Deflating quantum mechanics

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Abstract

By means of the GRW flash theory and Bohmian mechanics, the paper shows how quantum mechanics accommodates a classical ontology of localised objects with a dynamics that describes the evolution of these objects. That dynamics is non-classical due to the entanglement of the wave function; but it can be entirely deterministic as illustrated by Bohmian mechanics. The wave function is a nomological parameter that can be construed according to any of the major philosophical stances with respect to laws. Against this background, the paper argues that quantum mechanics fits into the paradigm of modern physics as set out by Descartes. The far-reaching claims that call for receiving quantum mechanics as opening up a new paradigm of science are based on a confusion between science and scientism.

Keywords: Bohmian mechanics, Cartesianism, dispositionalism, entanglement, flashes, GRW, Humeanism, localised objects, non-locality, scientific realism, scientism

1. Introduction

Quantum mechanics has given rise to all sorts of far-reaching claims over the past 100 years. These are claims about the physics in the first place, such as its abandoning individual objects, or even objects altogether in its ontology (e.g. Ladyman & Ross 2007, ch. 3) and its implementing indeterminism in its dynamics with probabilities being irreducible and thus fundamental (e.g. Popper 1990). But there are also broader claims in metaphysics that all amount to maintaining that quantum mechanics somehow overcomes the paradigm of natural science as set out by Descartes: for instance, quantum mechanics is supposed to abandon the "mechanistic worldview" (see most recently Desmet 2022, chs. 1, 9 and 11), to make room for free will in the physical world (see e.g. Jordan 1932, pp. 819–820, Margenau 1967, van Inwagen 1983, ch. 6.2 and see Loewer 1996 for a conclusive counter-argument), or even to solve the problem of mental causation (e.g. Eccles, 1994, pp. 160 and 163), if not the mind-body problem *tout court* (as e.g. in the generalised quantum theory proposed by Römer 2023).

The present paper is intended to be an antidote to all these claims. Its aim is to deflate quantum mechanics. By means of two case studies, namely the GRW flash theory and Bohmian mechanics, I will show that the ontology of quantum mechanics can be formulated as a classical ontology of localised individuals. The dynamics is in any case non-classical because of entanglement. But the ontological status of the dynamical variables – that is, the wave function in the first place – is an open issue of philosophical debate with all the major philosophical stances about laws being applicable to the wave function. In conclusion, I will argue that quantum mechanics entirely fits into the paradigm of natural science as conceived by Descartes.

This is not meant to close the debate. It is meant as a challenge for all those who make far-reaching claims about quantum mechanics such as the mentioned ones. Before going ahead with such claims, they should give an argument why it is wrong-headed to receive quantum mechanics as a physical theory like all the other ones within the paradigm set by Cartesian science. In any case, it is unacceptable to present such claims to the public as following from the physics itself.

In the first place, let us recall that a controversy like the one known as the interpretation of quantum mechanics is by no means unique to this physical theory. It is rather the generic case in physics. Newtonian mechanics is committed to absolute space and time through the three Newtonian laws of motion. Leibniz challenges this commitment. Since the work of Julian Barbour and his collaborators from the 1970s on at the latest, it is well known that there is a fully-fledged Leibnizian relationalist theory of classical mechanics available (see notably Barbour & Bertotti 1982 and Barbour 2012). The same applies to general relativity theory: one can either have a theory that abandons absolute simultaneity, but is committed to an absolutist metrics; or one can have a relationalist theory that employs only scale-invariant quantities, but that then works with well-defined three-dimensional geometrical configurations and is thus committed to absolute simultaneity (see Gomes et al. 2011, Gomes & Koslowski 2013, Mercati 2018, ch. 7). The relationalist formulations, known as shape dynamics, are more complicated to handle both in the Newtonian and the relativistic case. They are therefore not popular with working physicists, but this fact obviously does not cut any ontological ice. Something similar applies to many interpretations of quantum mechanics.

Furthermore, the issue of a local dynamics that overcomes Newtonian action at a distance in terms of local fields is by no means settled. The commitment to local fields in classical electrodynamics gives rise to the famous self-interaction problem: the charged particle generates a field that acts back on the particle itself with the consequence that the energy at the particle location becomes infinite. To overcome this problem, Wheeler and Feynman (1945) sought for a theory of classical electrodynamics without fields. As Feynman put it in his Nobel lecture,

> You see, if all charges contribute to making a single common field, and if that common field acts back on all the charges, then each charge must act back on itself. Well, that is where the mistake was, there was no field. It was just that when you shook one charge, another would shake later. There was a direct interaction between charges, albeit with a delay. (Feynman 1966, p. 699)

This is non-local interaction across space with a delay in time, as imposed by the empirical confirmation of the invariance of the velocity of light. There are mathematical means to handle the issue of the interaction of particles and local fields in classical electrodynamics, general relativity and quantum field theory, but the problem of a coherent theory that recognises both particles and fields is not solved, leaving the door open for various interpretations and formulations of the physical theories at issue (see Deckert 2010).

Against this background, quantum mechanics and its interpretation is not an unfortunate exception, but rather a fortunate case. There is an algorithm how to generate statistical predictions of measurement outcomes that is accepted by all sides of the debate, namely the

Born rule. More precisely, this is a rule how to obtain statistical predictions of positions as output (such as measurement results) given initial positions as input (such as an experimental set up). The Born rule is accurate and empirically confirmed, to the extent that anything has ever been empirically confirmed in modern physics. Accordingly, position is privileged in all formulations and interpretations of quantum mechanics.

In this vein, John Bell famously said:

> … in physics the only observations we must consider are position observations, if only the positions of instrument pointers. … If you make axioms, rather than definitions and theorems, about the 'measurement' of anything else, then you commit redundancy and risk inconsistency. (Bell 1987, p. 166)

Thus, since the measurement of all the other observables is registered as position outcomes, they can all be construed on the basis of position measurements (see also Maudlin 2019, pp. 49-50, and Esfeld 2020, ch. 1.1). The question hence is how to understand the transition from given initial positions as input to the output positions as calculated by the Born role. This is the issue of the interpretation of quantum mechanics. The various interpretations of quantum mechanics answer this question in different ways. In other words, the task is to give an account of why the Born rule holds. The Born rule is the only link between the theory and empirical, observable reality. Accounting for the Born rule therefore means accounting for why quantum mechanics is a successful physical theory.

Consider how Ned Hall puts the issue in general terms:

> … the primary aim of physics – its first order business, as it were – is to account for *motions*, or more generally for change of spatial configurations of things over time. Put another way, there is one Fundamental Why-Question for physics: Why are things located where they are, when they are? In trying to answer this question, physics can of course introduce *new* physical magnitudes – and when it does, new why-questions will come with them. (Hall 2009, § 5.2)

In quantum mechanics, the main new physical magnitude is the wave function. Accordingly, in accounting for the Born rule, any interpretation of quantum mechanics has to clear up the status of the wave function and its dynamics.

2. Case study one: the GRW flash theory

The standard textbook formulation of quantum mechanics following von Neumann (1932) proposes a twofold dynamics: the wave function of a system evolves according to the Schrödinger equation, which is linear and deterministic. When a measurement occurs, this evolution is interrupted and the wave function collapses to indicate a measurement result; the collapse is indeterministic and moreover irreversible in time. The problem with this formulation is that it treats the measurement interaction as a primitive, requiring a specific law or lawlike postulate; but doing so obviously does not make sense: measurement is not a further fundamental type of interaction that calls for a specific law on a par with gravitation, electromagnetism and the weak and the strong interaction. Measurement apparatuses are not a natural kind on a par with electrons, neutrons, tigers and the like. Schrödinger (1935) illustrated the nonsense resulting from treating the measurement interaction as a primitive with the famous thought experiment of a cat being tied to a quantum system.

The dynamics proposed by Ghirardi, Rimini and Weber in 1986 (GRW) seeks to make sense of the collapse of the wave function by overcoming the treatment of the measurement interaction as primitive. GRW modify the Schrödinger equation such that the collapse of the wave function is integrated into the dynamics in the guise of the spontaneous localisation of the wave function in configuration space. Its spontaneous localisation in configuration space indicates the occurrence of a discrete, point-like event in physical space, such as – but not exclusively – a measurement. The localisation of the wave function occurs spontaneously so that it is not tied to measurement interactions (or indeed any interactions at all). GRW add two terms to the Schrödinger equation: the probability for a spontaneous localisation to happen, which is extremely small for an isolated quantum system, but extremely high for a macroscopic system; and the width of the localisation in configuration space, which cannot occur exactly at a point in configuration space – otherwise, there would be a singularity with infinite energy at that point.

To be precise, the GRW equation does not yield exactly the same predictions as the Born rule in all cases. An experimental test of the GRW equation against the Born rule therefore is in principle possible (see Curceanu et al. 2016). However, the two parameters that GRW add to the Schrödinger are not fixed once and for all times: they are a conjecture how to integrate the collapse postulate into the Schrödinger equation and can therefore be adapted to future empirical results (see e.g. Carlesso et al. 2016). In that sense, there is no question of the GRW formalism superseding the Born rule or being refuted by experimental confirmations of the Born rule. The issue, again, is the interpretation of quantum mechanics.

The question thus is how to interpret the GRW formalism. John Bell (1987, ch. 22) proposed to conceive this formalism in such a way that it hooks on to physical reality only when a spontaneous localisation of the wave function in configuration space occurs. The corresponding discrete, point-like events in physical space are known as flashes in the literature. The term "flash", however, is not Bell's, but was introduced by Roderich Tumulka (2006, p. 826). According to the GRW flash theory (GRWf), the flashes are all there is in space-time. Consequently, the temporal development of the wave-function in configuration space does not represent the distribution of matter in physical space. It represents the objective probabilities for the occurrence of further flashes, given an initial configuration of flashes.

To illustrate what this proposal means, consider the double slit experiment. The question whether the quantum system passes through one or both slits makes no sense on this theory. As far as the quantum systems are concerned, there only is a flash at the source of the experiment and a flash registered on the screen at the end of the experiment, but nothing in between. More generally speaking, the question of whether quantum systems are particles or waves or both makes no sense on the GRW flash theory. There is no continuous distribution of matter in physical space, namely no trajectories or worldlines of particles, and no field or wave either. There only is a sparse distribution of single, discrete events in space-time. Macroscopic objects are, to use Bell's terms (1987, p. 205), galaxies of such events, that is, galaxies of flashes. They are hence not continuous objects in space with a continuous existence in time, but composed of discrete events. However, there are very many of these events so that they are dense, making up macroscopic objects that appear to be continuous. Consequently, the theory is empirically adequate (but see the objection of Maudlin 2011, pp. 257-258).

To put it in a nutshell, *the GRW flash theory is a classical ontology of particles deprived of trajectories*. It is the most parsimonious classical ontology of matter that is close to the standard textbook formalism of quantum mechanics with collapse of the wave function, when this formalism is made precise by removing the notion of measurement as a primitive. The GRW flash ontology thus is a clear cut example of how a classical ontology of discrete material entities in space-time can be proposed for quantum mechanics. None of the above mentioned far-reaching claims applies to this theory, apart from the fact that its dynamics is probabilistic instead of deterministic. As far as the GRW probabilities are concerned, they can be understood according to all the main positions in the philosophy of probabilities, notably in the Humean way (see Frigg & Hoefer 2007) or in the Popperian way as propensities (see Dorato & Esfeld 2010).

Since the flashes are single events with no direct connection among them, GRWf is committed to a background space-time into which the flashes are inserted. GRWf thus excludes relationalism about space-time. But since the advent of the GRW dynamics and Bell's proposal for an ontology of single events, claims have been raised in the literature according to which the GRWf theory is the quantum theory with an ontology of localised events – "local beables" in Bell's terms (Bell 1987, ch. 7) – that comes closest to accommodate the four-dimensional space-time of special relativity without a privileged foliation into three-dimensional space and one-dimensional time, if not being outright compatible with Lorentz invariance. These claims go back to Bell himself (1987, pp. 206-209) and have been elaborated on in detail by Tumulka (2006).

Indeed, it is not in dispute that the theory is Lorentz-invariant when one considers the entire distribution of the flashes throughout the whole of space-time (as e.g. in a block universe ontology): that distribution is compatible with any foliation of four-dimensional space-time into three-dimensional space and one-dimensional time. But this does not imply that the GRWf dynamics is Lorentz-invariant. When it comes to reconstructing the temporal evolution of a given initial configuration of flashes, that evolution arguably cannot be understood in a Lorentz-invariant manner; it requires the commitment to a privileged foliation of space-time (see Esfeld & Gisin 2014).

Finally, the flashes are characterised by their position only. They do not have any further material properties. They thus are primitive stuff. The GRWf theory therefore is not only committed to an absolute background space-time, but also suggests an ontology of super-substantivalism according to which there only is space-time: space-time occasionally flashes so to speak. If one takes super-substantivalism to be a serious option in the ontology of physics (see Lehmkuhl 2018), then the GRWf quantum theory arguably is its best illustration (and not general relativity theory, because it is unclear how the matter fields could be reduced to properties of space-time).

3. Case study two: Bohmian mechanics

From a systematic point of view, but in contrast to history, the quantum theory developed by Louis de Broglie (1928), David Bohm (1952) and John Bell (1987) and known today as Bohmian mechanics (see Dürr & Teufel 2009, Dürr, Goldstein & Zanghì 2013) can be construed as a theory that connects the flashes with one another through trajectories and thereby restores an ontology of classical particles for quantum mechanics. The basic postulate of Bohmian mechanics is that quantum systems are discrete objects that always have a definite position. Position is the variable that is added to the wave function, therefore sometimes referred to as "hidden variable". But this expression is misleading, since positions are – all – our evidence about physical reality via measurement records, as mentioned above.

What is added in Bohmian mechanics and is subject to restrictions in epistemic accessibility is the fact that, according to this theory, quantum systems *always* have positions. They hence move on trajectories. The particles thus are individuals, which are absolutely discernible (see Saunders 2006 on absolute discernibility).

Since the wave function and its development according to the Schrödinger equation do not yield the information about the trajectories, Bohmian mechanics requires a further dynamical equation, which is known as the guiding equation. Given initial particle positions, this equation fixes the evolution of the particle positions via the wave function. Any uncertainty about the exact initial particle positions obviously translates into uncertainty about the actual trajectories.

While the ontology of Bohmian mechanics is one of classical point particles moving on trajectories, its dynamics is non-Newtonian. The guiding equation is a first order equation: it takes particle positions as input and yields particle velocities as output. Bohm (1952) proposed a second order formulation of the dynamics with the wave function supposedly giving rise to a specific quantum force called the "quantum potential", but this formulation is unnecessarily complicated. The theory can in any case not be cast in the framework of a Newtonian dynamics, since it violates Newton's third law: if one conceives the wave function as a quantum force (potential), one may say that this force acts on the particles. But the particles do not act back on the wave function. The wave function does not disclose the evolution of the particle positions, i.e. their trajectories.

Like the dynamics of Newtonian mechanics, the dynamics of Bohmian mechanics is non-local. Bell proved with his theorem in 1964 (reprinted in Bell 1987, ch. 2) that variables added to the wave function ("hidden variables") cannot evolve according to a local dynamics and thus restore locality in quantum mechanics if the empirical predictions generated by the Born rule are to be respected. The experiments from Aspect et al. (1982) on then proved that these predictions are confirmed also in a setting that tests the correlations figuring in the inequalities on which the proof of Bell's theorem is based at space-like distances.

This non-locality is taken into account in the dynamics of Bohmian mechanics: strictly speaking, the guiding equation takes as input all the particle positions of the universe at a given time. It thus correlates the evolution of strictly speaking all the particle positions with one another. This is relevant for instance in the double slit experiment: the particle moves on a trajectory that passes through one of the two slits. However, its trajectory after that passage depends on the positions of the particles that make up the other slit, namely on whether or not they constitute the configuration of an open slit. In Bohmian mechanics, non-locality thus manifests itself long before a measurement occurs, or before a spontaneous localisation of the wave function takes place according to the GRW dynamics.

That notwithstanding, Bohmian non-locality is limited for all practical purposes. Many situations can be described by what is known as an effective wave function that abstracts from non-local correlations among the evolution of the particle positions. Generally speaking, quantum non-locality is restricted for all practical purposes, as is Newtonian action at a distance. In Newtonian gravity, strictly speaking, the acceleration of any massive object at a given time depends on the positions and velocities of all the other masses in the universe. However, since the action at a distance diminishes with the square of the distance, the action of distant masses can often be ignored. In quantum mechanics, the non-local correlations between measurement outcomes – or, more generally speaking, local beables in Bell's terms –

are completely independent of spatial distance, but they are discriminatory: they usually are significant only in the case of quantum systems that have interacted in a specific manner in the past. That is why highly sophisticated experimental setups such as the one of Aspect et al. (1982) are necessary to detect these non-local correlations.

Bohmian mechanics does not countenance superpositions in its ontology. The particles always have a precise position. Quantum entanglement is construed as non-local correlations in the evolution of the particle positions. Since these non-local correlations are relevant long before a measurement occurs (as e.g. in the double slit experiment), there is nothing specific about measurement events in Bohmian mechanics, and there is no need for a collapse of the wave function in its dynamics: everything is accounted for through the postulate of the particles always having definite positions and the dynamics of the guiding equation that correlates the evolution of the particle positions in a non-local manner. Consequently, the dynamical equations of Bohmian mechanics – both the guiding equation and the Schrödinger equation – are entirely deterministic.

Probabilities come in as in classical statistical mechanics, namely through ignorance of the precise initial conditions. Bohmian mechanics adds a postulate to the effect that the initial state of the universe is a state of what is known as quantum equilibrium. This then enables the derivation of the Born rule as valid for the measurement outcome statistics of subsystems within a universe whose initial state is one of quantum equilibrium (see Oldofredi et al. 2016). Hence, Bohmian mechanics proves that there is a quantum mechanics with a classical ontology and a deterministic dynamics available that accounts for the quantum probabilities.

Due to the non-locality implemented in the dynamics of Bohmian mechanics, the theory is committed to a privileged foliation of space-time into three-dimensional space and one-dimensional time. However, because the particle positions make up continuous trajectories, Bohmian mechanics is not committed to an absolute space-time into which the particles are inserted. Bohmian mechanics can be conceived in a relationalist manner as regards space and time; more precisely, it can be inserted into the framework of the relationalist theory (shape dynamics) developed by Julian Barbour and collaborators, which works with instantaneous configurations anyway (see Dürr et al. 2020).

Furthermore, although the Bohmian particles are characterised by position only, they do not have to be conceived as primitive stuff. Bohmian mechanics can be construed in terms of ontic structural realism with the structures being the distance relations among the particles, and these relations individuate the particles. In this case, there neither is a commitment to primitive stuff nor a commitment to a primitive numerical plurality of the particles; the particle number is derived from the distance relations that individuate the particles (see Esfeld & Deckert 2017, chs. 2 and 3).

In comparison, one can conceive both the ontology of GRWf and the ontology of Bohmian mechanics as a package deal: Bohmian mechanics makes the additional postulate of connecting what is conceived as single events in GRWf through trajectories. But doing so has the payoff of being able to avoid the commitments to absolute space-time and to a primitive numerical plurality of the particles as well as restoring a fully deterministic dynamics. GRWf is the more parsimonious ontology of matter by avoiding the additional variable of there always being positions. But since there are only single events with no direct connection among them, the theory is committed to an absolute background space-time into which the flashes are inserted.

In any case, both the GRW flash ontology and Bohmian mechanics prove that quantum mechanics can be received as supporting a classical ontology of localised single objects that are individuals and absolutely discernible with a non-classical dynamics that describes the evolution of these objects; that dynamics can be deterministic, as illustrated by Bohmian mechanics.

4. *The status of the wave function*

The main – and new – dynamical variable in quantum mechanics is the wave function. The wave function cannot be construed as being or representing a wave. It is not defined on physical space, but on configuration space. As soon as the wave function describes the dynamics of two or more quantum objects, it does not have definite numerical values at the points of space or space-time. If one sets out quantum mechanics in terms of a classical ontology of localised single objects (single events or particles moving on continuous trajectories), the wave function comes in only as a dynamical variable that describes the evolution of these objects – either directly by indicating probabilities for the occurrence of flashes given an initial configuration of flashes as in the GRW modification of the Schrödinger equation or indirectly through its role in the guiding equation describing the evolution of the particle positions in Bohmian mechanics, with the wave function itself evolving according to the Schrödinger equation. If the wave function is a dynamical variable, it is nomological (see Dürr, Goldstein & Zanghì 2013, ch. 12.3): it enters the theory through its role in the dynamical equation(s) of the theory.

The role of the wave function is to give rise to a non-classical dynamics through entanglement. But that is all that is specific about the wave function. This does not ground any of the above mentioned far-reaching claims about quantum mechanics, apart from the fact that the dynamics can be irreducibly probabilistic instead of deterministic, as in the GRW dynamics. Indeed, all the standard philosophical stances about laws of nature can be applied to the wave function, notably the following three ones:

- *Primitivism and Platonism*: The wave function can be conceived in a Platonic manner as an ontological primitive in the same way as laws can be conceived as an ontological primitive that exist over and above the matter in motion and that have their own, specific ontological status (see Maudlin 2007).
- *Dispositionalism and Aristotelianism*: The wave function can be conceived in an Aristotelian manner as referring to dispositions or powers that are inherent in the material objects and that manifests themselves in the dynamics that is described by the equation(s) in which the wave function figures. That disposition or power can be construed as belonging to the configuration of the material objects as a whole, giving rise to the stance known as quantum cosmic hylomorphism (see Simpson 2021), or it can be construed as belonging to the individual objects (see Suárez 2015).
- *Best system analysis and Humeanism*: The wave function can be construed as a dynamical variable that is part and parcel of the best system account of laws of nature, namely the system that achieves the best balance between being simple and being informative about the actual evolution of the configuration of matter of the universe (see notably Lewis 1994). This view is known as Humeanism, because it does not countenance any primitive modal entities, such as laws as a primitive or primitive dispositions or powers. There only is the configuration of matter consisting in spatio-temporal positions and the evolution of

these positions. The wave function is part and parcel of the dynamics that achieves the best balance between being simple and being informative in describing this evolution. There hence are no relations of quantum entanglement instantiated in the universe over and above the spatio-temporal relations between localised material objects. These latter relations evolve in such a way that an entangled wave function figures in the best system describing their evolution. This stance is known as quantum Humeanism. It has been set out by Callender (2015), Esfeld (2014) and Miller (2014) independently of one another. It can be applied to all dynamical variables, including the classical ones of mass and charge. The resulting stance then is known as Super-Humeanism (see Esfeld & Deckert 2017, ch. 2.3): there only is the – primitive – ontology of positions and their evolution. Everything else comes in as a package to describe the evolution of the positions in the way that achieves the best balance between being simple and being informative.

Which one of these stances one prefers depends on how one weighs the philosophical arguments. There is nothing specific about the wave function and quantum mechanics here.

5. Conclusion: quantum mechanics as Cartesian science

Modern natural science – and in particular modern physics – can be traced back notably to Descartes. Three features characterise the Cartesian conception of natural science:

- *Objectivity*: Science abstracts from all subjective and evaluative features. This includes not only a strict separation between claims about facts and claims about norms, but also dismissing the sensorial qualities such as colours, sounds and smells. Descartes thereby gets to conceiving non-human nature as *res extensa*, characterised solely by extension and motion, namely positions with distance relations linking these positions (extension) and change in these distance relations (motion).
- *Methodological scepticism*: Since all human enquiry is influenced by subjective elements including the social and cultural context, any scientific claim has to be submitted to rigorous scrutiny to find out what exactly is confirmed by empirical evidence.
- *Limited domain of applicability*: Since science abstracts from all subjective and evaluative features, it meets a principled limit when it comes to human consciousness, the mind and normative judgements. The price to pay for science being objective is that it cannot say anything about this domain (see Esfeld & Lopez 2024, ch. 2.1, for elaborating on the Cartesian conception of science in this vein).

Quantum mechanics entirely fits into the Cartesian conception of natural science. It can even be construed as a paradigm case of Cartesian science. As both the GRW flash theory and Bohmian mechanics show, quantum mechanics can fully be received as a theory of positions only, describing the evolution of positions by means of the wave function and the dynamics in which the wave function figures. Recall again this quote from Bell:

> … in physics the only observations we must consider are position observations, if only the positions of instrument pointers. It is a great merit of the de Broglie–Bohm picture to force us to consider this fact. If you make axioms, rather than definitions and theorems, about the 'measurement' of anything else, then you commit redundancy and risk inconsistency. (Bell 1987, p. 166)

The link to positions and the empirical confirmation of predictions of position measurements is provided by the Born rule only. This rule is best confirmed by the empirical evidence that is available according to the current state of the art. But when it comes to accounting for the

Born rule in what is known as the interpretation of quantum mechanics, methodological scepticism is appropriate. The standard there is one of argument and clarity of the mind in setting out an account as precisely as possible and weighing its pros and cons.

Finally, there is no reason at all to expect quantum mechanics to bear on issues that one may have with modern natural science. Descartes sets out a clear-cut case for science being objective and its objectivity analytically and thus trivially implying that natural science as such cannot reach out to the features of the human mind such as consciousness in the sense of a subjective perspective on the world (the qualitative features of sense experience), meaning, freedom, normativity and values. One may with good reason hold that Descartes overshoots in conceiving the human mind as a substance that is independent of matter (*res cogitans*), but such well-grounded reservations to do not touch upon his arguments for the limits of modern natural science. These limits clearly apply also to quantum mechanics, being a theory of the motion of matter.

In particular, what may be referred to as the "mechanistic worldview" inspired by classical physics is not science, but scientism. This is the view that science informs us not only about what there is in the natural, non-human world and what the laws of motion of inanimate objects are, but that science is also the guide to answer all meaningful questions, including the questions relating to human thought and action (see Voegelin 1948 and most recently Peels 2023; for discussion, see the papers in de Ridder et al. 2018 and in Boudry & Pigliucci 2018). The broader claims in metaphysics based on quantum mechanics tacitly take scientism for granted. They regard modern science as entailing a mechanistic worldview that includes the human mind. They then expect quantum mechanics to usher in a new type of science that resolves the issues that arise when one receives modern science in the framework of scientism, such as, in particular, issues concerning human consciousness, thought, freedom, mind-body interaction, etc.

However, this attempt is misguided. It is wrong-headed to call for some sort of a new science and to appeal to quantum mechanics as such a new science if one intends to overcome the "mechanistic worldview" (e.g. Desmet 2022, chs. 1, 9 and 11). The syllogism that underlies this argument is a paralogism. There is no valid *modus ponens* that goes from modern natural science to the "mechanistic worldview". Hence, there is no valid *modus tollens* either that goes from the rejection of the "mechanistic worldview" to the rejection of modern natural science in the sense of the call for replacing it with a new type of science.

The basic mistake is to assume that natural science, of whatever type, can serve as a sort of normative guide to human action. One can with good reason object to the consequences to which receiving the modern natural science that goes back to Descartes in this vein leads. Already in the exchange between Friedrich von Hayek and Karl Popper in the 1940s, Hayek (1952) showed how doing so amounts to a "counter-revolution of science" and Popper (1945) argued that doing so fuels the ideologies of the "enemies of the open society". If one intends to go against this misuse of science in the "mechanistic worldview" and its consequences, one can entirely rely on these philosophical arguments (see Esfeld & Lopez 2024, chs. 2 and 3). If, by contrast, one expects quantum mechanics to set the paradigm for a new type of science that bears on the questions concerning the human mind, one repeats the mistake of the paralogism that goes from modern natural science to scientism. One again expects natural science, albeit a new type of natural science that one then mistakenly locates in quantum mechanics, to be able to serve as a normative guide for human action and to provide for answers to the central questions of human existence.

To put it differently, as so often, it is philosophy in, philosophy out. That is: If one puts scientism as philosophy in, then one will get all the objectionable consequences of scientism as philosophy out. If one seeks to go against these consequences, one has to go against the philosophical reception of modern natural science in the vein of scientism, but not against the science itself. This applies to any scientific theory including quantum mechanics. Again, there is nothing specific about quantum mechanics here. It is therefore appropriate to deflate quantum mechanics: one should appreciate its scientific quality, its empirical success and the specific features of its dynamics due to entanglement. But one should refrain from expecting quantum mechanics to resolve the wider philosophical and societal issues that arise with the advent and the empirical and technological success of modern natural science.

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