of nature itself. Of course, only nature could, at least thus far, create new worlds on the ultimate scale of the Universe (assuming we can assign such human concepts as "creation" to nature), but we can, with nature's help, create new, quantum-based, configurations of technology in the world around us.

Proceeding via and radicalizing Kant's critical philosophy, Romantic quantum-like models are closer to Milton's view in the materialist aspects of it just suggested than to the philosophy and ideology of Enlightenment, and for the British Romantics Milton, including this passage, was one of the inspirations in developing these models, especially in Shelley and Keats. As noted above, the Enlightenment was shaped by classical thinking, to which Hume and Kant subscribed as well, in spite of their critique of causality. The classical view may be further illustrated by a famous excerpt from A. Pope's *An Essay on Man* and his, equally famous, proposed epitaph for Sir Isaac Newton as examples of this dominance of the classical view during the eighteenth century. The first passage is a variation on G. Leibniz's theme of pre-established harmony, an important part of the history in question, which cannot, however, be considered here. Pope says:

> All Nature is but art, unknown to thee;
> All chance, direction, which thou canst not see;
> All discord, harmony not understood;
> All partial evil, universal good:
> And, spite of pride, in erring reason's spite,
> One truth is clear: Whatever IS, is RIGHT.
> (*An Essay on Man*, Epistle 1, 289-94)
> Nature and Nature's laws lay hid in night;
> God said: let Newton be! and all was light.
> ("Proposed Epitaph for Isaac Newton, who died in 1727")

The epitaph is of more interest here, first, because, as noted earlier, Newton's physics was a paradigmatic example of and a justification for the classical view or models in science and philosophy. Secondly and more significantly, there is a subtle shift of perspective vis-à-vis the first passage, although this perspective is found in *An Essay on Man* as a whole. The epitaph reflects the Enlightenment belief in human capacity to perceive the ultimate nature of things with a great degree of approximation, even if never completely. The human genius, for which the genius of Newton stands, is sufficient for understanding the laws of material and human nature alike, as ultimately set by God, who is not dead yet. Pope is no Nietzsche.

The questioning of the Enlightenment view of nature and mind began to emerge alongside the Enlightenment and often from within the Enlightenment itself. Hume's and Kant's philosophy were the harbingers of this questioning, although both thinkers, again, ultimately retreated to the classical view as a the foundation of both, in Kant's terms, "pure" (essentially philosophical) and "practical" (essentially ethical) reason.[9] Romantics acutely realized these tensions, and they were unafraid to take Hume's and Kant's thought to the limits that it allowed for and even demanded, against Hume's and Kant's own grain. The questions posed by nature and life, biological and human, required a different, more radical response.

The question of light was one of these questions. The corpuscular view of light dominated physics until the eighteenth century, primarily because of the impact of Newton's optics, which stemmed from, at the time, serious difficulties of understanding light as a continuous phenomenon. However, the competing understanding of light as a continuous, wave phenomena, developed earlier by Descartes and Huygens, among others, was not entirely defeated by Newton's corpuscular optics, which had difficulties in accounting for such phenomena as diffraction and interference. Philosophical objections to Newton's theory were formidable and persistent as well. Eventually, following the famous experiments of Young and Fresnel in the 1800s, which confirmed, almost definitively at the time (but not without

[9] There were significant criticisms of Newton's mechanics (or optics) by his contemporaries, such as, most famously, Bishop Berkeley. However, these criticisms proceeded along strongly classical lines, in contrast to Kant's philosophy, which, while in part grounded in Newton's physics, bordered on nonclassical thinking.

some residual doubts), the wave behavior of light, the wave theory took over. The wave-theory of light was considered established by the mid-nineteenth century with the introduction of Maxwell's electromagnetic theory of light. However, Maxwell's theory did not fully account for all among the experimentally established properties of light, and posed new complexities concerning the nature of wave phenomena, which eventually led to (special) relativity theory. Besides, even as the wave theory dominated the conception of radiation, the atomic and, hence, discrete theory of matter dominated the nineteenth-century conception of matter, from Dalton's atomism on. A new crisis was brought by Planck's black-body-radiation law and quantum physics around 1900. This crisis rekindled the eighteen-century dilemma in a new and more dramatic form, eventually (following quantum mechanics) making one to think in terms of the unknowable and even unthinkable nature of light and of all elementary constituents of matter, with both wave and particle features involved as only surface effects. Throughout the history of modern physics, then, from the sixteenth century on, there has never been a theory that would have had definitively established either the particle or the wave nature of light, even when one or the other view was more dominant. At certain points of this history, such in the late-eighteenth and early-nineteenth centuries, the problem of light posed ontological and epistemological difficulties not unlike those that confronted quantum theory later on. It can be shown that the question of light has significant connections to Hume's and Kant's philosophy and some of Romantic poetry, such as that of Blake or Shelley. In Shelley's case, this question helped to bring him to the threshold of nonclassical thinking. Given my limit here, I shall not address the role of light in Romantic poetry any further here.[10]

In any event, it was, arguably, the realization of the complexities at stake in Kant's and related philosophical arguments on the part of the Romantics, and their willingness to question these arguments' response to these complexities by means of classical models that led Romantics to nonclassical thought and models, presented by them primarily in literary and indirect terms. It took Nietzsche, a culmination of Romantic tradition in this respect and the first full-fledged nonclassical thinker, to expressly articulate a nonclassical model in philosophical terms.[11] Consider this passage from Shelley's great poem "Mont Blanc:"

> Mont Blanc yet gleams on high—the power is there,
> The still and solemn power of many sights,
> And many sounds, and much of life and death.
> …The secret strength of things
> Which governs thought, and to the infinite dome
> Of heaven is as a law, inhabits thee!
> And what were thou, and earth, and stars, and sea,
> If to the human mind's imaginings
> Silence and solitude were vacancy?
> (*Mont Blanc*, ll. 127-129, 139-144)

These lines are often read as the affirmation of human imagination in perceiving, conceiving (which is part of perceiving as well), and naming: "earth," "stars," and "sea," or of course Mont Blanc itself, as a "white mountain" or "thou," or yet something else, and the poem gives it many other names. There is no problem with this reading, insofar as one does not forget Shelley's question mark. This question mark, I would argue, carries the following message. While our imagination "sees" nature and forms ideas about it by, as the poem says, "holding an unremitting interchange with clear universe of things around" [l. 40], we are also able to imagine that the ultimate constitution of nature (or mind) is something that cannot be

[10] I have considered the subject in [18].

[11] Not all Romantic authors subscribed to nonclassical ontology, and some rejected it, as Blake did, even though he also rejected Newton's vision and came close to Bohr's nonclassical concepts of atomicity, a subject that I have discussed elsewhere [19]. Nevertheless, many Romantics have confronted this ontology as a *possibility*, however troubling or undesirable.

imagined by us. In view of the well-known connections between Shelley's thought and the ancient and contemporary atomism, one might argue that in asking this question Shelley had in mind the atomic constitution of nature. This is possible, and the meaning of Shelley's question is unavoidably a matter of interpretation. I would argue (this would be my interpretation) that Shelley's poetic ontological model goes beyond the atomist model. The poem suggests that any atomistic conception of nature (from those of the ancient atomists to Newton's optics to Dalton's chemistry) is a hypothesis created by human mind's imaginings trying to understand the ultimate nature of the world. Shelley is closer to envisioning a Kantian and, I would argue, even nonclassical ontology—the ontology of the unthinkable.

Shelley's use of "to be" in "What *were* thou … if?" can hardly be seen as outside this thought, just as Bohr's question, perhaps with Hamlet, the Prince of *Denmark* (close to home), in mind, in response to H. Hoffding's concerning where a photon could be said to be: "To be, to be. What does it mean to be?"[12] Shelley's more skeptical and radical poetry, such as "Mont Blanc" or still darker *The Triumph of Life* (his last unfinished poem), appears to entertain the idea of the abyssal darkness that cannot be made visible by thought, to paraphrase Milton's description of Hell as the "darkness visible" [*Paradise Lost*, Book 1, l. 63]. Shelley's poetry is pervaded by the questioning of this capacity, and, in part under the influence of Hume, of the underlying causality on the world. As explained earlier, the suspension of causality is an automatic consequence of any nonclassical ontology, and I shall not discuss Shelley's persistent critique of causality here. To cite Paul de Man, one of the more perceptive commentators on Shelley and Romanticism, in addressing *The Triumph of Life*: "[Shelley's poetry] warns us that [at the ultimate level] *nothing*, whether deed, word, thought or text, *ever* happens in relation, positive or negative, to anything that preceded, follows, or exists elsewhere, but only as a random event whose power, like the power of death, is due to the randomness of its occurrence" (21, p. 122; emphasis added). For Shelley, causal or ordered, as well as random or disordered, events always mask, but also unmasks, the impossibility of causality and, again, any conception of the ontology ultimately responsible for these events.

Shelley's question closing "Mont Blanc" is the same question as the question Einstein famously asked A. Pais "whether [Pais] really believed that the moon exists only when [he looked] at it" [22, p. 907]. The answer would be yes, even short of quantum-mechanical or otherwise nonclassical considerations, since Kant's ontology of things-in-themselves is already sufficient for this answer. The moon exists *as the moon* only when there is somebody who can look at it. It does not exist *as the moon* if there is no one to look at it. This does not mean that nothing exists where we see the moon. But whatever it is—and we do not know and perhaps cannot conceive what it ultimately is—it would not be what we see as the moon. As M. Proust observed: "the trees, the sun, and the sky would not be the same as what we see if they were apprehended by creatures having eyes differently constituted from ours, or else endowed for that purpose with organs other than eyes which would furnish equivalents of tree and sky and sun, thought not visual ones" [23, v. 3, p. 364]. Perhaps such "organs" would not furnish even as much, and in any event nothing equivalent.

Well familiar with Kant, Einstein would not deny the points just made. His question was asked in the quantum-mechanical context and is about whether one can speak of the actual constitution of a physical object as independent of an act of observation, which appears to play, and in the nonclassical view, such as that of Bohr (who is on Einstein's mind here), does play, a constitutive role in this respect. This aspect of quantum mechanics greatly worried Einstein, who believed and hoped that our mathematical-physical concepts should, in principle, be able to capture, at least approximately, an independent physical reality, also in quantum physics. This view is close to that of Kant. As explained earlier, for Kant, the

[12] This statement is reported by J. A. Wheeler [20, p. 131].

noumenal reality (that of things-in-themselves) is, while unknowable, is still thinkable, in contrast to the ultimately unthinkable nature of "reality" (to the degree the term applies) in the nonclassical view. It follows that, on Kantian lines, our thinking concerning this reality may in principle be correct, and at least in physics, our observations concerning the worlds governed by this reality can increase the probability that our thinking is correct. This is what happened in relativity and even classical physics, for example, classical molecular physics, within their proper limits, and their success in part guided Einstein's view, as concerns both physical reality and causality. However, quantum physics introduced new phenomena, which classical-like theories failed to handle. Ultimately, a new physical and mathematical type of theory, quantum mechanics, was introduced, which brought classical physical and epistemological thinking into a new type of questioning, and, in nonclassical interpretations of quantum mechanics and of quantum phenomena themselves, made this thinking inapplicable beyond certain limits. As Bohr says in response to Einstein: "In quantum mechanics, we are not dealing with an arbitrary renunciation of a more detailed analysis of atomic phenomena, but with a recognition that such an analysis is *in principle* excluded" [6, v. 2, p. 62]. Hence, the ultimate constitutions of nature may be in principle unavailable to our thought and concepts, a view that Einstein found difficult to accept or even to consider.

This is not only a matter of the *inconceivable character* of the existence of quantum objects (micro or macro), and of the fact of their *independent existence*, apart from our interactions with them, or apart from our existence. For several reasons, the assumption of this independent existence apart from observation and measurement is important for a proper functioning of quantum theory.[13] It is this existence (again, as something that had existed before we appeared in the Universe and that will exist when we will no longer exist) that is responsible for quantum phenomena, as we observe them in our "interchanges" with nature, in the form defined by our particular evolutionary biological constitution. Quantum objects are real insofar as they exist, but there is nothing we can say or, in the first place, think about their reality except as manifest in their *effects* upon measuring instruments. Quantum objects and processes (including the quantum strata of measuring instruments, through which they interact with quantum objects) are the undescribable and inconceivable efficacy of these effects. It is the inconceivable nature of this efficacy that defines quantum objects: it is their *independent* property, and these terms—"object," "quantum," "efficacy," "property," or "independence"—or any other terms only apply provisionally and not rigorously under these conditions.

Could one, then, say that when there is no one to look at the moon, the moon is a quantum object, which cannot be seen by us as such? It would, I think, be difficult to make this claim, given other physical, including classical, aspects of the moon, in particular those defined by gravity, which arguably dominate its behavior, and in this respect its behavior may not be that different from what we can imagine even in our absence as observers. Ultimately, the moon is an object that is, for now, not only inconceivable but also not theorizable by physics, since we do not have a theory that brings together gravitation and quantum physics, which would be necessary to fully understand the moon by physics. If, however, such a theory will prove to be quantum, then one can say that if there is no one to look at the moon, it is a quantum object.

I am of course not claiming that Shelley envisioned the situation to the degree of the account just given. My claim instead is that Shelley provided an ontological-epistemological literary model congruent to the philosophical model underlying quantum mechanics in a nonclassical interpretation, except as concerns probability, although, as will be seen, "Mont Blanc" makes an implicit appeal to probability as well.

3. FROM CHANCE TO PROBABILITY

[13] Maintaining the locality of quantum mechanics is one of such reasons [5, pp. 7].

Although, as is the idea of chance, the idea of probability is old (it is found in both Plato and Aristotle, whose concept of "propensity" was invoked in discussions of quantum probability), the exploration of probabilistic thinking as a way of handling chance, has, as I said, a much shorter history. This history began roughly around the seventeenth century, around the time of Pascal and, in part, thanks to Pascal.[14] Pascal went quite far in understanding and expanding the role of probability, and famously, used probability calculus to justify the belief in God in Pascal's famous wager (a Bayesian bet), something scandalous at the time, especially coming from Pascal, known for his piety. The most significant early developments in probability theory *historically coincide* with the rise of Kant's critical philosophy and then Romantic thought, and the corresponding ontology and epistemology, which is, I argue here, close to quantum-like and even nonclassical ones. Kant himself, while admitting the role of probabilistic thinking in practical matters, expressly forbade the use of, in his words, "the game of probability" in philosophy [17, pp. 384, 589, 661-662]. Against the grain of this prohibition, however, his argument itself opens new pathways to probabilistic thinking, in principle even of the nonclassical type. Of course, probability theory itself works equally well when the ontology is classical, as exemplified in Laplace's famous view of nature. Laplace put probability strictly in the service of causality and even a form of determinism, since the corresponding probabilistic estimate allows us an asymptotic approach to reality in, so Laplace argued, virtually all areas of our understanding of nature and mind, or culture, such as morality, law, politics, and so forth [25]. While, then, the nonclassical or near-nonclassical understanding of chance emerged in Romantic thinking around the time of Laplace, the nonclassical concept of probability had to wait until quantum mechanics.

One could not say that the question of probabilistic thinking was not implicitly posed in literature, beginning, again, arguably with the ancient Greeks. Oedipus makes a bet, which proves to be a good one, that he can solve the crime, that of killing the previous king of Thebes, Laius. What Oedipus did not bet on was (to him) a highly improbable event that he has committed this crime, and moreover that it was patricide. Or, consider the following two passages from Shakespeare's *Hamlet*, which suggest probabilistic estimates in making ethical decisions, even though the corresponding situations are not seen in these terms by Hamlet himself. The first is one of the most famous passages in all of literature:

> *To be, or not to be, that is the question:*
> Whether 'tis nobler in the mind to suffer
> The slings and arrows of outrageous fortune,
> Or to take arms against a sea of troubles
> And by opposing end them. To die—to sleep,
> No more; and by a sleep to say we end
> The heart-ache and the thousand natural shocks
> That flesh is heir to: 'tis a consummation
> Devoutly to be wish'd. To die, to sleep;
> *To sleep, perchance to dream*—ay, *there's the rub:*
> For in that sleep of death what dreams may come,
> When we have shuffled off *this mortal coil,*
> Must give us pause—there's the respect
> That makes calamity of so long life. …
> Thus conscience does make cowards of us all,
> And thus the native hue of resolution
> Is sicklied o'er with the pale cast of thought,
> And enterprises of great pitch and moment

[14] For a helpful account of this history, see [24].

With this regard their currents turn awry
And lose the name of action.
(*Hamlet*, III.2.55-87; emphasis added)

At stake here is, among other things, the uncertainty that often leads to one's incapacity for action. In this case, however, probabilities of either choice are difficult to assign (apart from the type of reasoning found is Pascal's wager), and this difficulty is part of the dramatic power of the situation. The second situation appears to be more open to such an estimate, although Hamlet, again, does not think in these terms. Hamlet is passing by Claudius, who is praying and does not see Hamlet. By this point, Hamlet believes that he has established with certainty that Claudius killed Hamlet's father, and, with this certainty in place, Hamlet plans to kill Claudius. However, the fact that Claudius is praying stops Hamlet, for understandable, but misplaced, reasons:

To take him in the purging of his soul
When he is fit and seasoned for his passage?
No. Up, sword, and know thou a more horrid hent.
When he is drunk asleep, or in his rage,
Or in th' incestuous pleasure of his bed,
At game a-swearing, or about some act
That has no relish of salvation in 't—
Then trip him, that his heels may kick at heaven,
And that his soul may be as damned and black
As hell, whereto it goes. My mother stays
This physic but prolongs thy sickly days.
(Hamlet exits.)
(*Hamlet*, III.3.86-97)

Shakespeare, who rarely misses a chance to makes things more interesting, proves Hamlet wrong in his assessment of the situation:

Claudius (*rises*):
My words fly up, my thoughts remain below.
Words without thoughts never to heaven go.
(*Hamlet*, III.3.100-103)

Hamlet wants to be certain, which is understandable in such decisions—to be or not to be, to kill or not kill—or in ethical decision in general, where we prefer to be certain. Unfortunately, however, it is often impossible to be certain, sometimes in situations where our decisions carry great force and implications. Given what Hamlet knows by this point of the play, he should think that it would be unlikely that Claudius's praying changes anything, and killing him would be a pretty safe bet as concerns Claudius's fate after his death. It is not altogether certain: it never is, which fact connects both scenes considered and gives the characteristically Shakespearian complexity to Hamlet's and our own moral dilemmas. Hamlet's decision ultimately cost him his life, but, as one might expect in Shakespeare, not right away. There is a sequence of chance events, good and bad, beginning with a mistaken, by chance, murder of Polonius, whom Hamlet takes for Claudius, and then a chance disaster at sea, which saves Hamlet's life (he would have been killed in England at Claudius's request), or, more accurately, delays his death. *Hamlet* and other Shakespeare's plays are often about the complexity of our decisions, and in this respect are about *probability*, even if without naming it. But then, it is not as important to name it as to show its significance.

Quite a few other examples of this type can be brought up here, beginning with multifaceted decision-making problems pervading *Paradise Lost*, where only God does not hesitate and does not confront difficult choices. Those of others are almost always nearly impossible to make. Most of the (realist) novels of the 18th century (from Defoe on) and then the 19th century are often informed by probabilistic thinking and even the mathematical theory of probability, for example, as presented in the work of J. Bernoulli, Laplace, and others. The very argument for literary realism was often made in terms of the portrayal of the more probable (more probable events and more probable characters), although the novelistic uses of probability underwent significant changes from the 18th to the 19th century [26]. This argument for the more probable was usually correlative to the underlying classical view of chance and probability, to which both Bernoulli and, as discussed earlier, Laplace subscribed as well. By mid-nineteenth century, novels, while still realist, develop more complex attitudes toward chance and probability.

Portrayals of *probabilistic thinking* itself on the part of characters are rare until late in the 17th century and the early 20th century, and are found especially in detective fiction. Thus, probability plays a significant role in Sherlock Holmes's "deductive method" in Sir Arthur Conan Doyle, as shown, for example, in the opening of "The Hound of Baskervilles," where the word probability, already mentioned before, on the first page, appears three times in one page. Holmes and Dr. Watson are trying to establish a "profile" of an visitor to their flat, whom they missed but who is about to return, and thus (this is Conan Doyle's point) to confirm or refute their reasoning, which is mostly, if not completely confirming it. But then, a degree of expectation and hence of confirmation is itself characteristic of probabilistic reasoning.

> "[Holmes:] The *probability* lies in that direction. And if we take this as a working hypothesis we have a fresh basis from which to start our construction of this unknown visitor."
>
> "[Watson:] Well, then, supposing that 'C.C.H.' does stand for 'Charring Cross Hospital,' what further inferences may we draw. …"
>
> "[Holmes:] On what occasion would it be most *probable* that such a presentation would be made? ... Is it, then, stretching our inference too far to say that the presentation was on the occasion of the change [in the person's place of medical practice]?"
>
> "[Watson]: It certainly seems *probable*." [27, p. 3]

Holmes's (and Conan Doyle's) probabilistic thinking is classical, and in most cases Holmes manages to convert probability into certainty in deducing what had actually happened, but not in all cases. His powers are human, too, and on occasion, he can be outwitted.

As indicated above, while the classical view was still nearly as common in nineteenth-century as in eighteenth-century realism, the practical access to reality and causality was questioned more frequently and radically, and chance and probability were given a greater role, sometimes bordering on nonclassical thinking. As S. J. Gould observes: "Although contingency has been consistently underrated (or even unacknowledged) in stereotypical descriptions of scientific practice, the same subject remains a perennial favorite among literary folk, from the most snootily arcane to the most vigorously vernacular—and it behooves us to ask why" [9, p. 1340]. Gould invokes Tolstoy's *War and Peace* and Emily Brontë's *Wuthering Heights* [9, p. 1340]. He notes that Tolstoy argues that "Napoleon's defeat in Moscow in 1812 rested upon a thicket of apparently inconsequential and independent details, and not upon any broad and abstract claim about the souls of nations or the predictable efficacy of Russia's two greatest generals, November and December" [9, p. 1340]. In this view of war, Tolstoy has a key precursor in Stendhal. It appears to me, however, that all these authors, except perhaps for Stendhal, who is closer to Romanticism, ultimately settle for the classical view of the underlying reality, however "fantastic" it may be. Dostoyevsky invokes the idea of "fantastic realism" as his literary ideal—that of trying to represent this fantastic reality, and perhaps for this reason his novels famously appealed to Einstein. Dostoyevsky's philosophical views appear to have been classical, although they are a matter of interpretation, most of which appear to be classical anyhow. On the other hand, the actual portrayal of the world in his novels has waged a war against his philosophical view of the world, and brought his novels closer to literary modernism, to the quantum-like reality of Joyce and Beckett.

Besides, this fantastic confluence of existence and the impossibility of realism in portraying it may be more real than any realism, as the Romantics, I think, understood, and in fact they understood that any ontological claim might only be a bet. Thus, it can be shown that Shelley's "Mont Blanc" tells us that ontology, too, even the ultimate ontology of the world, may be a matter of our decisions, bets, although, more often than not, such decisions, in Kant, for example, are based on metaphysical certainty rather than on skepticism and only probability of their being right. "Mont Blanc" presents a series of such possible decisions, Bayesian "bets," concerning the ultimate nature of mind and matter, or the relationships between them, and the poem suggests that each reader must make such bets in the absence of the ultimate causality grounding these bets. Thus, assuming that this ultimate ontology is classical or causal or, conversely, assuming that it is, as present in the end of poem, as considered above, quantum-like or nonclassical (nonrealist and, again, noncausal, which makes chance and probability irreducible) is a conjecture, on which one bets. Betting on nonclassical ontology was at the time and still is a common bet. Most bet on causality and on realism, but that does not necessarily make nonclassical ontology less probable, as quantum physics taught us, *some of us*. Einstein and many others (often inspired by his unshakable conviction) had never accepted this view or quantum mechanics as the ultimate theory of nature. They bet against the unthinkable and have taken their chances against chance.

4. CONCLUSION: *ENDGAME*

According to Heisenberg in his Chicago lectures of 1929:

> It is not surprising that our language [and concepts] should be incapable of describing processes occurring within atoms, for … it was invented to describe the experiences of daily life, and these consist only of processes involving exceedingly large numbers of atoms. … Fortunately, mathematics is not subject to this limitation, and it has been possible to invent a mathematical scheme—the quantum theory [quantum mechanics]—which seems entirely adequate for the treatment of atomic processes. [28, p. 11]

It would appear, then, that quantum mechanics is able to get hold of that which is beyond language, descriptions, and even thought itself by virtue of its mathematical nature, not subject to the limitation of daily language or concepts, at least those corresponding to the experiences of daily life. There is still a question of the relationships between mathematical and philosophical concepts (and their relationships with language). I shall, however, put this question aside, since it does not affect my main point the moment, which is the nonclassical character this mathematical scheme (to which Heisenberg subscribes here, following Bohr [28, pp. 11-13]) and the sense, strictly predictive and not descriptive, in which it is "*entirely adequate* for the treatment of atomic processes." Not everyone would agree with this claim, beginning, again, with Einstein, who had argued that this scheme is not entirely adequate throughout his life. In any event, in this sense, and in this type of interpretation quantum mechanics may be seen as a mathematical form of a nonclassical philosophical scheme. Indeed, Heisenberg based his approach on the probabilistically predictive and not descriptive character of the formalism he aimed to find. Schrödinger, by contrast, arrived at his, mathematically equivalent, scheme on the basis of a classical-like physics, which, however, encountered considerable and, it appears, insurmountable difficulties, although Schrödinger remained ambivalent on how insurmountable these difficulties were throughout his life.

Be that as it may, it is this philosophically nonclassical underpinning of quantum mechanics that is of primary interest here, because this type of scheme is, I argue, possible elsewhere, apart from the use of mathematics, which is essential in quantum mechanics, or physics in general and, by this point, most other science. In this sense, what was most fortunate was not so much that mathematics is not subject to the limitation of our daily (or philosophical) language and concepts, but rather that one could find such a mathematical scheme in the situation in which there is no mathematized ontological description of the processes responsible for the phenomena in question. Accordingly, the task of nonclassical quantum-like mathematical modeling, when it is possible, in other fields (such as economics, psychology, or sociology) is to find the mathematics and rules for estimating probabilities involved. This mathematics and these rules may be identical or analogous to that of quantum mechanics and its rules, such as M. Born's rule, arguably the only nonclassical mathematical model we have thus far. But it is also conceivable that different mathematical models and rules might be necessary. It might not be easy, and one might need to be fortunate to do so, just as we were in the case of quantum mechanics.

Now, while it may be surprising that quantum-like nonmathematical models, especially nonclassical ones, have appeared in literature or philosophy (although Nietzsche's model might be the only one in philosophy), before quantum mechanics, it can hardly be surprising that such models would emerge in modernist literature and art, or in philosophy, in the wake of quantum mechanics. A number of prominent modernist literary figures (or those in visual arts) could provide dramatic examples here, such as Kafka. His work could be expressly connected to the old quantum theory (that of Planck, Bohr, A. Sommerfeld, and Einstein), although not to quantum mechanics itself, which was introduced after Kafka's death (in 1918). Kafka's works, especially his novels, *The Trial* (*Das Prozess*), *America*, and *The Castle*, refer to phenomena or processes and places, such as those named by these titles, whose ultimate nature or, one might say, structure—topology and geometry—are ultimately unknowable and even inconceivable. It is never possible to know or to explain how, by what hidden play of forces, one is accused, investigated, and ultimately convicted or acquitted in a criminal procedure: one is always before the law and yet always outside the law never can enters.[15] It is never possible to define, to know or even conceive, what is this place (or even if there is such a place) that we call "America." It is never possible to arrive at the castle, even when one is seemingly there. Joyce's *Finnegan's Wake* and Robert Musil's *The Man without Qualities* also offer instances of quantum-like thinking or modeling, sometimes, of a nonclassical type.

I would like, however, to close with Beckett and, in particular, with *Endgame*, the title especially fitting for closing a paper, or better leaving it forever open, just as Beckett's play is. My main reason for doing so is, however, it provides a quantum-like nonclassical model of probabilistic reasoning, which does not appear and is unlikely to have been found anywhere before quantum mechanics. As stressed throughout this paper, in the view adopted here, quantum mechanics is a *probabilistic* theory of *individual* quantum processes or events. The equations of quantum mechanics and particular rules of using them, such as Born's rule, based in his revolutionary interpretations of Schrödinger's wave function in terms of probabilities. Born's rule allows one to make probabilistic estimates concerning outcomes of certain experiments on the basis of the data obtained in certain other previously performed experiments. Born also gave a new meaning to the wave-particle duality in quantum theory, whereby the concept of wave is no longer given a physical meaning but only refers, metaphorically, to the way probabilities of our predictions would "propagate" depending on the point to which a prediction would refer [30]. The term "particle" still has a physical meaning, corresponding to the ultimate individual constituents of matter or elementary particles (photons, electrons, and so forth), except that, in the nonclassical view, we cannot form a descriptive concept of such entities.

Consider an individual quantum object, say, an electron, whose initial position is specified by a measurement. In the nonclassical view, the corresponding Schrödinger equation allows one the predict the probability of finding the electron in a given region of space at a future time, say, in one second, without *describing* the behavior of the electron itself between these

[15] See, for example, [29].

two experiments, one already performed and one to be performed. In other words, unlike in classical physics, once we make a measurement of the position of an electron at a given point, which we can do exactly, we cannot say exactly where the electron will be at a later point. We can only estimate a probability that it will be in a certain region of space, and there is always a nonzero probability that it will not be found anywhere. In classical mechanics we can, ideally, know both the position *and* the momentum of the body considered, which allows for causality and indeed determinism: we can predict exactly where this body will be at any point, once we know where it is and what its momentum is at the initial point. In quantum physics, the combined simultaneous knowledge of both quantities is impossible in view of the uncertainty relations. They prevent us from simultaneously measuring or even defining both the position and the momentum of an electron, at any point, and thus, only allow us probabilistic estimates concerning its future behavior or, more precisely, its future interactions with measuring instruments. After one makes a measurement, one might speak of certain *potential* or *virtual* probabilities for each given subsequent point in time at which a measurement *could be* in principle performed. We can compile what Schrödinger called a *catalogue* of probabilities for predicting the outcome of experiments possibly to be performed at each such point [4, p. 158]. It is in this sense that Born referred (metaphorically) to the wave-like propagation of probabilities in quantum mechanics.

Now comes the most crucial point. Any act of measurement discontinuously resets both the future evolution of the system and the propagation of virtual probabilities following this measurement. In other words, the process starts anew, or in Schrödinger's words *ab ovo* ([4], p. 154), with each new measurement, which erases the outcome of the previous measurements (which we know) as meaningful for future predictions concerning the system. Each measurement changes the expectation catalogue, or rather creates a new one. Indeed, after a predicted measurement is performed, it may not be possible to use the object for any subsequent predictions at all. A new initial experiment upon a new object, and a new sequence of potential future measurements, will have to be set up. The preceding history of an event, say, a preceding history of the production or of a given reception of a statement, may, and generally does, have little impact on how it will function, how it will be reiterated, in the future by its recipients, even intended, let alone unintended, ones. In any event, no impact can ever be guaranteed. Quantum mechanics is about the future and the uncertainty of the future.

Under these conditions, the game begins anew each time, and there is, as Beckett, I think, realized in *Endgame*, no endgame, no-*end* endgame, in the sense of a possible causally determined trajectory of meaning [31]. In chess, to which the title refers as well, the endgame, *endspiel*, of each game or even in general could, in principle, be determined, since chess is a zero-sum game with complete information, and hence has a determined outcome. The current consensus is that the whites win, although that has not been proven. In principle, if we had sufficiently powerful computers, two such computers would always play the same game. Conceptually or logically, the game would be finished (which is what happened in the case of checkers already), although one could of course still play it. When humans play the game it is as much a matter of quantum-like resetting of probability spaces, since human factors diminish or destroy a formal inevitability of the outcome, or even causality.

The same type of belief in the causal enclosure of an event is perhaps also the fallacy of those "waiting for Godot" in the play under this name, another dramatic "quantum" formalism of the future [32]. The word "waiting" often implies a certain causality of an event coming from somewhere according to determinate expectation, perhaps ultimately determined by God, or by the second coming of God. By contrast, in Beckett it is a coin toss, a throw of dice. Just as in quantum mechanics, Godot may or may not come. Godot is also "go dot," dot by dot, as in quantum experiments, which can never be causally connected, or again, such a connection is never guaranteed. (It is not inconceivable that Beckett had this parallel in mind).

Accordingly, reversing the proverbial expression, it is always the question of *if*, and never of *when*. Only the more or less local conditions of the experiment and experimentation itself are ultimately significant, and, moreover, now unlike in quantum mechanics, there are no reliable algorithms for estimating our chances. Our historical knowledge, gained from previous experience, may help us in shaping our expectations and making our estimates, but it only helps sometimes, and our estimates are nearly always probabilistic and ultimately uncertain. In particular, long-term histories define little and never determine the ontology of events, which ontology is discontinuous, eruptive with respect to any given history, although continuous with respect to other local histories.

Beckett's *Endgame* is a literary-philosophical allegory of these conditions. As Theodor Adorno wrote in his great essay on *Endgame*, "Trying to Understand Endgame":

> The explosion of the metaphysical meaning, which was the only thing guaranteeing the unity of aesthetic structure, causes the latter to crumble with a necessity and stringency in no way unequal to that of the traditional canon of dramatic form. Unequivocal aesthetic meaning and its subjectivization in concrete, tangible intention was a surrogate for the transcendent meaningfulness whose very denial constitutes aesthetic content. Through its own organized meaninglessness, dramatic action must model itself on what has transpired with the truth content of drama in general. Nor does this kind of construction of the meaningless stop at the linguistics molecules; if they, and the connections between them, were rationally meaningful, they would necessarily be synthesized into the overall coherence of meaning that [*Endgame*] as a whole negates. Hence interpretation of *Endgame* cannot pursue the chimerical aim of expressing the play's meaning in a form mediated by philosophy. Understanding it can mean only understanding its unintelligibility, concretely reconstructing the meaning of the fact that it has no meaning. … The poverty of participants in *Endgame* is the poverty of philosophy. [33, pp. 242-243, 253]

There is no point of trying to finally understand either the endgame of the play or *Endgame* as a play, since it is impossible, insofar as both randomness and coherence, an order, which is only tentative, correlation-like, in Beckett, are the product of that which is ultimately unthinkable. Adorno's formulation, "Nor does this kind of construction of the meaningless stop at the linguistics molecules; if they, and the connections between them, were rationally meaningful, they would necessarily be synthesized into the overall coherence of meaning that [*Endgame*] as a whole negates," has a manifest quantum-mechanical flavor. Hence one can indeed speak of the poverty of philosophy, that is, of classical philosophy, which Adorno clearly means here, a philosophy that thinks in terms of classical models, shuns the unthinkable and the acausal. Adorno's title is literal—forever trying to understand, without ever being able to understand. To return to Bohr's question and my title, "To be. To be. What doesn't mean to be?," the answer my well be: we don't know, we cannot know, or even think what this meaning can possibly be. Feynman's statement "Nobody understands quantum mechanics" is invoked often, and not infrequently as a repudiation of quantum mechanics, and as reflecting the fact that an alternative theory of quantum phenomena is desirable [34, p. 129]. (Feynman's own position was more ambivalent and had undergone changes over the years.) On the other hand, that the ultimate behavior of quantum objects cannot be understood is part of the nonclassical *understanding* of quantum phenomena and quantum mechanics.

As noted from the outset, the very names "quantum," "object," and "process" are provisional: no concept associated with these names, or with any other names (names and concepts usually transferred from classical models) is rigorously applicable to quantum objects and processes, which are, thus, unnamable. Shelley spoke of the domain that he saw as allegorically defining the ultimate nature of light as "the realm without a name" (*The Triumph of Life*, l. 396). This unnamable makes possible certain physical effects, which are in turn responsible for certain nominal effects. *The Unnamable* is the title of Beckett's novel closing the Malloy trilogy, and one could give numerous quotations from it, or indeed, preferably, to cite the whole novel to illustrate that it offers a literary quantum-like model of nonclassical type [35]. By the same token, the novel and other works of Beckett also tell us that there may never be a master game, an *end* endgame. Instead, the game of probability, and moreover, probability without causality, becomes open and is interminable, and not only in practical matters, but against Kant's objections, as the defining game of philosophy. This may signal the misery of classical philosophy. But, Beckett's works tell us, it is not the only philosophy, and it is not certain that this philosophy is always our best philosophical bet. It may not always be our best bet on how to philosophically ground physics either.

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