Some Philosophical Remarks on Unobservability

Marcello Poletti*
San Giovanni Bianco, Italy
(Dated: October 14, 2025)

This paper should be read as a philosophical companion to recent formal results [1], where the technical derivations are presented. Here, the focus is on their conceptual and interpretative implications. Those results lead to a radically epistemic reading of quantum mechanics (QM): the theory emerges as an ineliminable logical necessity, even within classical, deterministic, and non-chaotic scenarios. This perspective allows QM to be reconciled with a strong—one might say Einsteinian—realism, and perhaps even to reinforce it. In this sense, QM is here reinterpreted as a certification of that very realism in a strictly epistemic sense.

PRELIMINARY REMARKS

The reflections that follow take a deliberately radical stance on the relation between ontology and measurement. They build upon a series of works—by von Neumann [2, 3], Brukner, Zeilinger [4–6], Szangolies [7], Wheeler [8], and more recently by the author [9–12]—where the focus shifts from ontology to measurement as the genuine object of physics. The essential formal framework underlying this discussion is presented in [1]. The technical results obtained there will not be rederived here, but are assumed as established knowledge on which the present analysis builds. The aim is to reconsider what physics itself is about—what it can describe, and from which point of view.

EXPOSITION

Let us consider the following problem in classical mechanics: a certain number of balls, which for simplicity we assume to have the same radius and mass, move in a Euclidean space with uniform linear motion, except for perfectly elastic collisions governed by the principle of conservation of momentum. This is a borderless variant of the perfect billiard, or equivalently, of a classical gas, though here we are not concerned with the complexities introduced by large numbers of balls.

Such a problem is typically addressed in the earliest introductions to Newtonian mechanics because of its conceptual and pedagogical simplicity. As is well known, this simplicity is largely apparent: a system of this kind exhibits chaotic behaviour even in rather simple configurations. Nevertheless, the study of individual collisions is elementary: the velocity components along the line connecting the centres of two balls are reversed, while the perpendicular components remain unchanged.

The purpose of this work is to persuade the reader that the world described by this model—so simple and deterministic—is, unexpectedly, genuinely quantum. That is, physicists living in that world, for instance on one or more of those balls, could only develop quantum mechanics as a logical necessity for the correct handling of predictions and measurements they can actually perform.

The first step in this direction will be to turn the model into an ontology. This should be quite a natural passage: presumably anyone who imagines that Euclidean space and those balls conceives them precisely as a world, a world that exists and is governed by the stated rules. That world exists—at least in our imagination—and we can refer to it through propositions as if they were Tarskian truths: “two balls collide at time t”, “the velocity of ball p_i is v_i”, and so forth.

Imagining an ontology and formulating such propositions places us in the uncomfortable position of a *deus ex machina*, or of Laplace’s demon [13], creating an annoying veil of philosophical contradiction. If that world were what truly exists, and in particular if it were all that exists, then it should at least contain the Cartesian ego [14, 26] that expresses itself about it; yet the mechanical model itself does not foresee our own existence.

To overcome this impasse, we shall imagine that on one of those balls lives a community of sentient beings interested in describing the world around them. We shall also assume that the presence of these beings is irrelevant to the dynamics, and that they are guided by typically human principles: they apply logic and the scientific method, make predictions and measurements, and are essentially a model of our own ego placed inside, rather than outside, the ontological model.

We must therefore manage appropriately the two possible points of view, paying special attention to the propositions we attribute to our clones within the model. In what follows we shall refer to the *demon* to indicate the point of view of the *deus ex machina*, and to the *scientist* to indicate the point of view of the inhabitants of the imagined world.

If, for example, the demon can casually assert “the ball p_i is at x_i”, since he, who imagines that world, simply decrees that things are so, the same proposition can be attributed to the scientist only with great caution. From what does the scientist infer that “the ball p_i is at x_i”? In what sense, from that point of view, can that proposition be regarded as true?

This subtle dichotomy is symptomatic of an equally subtle ambiguity inherent in physics itself. On the one

* epomops@gmail.com

hand, physics seems to wish to be that branch of thought which attempts to understand the real, nature, to discover the rules governing the things of the world, to model and imagine the ontology of reality—in short, to reconstruct as far as possible, through the force of rationality, the point of view of the demon.

On the other hand, however, physics adopts the scientific method as its fundamental and indispensable guide, and this method is by construction entirely agnostic with respect to ontology.

Consider the proposition "The cat weighs 2 kg." This is an ontological proposition: it indicates, it defines, a property of the entity *cat*. Such a proposition may be true or false in our real world, depending on whether the cat actually weighs 2 kg or not. It may also be simply true in an imagined world in which cats do weigh 2 kg. In both cases, however, a proposition of this sort concerns a Kantian *noumenon* that has no direct interaction with the scientist. To reach "true science," the ontological state must be converted into a measurement: "if you can capture the cat and place it on a scale in an illuminated room, your retinas will form the image of a needle pointing to 2 kg."

To comply with the precepts of the scientific method, it is necessary to be *within* the world, and it is necessary that the world allows or provides the causal relations capable of triggering the Kantian phenomenal chains [15] that transform an ontological state into a corresponding measurement—the formation of the mental state "I have verified that the cat weighs 2 kg."

Von Neumann defines *measurement* precisely as that intimate act of perception which enables the construction of the mental state "I have measured. . . ," to be compared with the mental state "I had predicted. . . ," in order to follow the rules of the scientific method. Moreover, he defines *psychophysical parallelism* as the set of phenomena that ensures the correspondence between the *noumenon* and mental states. He writes in particular:

> This principle *"ensures that it must be possible so to describe the extra-physical process of subjective perception as if it were in the reality of the physical world; i.e., to assign to its parts equivalent physical processes in the objective environment, in ordinary space."*

The words chosen by von Neumann are extraordinarily cautious. He does not say that a noumenon, existing in a metaphysical sense, produces a perceptual state through psychophysical parallelism. Rather, he states that this principle allows the Cartesian ego to interpret perceptions *as if* there existed corresponding entities in a "real" world.

Evidently, von Neumann was already fully aware in 1932 (EPR would appear only three years later [16], and Schrödinger had already expressed deep doubts about the reality of the matter wave since the late 1920s [17]) that the new mechanics raised ontological issues that required extreme caution. In other words, von Neumann's prudence stands as a barrier both against subjective idealism and against materialist reductionism: the correspondence between perception and world is not given, but constructed as a condition of intelligibility.

In the case of the billiard-world, we shall adopt a more audacious stance: the ontological world exists—we ourselves have created it. As demons, we can decree that the balls, their properties, and the rules of the world *are* reality. Following von Neumann, we may then ask how the psychophysical parallelism is realised—how ontological states are transformed into measurements. Naturally, this cannot concern the point of view of the demon, since by construction there are no phenomenal interactions between such a demon and the world. It concerns instead the scientists, those who truly inhabit that ontology. What do they measure? What kind of scientific theories do they produce?

Since those scientists are our mirror, we may easily suppose that they are capable, through their imagination and intuition, of developing Newtonian mechanics and of possessing, at least with some degree of confidence, a kind of "theory of everything" for their world. They, like us, imagine their world as a Euclidean space in which balls of constant radius and mass move freely except for perfectly elastic collisions governed by the principle of conservation of momentum. They thus possess an excellent ontological theory of their world.

Despite these premises, the theory available to those scientists has nothing predictive about it. To "make the model work," one would need some initial conditions; to obtain such data, one would need to perform some kind of measurement; and to do so, some form of psychophysical parallelism would be required.

It is in this sense that the scientific method has been described as agnostic with respect to ontology: "All right, we have the 'true' theory of the world—so what?" Such a theory remains "pre-scientific" owing to its decidedly metaphysical flavour. To do genuine science, one still lacks a piece that describes and allows one to handle the essential facts of the scientific method: a theory of what is measured.

Classical physics is permeated by this ontological flavour. It describes the world, it enables us to understand how the world is made and what rules it obeys, and it produces ontological propositions such as "The cannonball launched at that angle and that velocity will fall at that point." In such theories, the psychophysical parallelism is assumed *a priori*: the only scientifically relevant fact—". . . and there will exist some way to verify that it has fallen at that point"—is usually omitted as an implicit assumption.

Quantum mechanics represents the first case in which the procedure is clearly reversed. Heisenberg deliberately chooses to ignore the ontology of particles, orbits, velocities, and positions, and focuses exclusively on the outcomes of measurements, constructing tables of possible results and defining the algebra required to manipulate those tables. In this sense, quantum mechanics is the first true *theory of measurement* in the strict sense. In a provocative and aphoristic form, one could say that quantum mechanics, rather than posing the measurement problem, for the first time *solves* the measurement problem that was inherent and never fully articulated in classical theories.

What we shall attempt to show is precisely that even in the hyper-simplified and deterministic world of the billiard—despite the ontology being given and presenting no significant problems, and despite the scientists of that world knowing that ontology precisely—they will nonetheless be forced to develop an algebra equivalent to quantum mechanics, in its fundamental principles, in order to practise science in its full sense: to make predictions and to compare predictions with measurements.

In the billiard-world there is no light: the scientists cannot aim telescopes and determine the positions of the balls around them. Nor is there gravity, and therefore the ball that serves as the scientists' home experiences no tidal effects which, however slight, might at least in principle be measurable. That world has the peculiarity of reducing causal interactions to a minimum; in fact, the only event we can imagine as measurable is a collision—the only events the scientists observe are occasional impacts with their own habitat-ball.

This profound phenomenological poverty can be rephrased in another way. If one writes the Lagrangian of the system, it takes on a strongly discontinuous form due to the potential, which is almost everywhere zero in phase space except for infinite walls (a sort of Dirac delta) corresponding to distances between balls equal to twice their radius. In other words, the particular world under analysis possesses no continuous fields capable of transmitting information from one place to another.

A world that is equally classical—such as a Newtonian planetary system—behaves in a diametrically opposite manner. In that system, the Lagrangian is so smooth (being an analytic function) that the tidal effects on the planet inhabited by the scientists are, at least virtually, sufficient to determine every relevant property of the entire world (essentially, by analytic continuation). Every spatiotemporal neighbourhood, however small, of that world contains all the information necessary to describe the whole. We shall call this extraordinary overabundance of information *local determinism*. It is characteristic of most of classical physics, and it is what ultimately allows one to assume psychophysical parallelism as an always-available fact—and thus, finally, to identify the demon and the scientist: both have access to the same information, the former in a magical way, the latter more pragmatically, since, at least virtually, he can always measure the states of the world with arbitrary precision.

The billiard-world and the planetary-world thus lie at opposite extremes of a spectrum of measurability. It is important to stress, however, that psychophysical parallelism can be assumed *a priori* only and exclusively at the perfectly continuous planetary extreme. By modifying the law of universal gravitation, for example by making it a stepwise function of distance—even with extremely fine steps—one introduces into the system an intrinsic problem of measurability. The measurement of local tidal effects will no longer allow the ontological states of the system to be determined with arbitrary precision.

Put differently, physics is entitled to move effortlessly from the point of view of the *deus ex machina* to that of the physicist, and to assume a complete and continuous psychophysical parallelism, only and exclusively under the radical assumption that *natura non facit saltus*.

As we have seen, Newtonian mechanics itself contains no such constraint and allows the construction of "non-analytic" worlds. The constraint is largely psychological: we perceive the billiard-world as a strongly artificial construct, assuming that "the real world" in fact includes gravitational phenomena and that such phenomena are continuous. But are they truly, necessarily, so smooth as to be analytic?

The same holds for general relativity. It does impose certain calculability constraints: the functions defining the geometry $g_{\mu\nu}$ must be differentiable a couple of times in order to handle that algebra concretely, yet nothing requires analyticity or differentiability everywhere. Again, it is more a matter of psychological limitation and computational convenience that we prefer, in our calculations, analytic functions such as sine, cosine, powers, and logarithms, while steering clear of modulus, integer part, or mantissa.

Of all possible worlds, only those that strictly obey local determinism allow ontological theories and measurement theories to coincide. In all others, they diverge.

More concretely, the scientists of the billiard-world experience only occasional collisions. Let us assume that in the event of a collision they are able to determine, with arbitrary precision, every property of the ball with which they come into contact—its mass, radius, direction, velocity, and so on. The most obvious scientific problem those scientists would face consists in estimating when the next collision will occur.

By studying past collisions, they could construct a kind of map of the balls around them and, on that basis—together with the ontological model at their disposal—predict a series of collisions likely to occur in the near future. They could even hypothesise, with reasonable confidence, ontological facts that are not directly measurable, such as the collision of two balls not involving their own. Nevertheless, they would always be exposed to the possibility that an unobservable ball, coming from deep space, might upset the model they have so far constructed. Inevitably, they would be unable to produce predictions of the form "At time t we shall observe a collision," but only partially uncertain, probabilistic propositions such as: "The probability that a collision will occur within a certain neighbourhood of t is..."

This fact is in itself rather surprising. Even in the presence of a simple deterministic ontology, known in every detail—even if no chaotic phenomena were present, and even if what is measurable could be measured with arbitrary precision—it is still possible that the theory of measurement, the concrete and real predictions that can be made, possesses an intrinsically and irreducibly probabilistic nature.

Our scientists live, in a sense, in a world of hidden variables; however, the term "hidden" does not perfectly capture the situation being described. These variables are not hidden in the sense of residing in some secret compartment of the habitat-ball that, at least in principle, with appropriate technological advances, could be opened, converting those properties from hidden to manifest. The properties of the ball arriving from deep space are hidden *in principle* because they are unobservable—because there do not exist (or are not complete) the phenomenal chains that would transport the information "The position of the ball is x" and enact the psychophysical transfer allowing, at least in principle, the formation of the mental state "I know that the position of the ball is x." In other words, there is no complete and continuous causal connection between the ontological states and the perceptual (or perceptible) states of the scientist.

The intrinsically probabilistic nature of the theory of measurement has been called surprising, but this emphasis can easily be moderated. Classical mechanics is accompanied by the theory of error, which is itself a probabilistic theory: any physical measurement must always be expressed as $\pm\varepsilon$; that is, ultimately, it must always be expressed in a probabilistic form (where ε usually defines a confidence sigma). In what sense, then, should the case described here be surprising? Moreover, the theory of probability arose and developed in the same era as classical mechanics, since it was immediately evident that there exist epistemic scenarios in which initial data are inaccessible. Once again, what makes the present case different? Is it not precisely one of those cases?

The case under discussion is subtly peculiar. It has been shown that there exists an intrinsic limit to predictability, not only to measurement. That is, even given arbitrarily precise measurements and even in the absence of chaos, the theory that allows one to predict an event possesses a finite and ineliminable probabilistic limit.

Furthermore, a subtler issue arises: the probability of an unobservable property does not necessarily have much in common with the classical probability of dice and coins. Consider the problem faced by the scientists on the ball: "What is the probability that a ball from deep space is approaching?" This problem is insidious because it cannot be directly formalised along the lines established by Kolmogorov [18]. In fact, it is, one might say, a *second-order uncertainty*: not only is the state of a particular ball unknown, but even the statistical distribution of the balls is unknown. In this sense, the problem can quite legitimately be dismissed, within classical probability, as ill-defined.

On the other hand, this is precisely the kind of problem the scientists on the ball would legitimately seek to answer, regardless of whether or not it can be formulated in terms of measures over certain σ-algebras. One thing they can certainly do is to ignore, at least in the first instance, any theoretical formalisation and adopt an empirical, frequentist approach. They will count collisions over a sufficiently long period of time and define the probability by identifying it with the measured frequency. They can also give an operational definition of "sufficiently long period" by requiring that the frequency stabilise within arbitrarily chosen intervals. That frequency, however it is defined, will then represent the expected value for subsequent periods, and they can thus begin to do concrete science—making predictions and performing tests.

In attempting to construct a formal architecture for handling the observed frequencies, one encounters certain subtleties, a kind of self-referential loop. Obviously, the balls on which a measurement has been performed following a collision were, at least at the moment of that collision, observable. This is a tautology: unobservable balls are defined precisely as those on which no measurement can be made, even in principle; hence, the balls that have been measured are, at least at that moment, observable.

This entails that if we set out to calculate a given quantity, for instance "the number of balls with velocity greater than one versus the total number of collisions," a short circuit arises: the only frequency we can truly measure is more properly "the number of *observable* balls with velocity greater than one versus the total number of *observable* collisions."

More generally, let any proposition p be given, and let us say that p is observable for a certain observer O if, within some neighbourhood of O, sufficient information is available to determine its truth. Then O cannot properly measure the frequency of p, but, by definition, always and only the frequency of "p and p is observable."

In classical probability, to a property p one associates a set U (of unit-normalised measure) such that a portion of its elements, of measure $|p|$, possesses the property p, and the remainder, of measure $|\neg p| = 1 - |p|$, does not. $|p|$ and $|\neg p|$ are thus called the probabilities of p and of not-p, respectively.

However, if one introduces an additional partition of U with respect to the property $\bar{p}$: "p is observable in O," then what O can concretely measure will not be $|p|$ and $|\neg p|$, but at most $|p \wedge \bar{p}|$ and $|\neg p \wedge \bar{p}|$, normalised with respect to $|\bar{p}|$.

For a real observer O, the measured frequencies are necessarily probabilities *conditioned* by observability. These quantities can be expressed in terms of classical conditional probabilities $|p|_q$, that is, the probability of "p, given q." In classical theory, the following theorem holds:

$$|p|_q = \frac{|p \wedge q|}{|q|} \tag{1}$$

Hence, by denoting with $[p]$ the probability concretely measurable by O:

$$[p] = |p|_{\bar{p}} \tag{2}$$

From 1, in classical probability one obtains the well-known commutative rule:

$$|p \wedge q| = |p|\,|q|_p = |p|_q\,|q| \tag{3}$$

However, this rule becomes inapplicable when access is limited to the measurable quantity 2; the observer O will concretely measure instances of non-commutativity:

$$[p]\,[q]_p \neq [p]_q\,[q]$$

Here, $[q]_p$ may be defined as the probability $[p]$ restricted to the cases in which q has actually been verified.

This single technical detail leads to significant consequences: in the presence of unobservability, the algebraic relations among observed frequencies no longer follow the algebra of classical probability but that of quantum probability. The formal details of this derivation will not be discussed here; for them, see [1]

Classical probability, like classical physics, deals with ontological propositions: "In a bag there are 30 yellow balls and 10 red balls; therefore, the probability of drawing a red ball is 1/4," without taking into account the Kantian fact that such an ontology is not directly accessible to a real scientist—or, equivalently, implicitly assuming that there exists a causal connection, a psychophysical parallelism, between the ontology and the scientist.

But if we make this ingredient explicit, the problem becomes: "A scientist knows that in a bag there are 30 yellow balls and 10 red balls; therefore, for that scientist, the probability of drawing a red ball is 1/4." At first glance this specification seems entirely superfluous—after all, the final probability remains 1/4.

On the other hand, even in quantum mechanics, the measurement of a single property poses no problem: "the probability of measuring spin up is 1/2"; in this sense, spin behaves exactly like a classical coin. The problems arise when one attempts to construct the algebra of probabilities—that is, to compute joint probabilities such as "p and q" or "p or q." In these cases, the presence of additional terms $\bar{p}$ and $\bar{q}$ has concrete effects.

An effective way to visualise these effects clearly is to consider one of the simplest forms of Bell's inequality [19–21]:

$$p(A \wedge B) + p(\neg B \wedge C) \geq p(A \wedge C)$$

This theorem of classical probability follows directly from a corresponding theorem of set theory:

$$(A \cap B) \cup (B^c \cap C) \supseteq (A \cap C)$$

Indeed, if an element x belongs to $A \cap C$, then either it will also belong to B, and thus to $A \cap B$, or it will belong to B^c, and thus to $B^c \cap C$.

However, if A, B, and C are not absolute properties but are instead understood as *observable* properties in O, then that theorem is violated, because in $A \cap C$ there may exist an element that is neither "B and observable in O" nor "$\neg B$ and observable in O," whose being B is unobservable in O. And this occurs, it should be noted in passing, without any violation of the law of the excluded middle.

In this sense, quantum probability ceases to possess anything inherently peculiar that would distinguish it from classical probability. It would be "simply" classical probability that takes into account the problem of observability, of phenomenal transport, of psychophysical parallelism.

In conclusion:

> Even within a simple classical ontology—deterministic and non-chaotic—it is possible that a scientist may observe genuinely quantum phenomena: states of superposition, violations of Bell inequalities, tunnelling effects, interference fringes, quantum non-locality, and so forth, and may thus be led to develop quantum mechanics as an algebraic necessity for the manipulation of those measurements. This may occur, in particular, for any ontology that entails some form of discontinuity in the phenomenal chains and hence in the psychophysical parallelism—that is, ultimately, in any theory of the world that does not strictly respect local determinism.

From this point of view, Heisenberg's pioneering work can be reinterpreted in an original light: he did not, in fact, "discover a new physics," but rather rewrote the Hamiltonian formalism in its most properly measurable form—that is, he produced the theory of measurement associated with the ontology of classical mechanics.

The matter naturally becomes more complex with the emergence of quantum field theory, the introduction of relativistic effects, and of the new weak and strong nuclear forces, and so on. Yet the original core of the theory and its fundamental operational rules (complex Hilbert spaces, state vectors, operators, the Born rule, and so forth) would constitute the logically essential nucleus of any theory of measurement intended to deal with the presence of unobservability.

In essence, the founding principles of quantum mechanics would be a necessity that implies almost nothing at the ontological level—except for the violation of the very special case of local determinism.

Such a position may appear profoundly heretical. Quantum physics is strange and reveals an extraordinarily strange, almost unimaginable world; it seems utterly excluded that it could be the same physics as that of the billiard-world, where, for instance, no tunnelling effect occurs—each ball being constrained within regions of potential compatible with it.

Yet science, in the strict sense—that is, the theory of measurement—does not concern itself with whether or not the ball may cross a given potential barrier, but solely and exclusively with what is measured. And, as we have seen, the complexity of the psychophysical parallelism and of the (possibly discontinuous) phenomenal transport is such as to make it entirely plausible, and not at all contradictory, that "the violation of a potential barrier is measured."

Paradoxically, Heisenberg himself repeatedly emphasised, in his more philosophical writings, precisely this point: quantum mechanics does not concern itself with ontology; it does not describe the world, but enables one to handle correctly the outcomes of measurements. And this term, "measurement," has neither a metaphysical nor a magical nature: it involves a conscious act of perception (again, von Neumann) without any need to ascribe magical powers to consciousness itself. Such an act entails the collapse of the wave function—but the latter is not a thing of the world; it is, once more, a mental state. It collapses in exactly the same sense as a classical probability distribution collapses following observation: "Now I know that the value of the die is 3."

This kind of interpretation, if it can be called one, is particularly close to Rovelli's relational interpretation [22]—in a form in which, perhaps, every residual metaphysical tendency is removed. As in Rovelli, the point at issue is that physics cannot indefinitely assume the point of view of the demon: at some level, the fact that measurement itself is a fact of the world must be included in the account. The scientist measures by interacting, by constructing and accessing phenomenal chains; this act cannot be ignored once a sufficient level of detail is reached. Interaction is an essential part of the problem—indeed, more than that, interaction *is* the scientific act.

However, it seems to me that in its attempt to avoid, at all costs, any connection between measurement and consciousness—so as to avert the risk of a "psychomagical" drift in which consciousness acquires divine properties—the relational interpretation ends up promoting the interactions themselves to the status of ontology, as if they were a more fundamental ontology than the interacting entities themselves; as if, one might say, properties existed only in their interaction.

The impression is that the relational interpretation tends to reject ontological propositions of the form "There exist unobservable entities," since it would be possible to assert "x exists" only if x is observable, if there is interaction. Alternatively, this reluctance could be expressed by the formula "it makes no sense," in the form: "It makes no sense to assert that property p has value x prior to an interaction that reveals that that property has value x."

This approach, however understandable in its structure, appears frankly superfluous within a classical framework of strong realism: Bob exists and Alice exists, and nothing prevents Alice from possessing a property unknown to Bob, even if that property were intrinsically unobservable by Bob.

The sense of disorientation associated with unobservability is perhaps akin to that produced by the proposition "There exist true but unprovable theorems." How can a theorem be called true if it is unprovable? It is true simply because it is true, in the Tarskian sense: if, for instance, it asserts that "every prime number possesses property p," then it is true insofar as every prime number possesses property p; the provability of this theorem is a wholly different matter, and need not leave us particularly perplexed.

This logical transposition of the problem is not accidental. Logic, physics, and rationality are certainly connected through the properties of language. By identifying the information about the world available within a small neighbourhood of the observer, the measurement problem can be reformulated as: "Which truths, which theorems, can that observer deduce? Necessarily all possible truths?" Note that this parallel need not invoke Gödel's incompleteness theorems [23]: in a much more elementary sense, a set of axioms may be incomplete simply through manifest poverty. From "Socrates is a man" and "All men are mortal," it cannot be deduced whether Socrates was or was not Athenian.

In the billiard-world, the ball approaching from deep space exists—we ourselves, as demons, have invented it. We understand that the scientist on the ball has no means of assigning that proposition a definite truth value, but it is unclear why that scientist should not simply say, "I do not know whether a ball is approaching," instead of trapping himself in a metaphysics in which that ball will not exist until it interacts with him.

On the contrary, the very effects of unobservability may be used as an argument in favour of strong realism. It is a fact that realism lacks strong arguments enabling one to take a secure step beyond the *cogito ergo sum*. Cartesian scepticism hangs over our heads like a sword of Damocles, forcing us to bear the troublesome burden of solipsism. I exist, but everything else might be a delusion—a projection of my Cartesian ego.

Quantum mechanics, however, seems to open a subtle window within this desolate realisation. If the world were a projection of my Cartesian ego, that world would, by definition, be locally deterministic: every property of that world would be contained within me. But quantum mechanics appears to exclude locally deterministic ontologies and therefore, although QM says nothing concrete about the world, its validity implies that something exists beyond my Cartesian ego. And that something exists precisely to the extent that it possesses properties which, for me, are unobservable.

Certainly, this is not a conclusive argument—but, as said, it is a window: electrons exist insofar as they violate Bell's inequalities; if they did not, we could not distinguish them from a dream.

We shall close with a brief revisitation of Schrödinger's cat. A large part of the debate ignited by this brilliant thought experiment has focused on the ontological question: "What is inside the box? A living cat or a dead cat? Or something else?" There is a perfectly obvious answer to this question: "I do not know, since the box is conceived as an idealised screen that inhibits any phenomenal connection between inside and outside, and I, as the observer, am on the outside."

This natural answer is entirely analogous to the answer we give in a classical probability problem: "What will be the outcome of the coin toss?" Yet it does not satisfy us, owing to a fundamental problem: quantum probabilities do not coincide with classical ones. Bell's theorem, the CHSH [24] inequality, and similar results are all based on this premise; if the answer were purely epistemic, we would verify the theorems of classical probability (of which Bell's and CHSH inequalities are examples). Therefore, something "deeper" must be occurring inside that box.

But there is a significant weakness in this reasoning. The box does not create a "purely epistemic" gap: outside the box, nothing reacts to the cat's state because of a radical rupture in the phenomenal chains. The box affects the observer's knowledge just as much as it affects the dynamics themselves—the objective causal chains. It is not legitimate to assume lightly that in this case, defined as *onto-epistemic* in [1], the rules of classical probability apply; indeed, it is possible to show that the correct rules are those of quantum mechanics.

The difference between the cat and the coin lies in the fact that, in the latter case, we conceive ourselves as being in a condition that could be described as "entangled with the coin." If we knew every detail of its initial conditions, we could infer its motion; but our coarse senses confine us to a state of genuinely epistemic ignorance. In the case of the cat, however, the problem does not arise: there is no limitation in the sensitivity of the instruments—outside the box, the information "the cat is alive" is simply absent, for us as for any conceivable measuring device.

And this, as we have seen, triggers subtle differences in the calculation of probabilities, since the observer O, in order to decide the cat's state, must necessarily place himself within an epistemic context in which those chains are restored—for instance, by opening the box. And this epistemic shift carries a cost: it is no longer possible to verify merely the proposition "The cat is alive," but necessarily the stronger proposition "I have opened the box and the cat is alive."

Einstein was right [16]: quantum mechanics is incomplete—it does not describe all the things of the world. Bohr was right too: it cannot be completed, for physics is concerned, first and foremost, with that act of perception we call measurement—not with the ontology of the world—and can only describe what can be measured.

It is perhaps genuinely difficult to accept that physics does not deal directly with the real, but with the mental states "I have predicted that..." and "I have verified that...". Yet this should not be cause for concern. This does not make physics a branch of psychology: physics, I believe, may continue to employ its marvellous abstractions, to disregard—by design—the complex neurological mechanisms related to the problem of consciousness, and to apply the methodological cut that von Neumann so clearly identified in his analysis of the measurement process. In physics, we may assume that the physicist is a ball; what happens inside it does not concern us. But we can never forget that physics is the description of the world from the point of view of that ball, relative to the interactions that the ball experiences.

DECLARATIONS

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

The author declares no conflict of interest.

No experimental data were used or generated in the course of this study.

The author is solely responsible for the content of this work.

[1] M. Poletti, Observable and unobservable in quantum mechanics, Foundations of Physics **55**, 1 (2025).

[2] J. VonNeumann, *Mathematische Grundlagen der Quantenmechanik* (Springer, 1932).

[3] J. VonNeumann, *Mathematical Foundations of Quantum Mechanics, New Edition* (Princeton University Press, 2008).

[4] T. Paterek, J. Kofler, R. Prevedel, P. Klimek, M. Aspelmeyer, A. Zeilinger, and Brukner, Č, Logical independence and quantum randomness, New Journal of Physics **12**, 013019 (2010).

[5] Č. Brukner, Quantum experiments can test mathematical undecidability, in *Unconventional Computing*, edited by C. S. Calude, J. F. Costa, R. Freund, M. Oswald, and G. Rozenberg (Springer Berlin Heidelberg, Berlin, Heidelberg, 2008) pp. 1–5.

[6] Časlav Brukner, Quantum complementarity and logical indeterminacy, Natural Computing **8**, 449 (2009).

[7] J. Szangolies, Epistemic horizons and the foundations of quantum mechanics, Foundations of Physics **48**, 1669– (2018).

[8] J. Wheeler, Add “participant” to “undecidable propositions” to arrive at physics, https://jawarchive.files.wordpress.com/2012/03/twa-1974.pdf (1974).

[9] M. Poletti, On the strangeness of quantum mechanics, Foundations of Physics **52**, 1 (2022).

[10] M. Poletti, On the strangeness of quantum probabilities, Quantum Studies: Mathematics and Foundations **10**, 343 (2023).

[11] M. Poletti, Quanta iff discreteness, International Journal of Quantum Foundations **9**, 174 (2023).

[12] M. Poletti, Bertlmann’s socks from a viennese perspective (2023), arXiv:2308.03341 [physics.hist-ph].

[13] P. Laplace, *Essai philosophique sur les probabilités* (Bachelier, Paris, 1840).

[14] R. Descartes, *Meditationes de prima philosophia* (Michel Soly, Paris, 1641) contains the classical Latin formulation “Cogito, ergo sum.”.

[15] I. Kant, *Critique of Pure Reason* (Macmillan and Co., London, 1781) first edition (A edition); translated by Norman Kemp Smith, 1929.

[16] A. Einstein, B. Podolsky, and N. Rosen, Can quantum-mechanical description of physical reality be considered complete?, Phys. Rev. **47**, 777 (1935).

[17] E. Schrodinger, Die gegenwartige Situation in der Quantenmechanik, Naturwiss. **23**, 807 (1935).

[18] A. N. Kolmogorov, *Foundations of the Theory of Probability* (Chelsea Publishing Company, New York, 1950) originally published in German as *Grundbegriffe der Wahrscheinlichkeitsrechnung* (1933).

[19] J. S. Bell, On the einstein podolsky rosen paradox, Physics Physique Fizika **1**, 195 (1964).

[20] J. S. Bell, Bertlmann’s socks and the nature of reality, Le Journal De Physique Colloques **42**, 41 (1981).

[21] J. S. Bell, *Speakable and unspeakable in quantum mechanics: Collected papers on quantum philosophy* (Cambridge university press, 2004).

[22] C. Rovelli, Relational quantum mechanics, International Journal of Theoretical Physics , 1637 (1996).

[23] K. Godel, *Opere* (Bollati Boringhieri, Torino).

[24] J. F. Clauser, M. A. Horne, A. Shimony, and R. A. Holt, Proposed experiment to test local hidden-variable theories, Physical Review Letters **23**, 880 (1969).

[25] G. Birkhoff and J. V. Neumann, The logic of quantum mechanics, Annals of Mathematics **37**, 823 (1936).

[26] R. Descartes, *Discours de la méthode pour bien conduire sa raison, et chercher la vérité dans les sciences* (Jan Maire, Leiden, 1637) first edition containing the original formulation of “Cogito, ergo sum.”.