

'In Principle Observable': Werner Heisenberg's Discovery of Quantum Mechanics and Romantic Imagination

Arkady Plotnitsky

1. Introduction: From the (In Principle) Observable to the (In Principle) Unobservable

Werner Heisenberg's discovery of quantum mechanics in 1925 was in part enabled by his program of basing his new theory on the 'relationships between magnitudes [*Grösse*] that are in principle observable', as he famously announced at the outset of the paper introducing his momentous discovery.¹ On the surface, this is hardly a revolutionary move. Nearly all of physics, from Galileo or indeed Aristotle on, is based on such magnitudes and, it is worth stressing (the point is often missed), on the *relationships* between them. The revolution (we are weary of the term now, but if one can still use it) in this case, one could lay elsewhere – in how Heisenberg's *theory* approached the observable magnitudes in question and how it handled the relationships between them. Heisenberg may be said to approach nature no longer as a book, as classical physics did, but as something akin to what Jacques Derrida calls 'writing'. The concept of writing also signals 'the end of the book', at least as we have understood the idea hitherto, including in speaking of the book of nature, the trope invoked by Derrida as well.² In particular, the peculiar character of the experimental data of quantum physics vis-à-vis that of classical physics compelled Heisenberg to conceive of quantum mechanics no longer as a theory dealing with its principal objects, say, electrons in atoms, in the way classical, Newtonian, mechanics deals with classical objects, say, planets moving around the sun. In certain interpretations, such as the one to be adopted here, quantum mechanics does not deal with these objects at all. Instead it deals, and then only in terms of predictions, with the *traces*, 'that are in principle observable', of the interactions between these objects and certain other objects, such as cloud chambers or photographic plates, used in experimental physics. These traces may in turn be seen as 'traces' in Derrida's sense of the term (related to his sense of writing), that is, as something the ultimate origin or history of which cannot rigorously be reconstituted, even in principle.

Heisenberg's insistence on the 'relationships between magnitudes that are in principle observable' had its roots in, and was likely to emerge from, the preceding history of quantum physics, inaugurated by Max Planck's discovery of the discontinuous (quantum) nature of radiation, such as light, or even certain areas of classical physics, such as kinetic (molecular) theory of gases. One never did and apparently could not

observe quantum objects themselves or their physical properties, such as the position or the momentum of an electron in an atom. The preceding quantum theory, associated primarily with the work of Max Planck, Albert Einstein, Niels Bohr, and Arnold Sommerfeld, especially Bohr's theory of the atom, introduced in 1913 and developed during the next decade, was built *in part* upon this classical picture, with electrons moving along elliptical, Keplerian, orbits around the nucleus, analogously to planets moving around the sun. The correspondence with classical physics was only partial, however, since the theory also contained features incompatible with classical physics and indeed worked by virtue of this incompatibility. Bohr's own revolutionary move was to postulate, without any physical justification, such nonclassical features for his model of the atom, and thus inaugurate a radical departure from classical physics, which eventually led to Heisenberg's discovery. While a great success, especially as against strictly classical attempts, this theory encountered problems insurmountable by its means. These problems were solved by Heisenberg's quantum mechanics as matrix mechanics, as it became known (for the reasons to be explained below), and then by Erwin Schrödinger's wave mechanics. Both theories were quickly discovered to be equivalent, mathematically and experimentally (in terms of predictions they provided), although Schrödinger's version was based on, and initially offered hope for, a more classical-like view, developed in terms of wave propagation (rather than particle motion). Ultimately, however, the theory led to an even further departure from classical physics in relinquishing the possibility of speaking in terms of attributes of physical objects, quantum objects, with which it was concerned, at least in certain interpretations, such as Bohr's, known as complementarity, which was in part based on Heisenberg's initial insights.

Indeed, following both Heisenberg and Bohr, one could argue such properties to be not only, in principle, unobservable but also, in principle, unassignable, thus leading to an epistemologically radical – irreducibly noncausal and non-realist – interpretation of quantum mechanics, the interpretation that will be used throughout this article. On this view, quantum mechanics relates to the observable effects of the interactions between unobservable entities and measuring instruments upon those instruments, and only to those effects, without saying anything, and indeed disallowing one to say anything, about quantum objects themselves, assuming that such terms as 'quantum' or 'objects' still apply. (Rigorously, they do not in this interpretation). In other words, while based on magnitudes that are *in principle observable* and on the relationships between such magnitudes, quantum mechanics relates these magnitudes to *in principle unobservable* and ultimately *inconceivable* material entities, designated as 'quantum objects'.

In Bohr's words, with his theory Heisenberg 'succeeded in emancipating himself completely from the classical concept of motion', and handled the data in question by a formalism, very different, mathematically and epistemologically, from that of classical physics.³ This formalism enables excellent predictions, in general probabilistic in nature, concerning the outcome of the experiments in question. It is, however, in Bohr's terms, purely 'symbolic', and hence also essentially *algebraic* in character, rather than, as in classical physics, in any way representing or even in any way relating to the motion of the objects considered, which would, at least in principle, entail a certain *geometrical* picture of this motion. We can only use this formalism to relate to a certain

(Derridean) writing, which we can also obtain by means of our experimental technology, rather than to read the geometrical book of nature (e.g. trajectories of moving physical objects) in the way classical physics could, at least in principle. Heisenberg thus revolutionized not only physics itself but also, and correlatively, the relationships between mathematics and physics, and between both and philosophy. Mathematics no longer served to describe any physical process in the way it did in classical physics, but instead provided an abstract formalism enabling proper predictions of the outcomes of relevant experiments on the basis of previously preformed experiments. It allowed one to link certain events without relating to the processes that connect, especially causally, these events.

This article will discuss the epistemology just outlined, first, by relating it to Kant's epistemology of the beautiful and the sublime in *The Critique of Judgment* and to related ideas found in Romantic literature, and then in Marcel Proust. I shall also address the relationships between this epistemology and Edmund Husserl's 'principle of all principles', which defines the primordial intuition as a source of authority for knowledge. I shall then discuss, via de Man's work, the concept of history that is correlative to, and indeed inevitably arises from, this epistemology. Finally, I shall, suggest, via a reading of Shelley's 'Mont Blanc', that this epistemology, and thinking (literary, philosophical and scientific other) and practice based on or leading to it, may be viewed as Romantic, the argument intimated by Heisenberg himself in one of his later essays.

2. 'As Poets Do': From Causality to Perception

According to Kant's third *Critique*, *The Critique of Judgment*, we might be able to find the sublime in nature, if we regard nature, 'as poets do', that is, 'merely in terms of what manifests itself to the eye [*was der Augenschein zeigt*]'. Kant argues as follows:

[W]e must not take for our examples such beautiful and sublime objects of nature as presuppose the concept of a purpose. For then the purposiveness would be either teleological, and hence not aesthetic, or else based on mere sensations of an object (pleasure or displeasure) and hence not merely formal. Therefore, when we call the sight of the starry sky *sublime*, we must not base our judgment upon any concept of the worlds that are inhabited by rational beings, and then [conceive of] the bright dots that we see occupying the space above us as being these worlds' suns, moved in orbits prescribed for them with great purposiveness; but we must base our judgment regarding it merely on how we see it, as a vast vault encompassing everything, and merely under this presentation may we posit the sublimity that a pure aesthetic judgment attributes to this object. In the same way, when we judge the sight of the ocean we must not do so on the basis of how we *think* it, enriched with all sorts of knowledge which we possess (but which is not contained in the direct intuition), e.g., as a vast realm of aquatic creatures, or as the great reservoir supplying the water for the vapors that impregnate the air with clouds for the benefit of the land, or again

as an element that, while separating continents from one another, yet makes possible the greatest communication among them: for all such judgments will be teleological. Instead we must be able to view the ocean *as poets do*, merely in terms of what manifests itself to the eye – e.g., if we observe it while it is calm, as a clear mirror of water bounded only by the sky; or, if it is turbulent, as being like an abyss threatening to engulf everything – and yet find it sublime.⁴

According to de Man, ‘the only word that comes to mind is that of a material vision’.⁵ The nature of this materiality and of the formalism or of the phenomenality that accompanies it is complex, and, given my limits here, I can only offer a sketch of what is at stake.⁶ Both the beautiful and the sublime involve a radical decoupling of the experience from, first, any understanding of concepts and, second, more subtly, even from feeling, except for a certain formal feeling, at least at a certain (initial) stage of the experience. Accordingly, Kant’s ‘as poets do’ would apply in the case of the beautiful as well, but in this case the perceptual configuration in question would be integrated into a certain framed formal object, a beautiful object, analogous to and, in part, modelled on spatial figures considered in geometry. By contrast, in the case of the sublime, such integration, while it seems possible, or, as it were, teases us into being possible, always escapes us. The (minimal) formality and, in essence, perceptually geometrical or at least quasi-geometrical character of vision remains crucial in both cases, however, making de Man speak of ‘geometrization of pure [linear] optics’.⁷ This is how the initial formal vision and feeling are re-integrated after the perceptual data in question is divested of preceding forms of understanding it, including how it came about, and of any experience other than that (minimal) experience of form defined by de Man as ‘material vision’.

Kant’s invocation of poets’ vision is not without further complexities, which cannot be addressed here. Kant, however, does find allies and readers among ‘poets’, from his contemporaries, such as Kleist or Shelley. Marcel Proust is among them, when he invokes ‘the Dostoyevsky side of Mme de Sévigné’s Letters’. Proust writes:

But my grandmother [...] had taught me to enjoy the real beauties of her [Mme de Sévigné’s] correspondence, which are altogether different. They were presently to strike me all the more forcibly inasmuch as Mme de Sévigné is a great artist of the same school as a painter [Elstir] whom I was to meet in Balbec, where his influence on my way of seeing things was immense. I realized at Balbec that it was in the same way as he that she presented things to her readers, in the order of our perception of them, instead of first explaining them in relation to their several causes. But already that afternoon in the railway carriage, on re-reading that letter in which the moonlight appears – ‘... I find a thousand of phantasms, *monks white and black, nuns gray and white, linen cast here and there on the ground, men enshrouded upright against the tree-trunks*’ – I was enraptured by what, a little later, I should have described (for does not she draw landscapes in the same way as he draws characters?) as the Dostoyevsky side of Mme de Sévigné’s Letters.⁸

Proust develops the idea throughout his novel, including by arguing that in the case of Dostoyevsky at least, one also continuously finds a re-integration of these appearances (vis-à-vis impressions we form), including, again, a new history of their emergence. Proust also adopts the technique itself and deploys it throughout the book. It can also be shown that in Proust the new 'causes' to which our perception will be related in fact or in effect entail the suspension of classical causality, as is the case of Kleist and Shelley, or the key twentieth-century modernist and then postmodernist authors. Proust, of course, writes during the age of new physics, following Einstein's relativity and early (pre-Heisenbergian) quantum physics. All these authors, however, continue the questioning of causality that begins with Hume and Kant, and extends to Nietzsche and beyond in literature, philosophy and science.

It remains difficult to define the initial formal or/as material vision in question or to ascertain whether it can exist prior to any integration. The difficulty of pinpointing the nature of this vision is why de Man is so hesitant: 'a material vision' is merely 'the only word that comes to mind'. Accordingly, the beautiful and the sublime may, as I said, be seen as Kant's attempt to present two possible forms of, or arising from, such a vision, with, conceivably, nothing else possible for our experience short of this vision. Either way, however, when such a vision takes place, it is always more residual than primordial, a result of divesting certain elements of the preceding configuration. This divestment is crucial in the context of Heisenberg's vision, his un-writing of the *book* of nature and making physics into a reading of *writing* in Derrida's sense, in this case by divesting the experimental data in question of any process, 'history', describable in terms of classical physics. Kant gives us further clues throughout the third *Critique* and elsewhere, as does de Man in his commentaries on the subject. Edmund Husserl, however, may also help us here, at his arguably most defining and most Kantian moment, when he invokes 'the principle of all principles' in his *Ideas*. He writes:

But enough of such topsy-turvy theories [by which we try to ground immediate intuition of consciousness]! No theory we can conceive can mislead us in regard to the *principle of all principles*: that *very primordial dator Intuition is a source of authority (Rechtsquelle) for knowledge*, that *whatever presents itself in 'intuition' in primordial form* (as it were, in its bodily reality), *is simply to be accepted as it gives itself out to be, though only within the limits in which it then presents itself*.⁹

This may not be so simple, as Husserl's last qualification indicates. Husserl adds: 'Let our insight grasp this fact that the theory itself in its turn could not derive its truth except from primordial data'.¹⁰ This sounds close to Heisenberg's gesture of founding quantum mechanics on magnitudes that are in principle observable and, as such, are *given*, although in this case more residually than primordially – that is, as a result of a divestment of the data in question from the classical physical processes presumed responsible for the emergence of these data. In other words, Heisenberg's theory *derived* its truth, as a theory, only from the primordial data of quantum mechanics, in turn given to our intuition, but it did so through a very complex 'economy' of theoretical developments, investments and divestments, in working with various mathematical and conceptual frameworks in coordination with the data. But then, the same would be the case with Husserl's theory as well, even if one starts with a more or

less primordial datum of the intuition of consciousness. Indeed a certain type of theoretical divestment is textually apparent, inscribed, in Husserl's first sentence, announcing the divestment of preceding topsy-turvy theories in Husserl's own approach, which posits instead the principle that 'very primordial dator Intuition is a [sole] source of authority (*Rechtsquelle*) for knowledge'. In other words, perhaps deliberately, this sentence exemplifies this principle by what Husserl himself is actually doing at that moment. One could also invoke his *Cartesian Meditation* or Descartes's *Principles of the First Philosophy*, which this passage follows and according to which philosophy, unlike epic and its in *medias res*, always begins as if it sees the world anew, without any preceding knowledge.

I would, again, question that such absolute suspension of in *medias res* or a full divestment of the preceding knowledge is ever possible. Husserl's formulation may, however, be used to indicate a certain space and a certain moment at which, for example, because our science (say, that of classical physics) and 'its optimism, concealed the essence of logic, suffers a shipwreck', as Nietzsche said in *The Birth of Tragedy*.¹¹ While differently occasioned, Kant's beautiful and the sublime formalize this space and this moment of vision, and serve as model for the situations in which certain configurations emerge as freed from the preceding order of their emergence and could, if we are lucky, be theorized differently. As a result, a certain 'fresh start' may be possible, even though the success is never assured. Aristotle appeals to such a fresh start in *Physics*, in the final sentence of Book I, after he dispatches the preceding physics and establishes, just as Husserl and Heisenberg do, that 'there are principles and what they are and how many there are': 'Now let us make a fresh start and proceed'.¹²

3. Heisenberg's New Physics: from Motions to Traces

Quantum mechanics, as a theory dealing with the motion of electrons in atoms, was introduced in 1925–26 by Heisenberg and Schrödinger in two different ('matrix' and 'wave') versions, and developed in the work of Max Born, Pascual Jordan, Paul Dirac, Wolfgang Pauli and (primarily in terms of interpretation) Bohr. As I said, however, even as it has offered a degree of resolution to the problems posed by Planck's discovery of the quantum nature of radiation (which the preceding quantum theory failed to solve) and became the standard theory of quantum phenomena, it brought with it new epistemological complexities. In particular, it appeared to be able only to predict, mostly statistically, the outcome of experiments in question, but was unable to describe the motion of quantum objects in the way classical physics would for classical objects. Nor did it predict in the same way either, since it made chance in principle irreducible even in dealing with individual, rather than (as in classical statistical physics) only collective, behaviour. Indeed, the outcomes of collective behaviour could in certain circumstances be subject to (correlational) patterns or forms of order in quantum mechanics as well, which enables one to apply the idea of waves there. Individual behaviour, however, cannot.

It is worthwhile to consider briefly the double-slit experiment, a kind of archetypal quantum-mechanical experiment, containing the most essential features of the

situation. The well-known arrangement consists of a source; a diaphragm with a slit (A); at a sufficient distance from it a second diaphragm with two slits (B and C), widely separated; and finally, at a sufficient distance from the second diaphragm a screen, say, a silver bromide photographic plate. A sufficient number (say, a million) of quantum objects, such as electrons or photons, emitted from a source, are allowed to pass through both diaphragms and leave their traces on the screen. Two set-ups are considered. In the first, with both slits open, we cannot, even in principle, know through which slit each quantum object passes. In the second we can, either in practice or, importantly, in principle.

In the case of the first set-up, a 'wave-like' interference pattern will emerge on the screen, in principle regardless of the distance between slits or the time interval between the emissions of the particles. The traces, once a sufficiently large number of them are accumulated, will 'arrange' themselves in such a pattern, even when the next emission occurs after the preceding particle is destroyed after colliding with the screen. This pattern is the actual manifestation and, according to, at least, the present interpretation, the only possible physical manifestation of quantum-mechanical 'waves'.

If, however, in the second set-up, we install counters or other devices that would allow us to check through which slit particles pass, the interference pattern inevitably disappears. Merely setting up the apparatus in a way that such knowledge would in principle be possible would suffice.

These facts are extraordinary and difficult to confront and such often used locutions as mysterious, incomprehensible, or paradoxical are hardly surprising. It is as if particles could know, individually or, even more strangely, collectively, whether both slits are open or not or whether counters are installed or not (regardless of how distant a particle may be from the slits or counters, which moreover may be hidden behind the diaphragm with slits). Attempts to conceive of the situation in terms of physical attributes of quantum objects themselves appears to lead to unacceptable or at least highly undesirable consequences. Among them are logical contradictions; difficult assumptions, such as attributing volition to nature in allowing particles individual or collective 'choices' (e.g. quantum objects appear to 'know' whether both slits are open, or whether counting devices are installed); or the so-called nonlocality, as the instantaneous propagation of signals, incompatible with relativity.

One might, however, also see the situation, with Heisenberg and Bohr, as indicating the impossibility of ascribing any physical attributes to quantum objects themselves or to their behaviour. In this view, in considering individual marks on the screen we may rigorously speak of them only as *particle-like effects* or, in certain circumstances, as *wave-like effects*, and not as traces left by collisions with classical-like *particle or wave objects*. The latter, again, only result as a collective or, better, sequential (one by one) accumulation of particle like effects in a large number of trials with both slits open and there are no counters installed, otherwise sequential collectivities are particle-like in character, that is, random without a wave-like distribution pattern. We are dealing with two different and mutually exclusive types of *effects* of the interaction between quantum objects and measuring instruments upon those instruments under specific physical conditions.

This, apparently unavoidable, mutual exclusivity of certain types of arrangements (they can never be used at the same time) and yet equally the necessity of using them led Bohr to his complementarity language. Eventually the term came to designate his overall interpretation of quantum mechanics, in part as correlative to the unavoidability of such complementary situations of measurement there, through which one can also interpret Heisenberg's uncertainty relations. The latter place is an insuperable limit (regardless of the possible capacity of our measuring instruments) on simultaneous precision in measuring such variables as position and momentum, which is, at least in principle, possible in classical physics and which enables a causal and realist description of the behaviour of classical objects. If, instead of quantum objects, we were to measure classical objects we could avoid uncertainty relations and, by the same token, establish such variables for the corresponding classical objects themselves. In quantum mechanics, we could properly define either one type of measurement situation in question (that of momentum measurement) or the other (that of position measurement), but never simultaneously both together.

I speak of measurement situations, since, in the present view, such physical variables cannot, again, be attributed to quantum objects at all, but only to certain parts of measuring instruments, considered as classical physics objects, impacted by quantum objects, as uncertainty relations themselves would now pertain to such classical variables. What we see on the screen is now assumed to be the manifest effects of the interactions between quantum objects and measuring instruments upon the latter. Such effects are classical physically, insofar as they (but not their emergence) are described in terms of classical physics, and epistemologically, insofar as they (but, again, not their emergence) could be manifest materially and be present to our consciousness as phenomena. Each of these effects or marks is a discrete entity and, thus, an individual phenomenon. Bohr indeed defines *quantum-mechanical* phenomena in terms of individual effects of this type. This definition makes the corresponding material entities (i.e. the effects in question) available to our consciousness in terms of phenomena in Kant's sense, while anything at the quantum level is not available to such a representation, not even as Kant's things in themselves.

It is crucial that in this interpretation a rigorous reference to quantum objects and processes would remain impossible even when one speaks of single such attributes, rather than in the case of a simultaneous attribution of joint properties involved in uncertainty relations, and even at the time when the measurement takes place. In other words, *neither one nor the other* complementary variable could be assigned or even defined for quantum objects themselves, rather than only one or the other, say, a position or momentum. As a result, quantum objects are placed in the position of irreducibly inconceivable, unthinkable entities. We can describe the impact, the physical effects, of quantum processes upon our measuring instruments in a strictly classical – objective and realist – manner, but we can never describe the ultimate (quantum-level) dynamics leading to these effects.

These were essentially the same considerations that compelled Heisenberg to argue for the necessity of a 'new kinematics' for quantum mechanics in his first paper on quantum mechanics and other earlier works. Traditionally, as the term 'kinematics' indicates, it refers to a representation, usually by means of continuous functions, of the

attributes of motion, such as positions (coordinates) or time, or velocities of a body. The representation of dynamic properties, such as momentum and energy, are dependent on and are functions of kinematical properties, but are also dependent on and are functions of the mass of the bodies involved. By contrast, Heisenberg's new quantum mechanics did not deal with a description of the motion of quantum objects in space and time, which indeed makes the term 'kinematics', or for that matter 'mechanics', a misnomer here, however historically understandable. Instead, Heisenberg's 'new kinematics' referred its elements to what is observable in measuring instruments under the impact of quantum objects, rather than represented the attributes of these objects themselves. Accordingly, insofar as kinematical and dynamic properties of physical objects were involved at all, such properties are only those of certain parts of measuring instruments. In addition, these new kinematical elements were no longer functions, or any form of representation, of properties of quantum objects or their behaviour. These elements were conceived as infinite square tables or, as they are called in mathematics, matrices of complex variables (i.e. variables involving numbers such as $\sqrt{-1}$) rather than real variables used in classical physics, without, again, classical-like relations to the attributes of motion of quantum objects, but only to the impact of the latter upon measuring instruments. Classical *equations* of motion as such were formally retained, but were now applied, with momentous epistemological implications, only to such matrix variables and no longer to anything describing the motion of particles. By the same token, they were *no longer equations of motions* either.

A qualification is in order concerning Heisenberg's emphasis on the 'magnitudes which in principle are observable', in other words, magnitudes related to individual quantum effects on the interaction between quantum objects and measuring instruments upon the latter, which effects, rather than properties of quantum objects and of their behaviour, become subject to his 'new kinematics'. Heisenberg's *theory* qua theory was *not* founded only or even primarily on such magnitudes, but engaged with a much greater complexity of both experimental observations and theory production alike, and of their relationships. This complexity transpires already in Heisenberg's famous, but not always carefully read, opening statement, with which I began here: 'The present paper seeks to establish a *basis* for theoretical quantum mechanics founded exclusively upon *relationships* between magnitudes that are *in principle* observable' (emphasis added).¹³ 'Relationships' is the key word here, and the title of the paper was 'On Quantum-Theoretical Re-Interpretation of Kinematic and Mechanical *Relations*' (emphasis added). 'In principle' is crucial too. For, no matter how theory-laden and how complicated the processes of observation, the magnitudes in question, manifest in measuring instruments impacted by quantum objects, could in principle be observed and related to each other, while the classical-like physical (and ultimately any) properties of quantum objects themselves and of their behaviour could not.

Heisenberg's stroke of genius was finding his square tables of magnitudes into which the data in question, reinterpreted in terms of probabilities of transition from one state to another, could be arranged or rearranged, as against how classical physics would do it. These square tables had, moreover, to be infinite for the theory to work, for example, as became clear later, in order to derive uncertainty relations from it.

Accordingly, this new arrangement of data was itself a founding *theoretical* move. That is, this arrangement of the relationships between observable magnitudes in infinite matrices of complex numbers (never observable as such) rather than real numbers (which, technically, rational numbers, are used in measurements) is already *theory*, not observation of nature, which does not, insofar as we know, arrange anything in this way.¹⁴

From the perspective outlined earlier, via Kant, Husserl and Proust, the introduction of new mechanics in Heisenberg's paper may be seen as *arising* from an extraordinary form of 'vision' of the material constitution and, with respect to the viewpoint of classical physics, de-constitution of the emergence of the data in question in quantum mechanics, and then refiguring this emergence differently. In this *view* (in either sense), one divests the quantum-mechanical data, say, traces left on a silver screen in the double-slit experiment (in both types of set-up), of the presumed classical-like and hence configurable history of their appearance, of any history that could possibly be mapped, mathematically or conceptually, by a classical model. For example, they should not be seen either as points resulting from classically conceived collisions between 'particles' and the screen or as resulting from a classical wave propagation. Neither 'picture' corresponds to what in fact occurs. At this stage, even the radical (Derridean) trace-like character of these marks is suspended, although this character will have to be given to them in order to treat them in quantum-theoretical terms. In part by virtue of two possible outcomes of the experiment depending upon a chosen set-up, the appearance of these marks cannot ultimately be *explained* in these or any terms, only predicted by means of the quantum-mechanical formalism, but predicted properly corresponding to each set-up, such as the presence or absence of a wave-like interference pattern. Accordingly, in order for a theoretical formalization to take place, these marks, while 'visible', have to be divested of any form of mathematical and specifically geometrical representation as concerns the processes of their emergence. Classical physics is defined by the possibility of such representation of the situation, making it available to human intuition, defined by a possibility of geometrical visualization, at least in principle, of the processes it considers. This geometry can of course be given its algebra as well, in contrast, however, to quantum algebra, which suspends the possibility of such geometrical visualization even in principle. The (Derridean) traces forming the quantum-mechanical data must be seen as allowing for no classical physical description as concerns the processes or, again, history of their emergence.

Heisenberg, thus, first suspends the application of classical physics to quantum data and the very possibility of configuring the emergence of these data accordingly. Instead he treats these data as 'effects' divorced from any classical configurativity and hence also classical (there may be no other) causality as concerns their emergence. Heisenberg does not philosophically explore the epistemological consequences of the situation, of which he was only vaguely aware at the time. His main concern was to offer a mathematical formalism that would enable theoretical predictions in the situations where all previous attempts had failed. These consequences emerged in subsequent developments, both in Heisenberg's own work and in the work of Bohr and others. Heisenberg's invention of quantum mechanics, however, appears to have been partly enabled by the de-configurative vision just discussed.

It is indeed a miracle that Heisenberg proceeded from the disassemblage just considered, of experimental data to arranging or, as against the classical view, rearranging this data into his matrices with probabilities of transitions from one state of the system (cum measurement) to another as their elements. He was not even aware at the time that the corresponding mathematical theories (matrix algebra) had already existed at the time, which was realized by Max Born, his teacher, upon reading the paper. Heisenberg reinvented it. Of course, if one studies how Heisenberg arrived at his ideas, the situation does not look quite so dramatic. It never does. His invention was quite miraculous nevertheless.

4. Allegory and Discontinuity in de Man: From Phenomenality to History

Quantum mechanics may, then, also be seen in terms of the idea of history and as introducing a new conception of history in physics and beyond, although this conception has its precursors elsewhere, in particular, as Heisenberg recognized, in Romantic literature and Idealist philosophy, both of which are hardly any less materialist than idealist. Indeed, as it moves from Kant to Hegel, Idealist philosophy may even be seen as moving from phenomenology to history. This assessment must of course be qualified. For one thing, there is history in Kant and, even more self-evidently, as his most famous title tells, phenomenology, in Hegel. Hegel's idea of history, his greatest philosophical discovery, is epistemologically Kantian, at least if one argues the case along the lines of this essay. This type of argument would also bring a certain, indeed irreducible, materiality into ideality or phenomenality, even though and because it refigures (just as quantum mechanics does) all three, in part because they thus inhabit each other, as they do in Idealist philosophy and Romantic literature alike, or in quantum mechanics of Bohr and Heisenberg. We might, accordingly, see, as Heisenberg might well have, all of these endeavours as forms of Romanticism.

It is, then, not surprising that the question of history acquires a special significance at this juncture in de Man's work. De Man defines 'history' in terms of allegorical discontinuity in juxtaposition to 'temporality', at least if the latter is seen in terms of continuity. It is worth qualifying, however, that although, made apparent in quantum physics through discontinuous or (correlatively) random phenomena, the discontinuity of allegory is fundamentally epistemological in nature. It designates the impossibility of conceiving of the processes, especially of causal and continuous types responsible for the events considered. The discussion of the very concept of allegory in 'Pascal's Allegory of Persuasion' is linked to and proceeds toward this question, via the question of narrative and irony. De Man opens his essay with his arguably best and most 'quantum-mechanical' characterization of allegory, via, it is worth noting, Hegel: 'The difficulty of allegory is rather that [its] emphatic clarity of representation does not stand in the service of something that can be represented'.¹⁵ In view of the preceding analysis, this clarity may be said to stand in the service of what cannot be represented or even conceived of by any means that are or even will ever be available to us. From this perspective, one might see quantum mechanics as an allegorical theory. De Man closes, however, in his last sentence, with: 'The (ironic) pseudoknowledge of this impossibility, which pretends to order sequentially, in a narrative, what is actually the destruction of all sequence, is what we call allegory'.¹⁶

This statement, accordingly, also implies that allegory in de Man's sense involves a production of a certain, perhaps pretended, (epistemologically) classical configuration, superimposed on a quantum-like assemblage of events (either random or organized in a certain pattern), which cannot itself be rigorously read classically, except by way of a misprision, blindness, or pretence. History in de Man's sense may then, be seen in terms of quantum-like singular events, whereby we are irreducibly deprived of any possibility of conceiving of how these events could be linked and, it follows, theorized as continuous with the ultimate processes responsible for their emergence. Collectively, such events may exhibit certain organizations, either sequentially or in parallel. But this organization, too, disallows the possibility of establishing how it came about. Hence 'the [ultimate] destruction of all sequence' whereby we can, with '(ironic) pseudoknowledge', at most only 'pretend' to order this dynamics and this emergence 'sequentially, in a narrative'. By the same token, while history itself is seen in terms of such events, as effects, each of which 'has the materiality of something that actually happens, that actually occurs', the processes themselves responsible for these events cannot be seen in terms of history any more than in any other terms.¹⁷ De Man describes this view of history most explicitly in 'Kant and Schiller'. He says:

History is not thought of as a progression or a regression, but thought of as an event, as an occurrence. There is history from the moment that words such as 'power' and 'battle' and so on emerge on the scene. At that moment things *happen*, there is *occurrence*, there is *event*. History is therefore not a temporal notion, it has nothing to do with temporality, but it is the emergence of the language of power out of a language of cognition. An emergence which is, however, not itself either dialectical movement or any kind of continuum that would be accessible to a cognition, however much it may be conceived of, as would be the case in a Hegelian dialectic, as a negation.¹⁸

The ultimate processes responsible for 'events' are inaccessible first, by means and in terms of de Man's model in question and second, beyond this model in terms of any available or conceivable terms, including in terms of negation of terms, concepts and predicates. In other words, this inaccessibility is the epistemological discontinuity of allegory in de Man's sense, as explained above. Hence, the separation (i.e. discontinuity) in question allows for 'no mediation whatsoever', dialectical or other, as de Man further explains in the context of the historical relationships between the performative and the cognitive or the tropological, to which he applies his historical model.¹⁹

De Man makes his arguably strongest epistemological claim in the famous elaboration closing 'Shelley Disfigured'. He says: '*The Triumph of Life* warns us that, *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' (emphasis added).²⁰ One may speak of the radical, irreducible singularity and discontinuity of random events, into which any given event or historical trajectory would always ultimately *decompose* itself, just as any human body will ultimately do after 'death'. This decomposition or this death, however, begins much earlier, although the effects of

death to which we give a particular sense in the context of what we call human existence are of course significant, including as providing a model for other conceptions of death. Life is always death, but death is not always life. As it makes allegory irreducible in any representation, phenomenalization, knowledge, and so forth, death or life-death becomes a model for or an allegory, and perhaps the allegory, of the ultimate structure of *every* event of life. At the ultimate level, any event is either itself unique and singular or, however ordinary or un-eventful it is or appears to be, is decomposable into an assemblage of such events, whether organized or not. Any classical-like organization or a classical-like view of each event could only be superimposed upon, and is itself an effect, of the quantum-like, ultimately inaccessible and inconceivable, dynamics governing the situation. It would, as in quantum mechanics, be difficult to speak of this dynamics as itself random, any more than causal, or any more discontinuous than continuous, or, again, in any given or even conceivable terms.

Certain literary and philosophical texts offer us new models of singular events or hence of un-patterning, unordering, and unlawfulness, and new ways in which these relate to patterns, order and law. De Man does not close 'Shelley Disfigured' with the randomness of death as the final warning of Shelley's poem. Instead, he adds:

[The poem] also warns us why and how these events [and at bottom the ultimate events constitutive of any event] *then* have to be reintegrated in a historical and aesthetic system of recuperation that repeats itself regardless of the exposure of its fallacy. This process differs entirely from the recuperative and nihilistic allegories of historicism. If it is true and unavoidable that any reading is a monumentalization of sorts, the way in which Rousseau is read and disfigured in *The Triumph of Life* puts Shelley among the few readers who 'guessed whose statue those fragments had composed'. Reading as disfiguration, to the very extent that it resists historicism turns out to be historically more reliable than the products of historical archeology. To monumentalize this observation into a *method* of reading would be to regress from the rigor exhibited by Shelley which is exemplary because it refuses to be generalized into a system. (Emphasis added.)²¹

This multi-component and multi-level machinery is also applied to the history of reading Shelley's poem itself or, via Shelley and Romanticism. All of these are 'analytically thematized' by Shelley's poem, which as a reading of (the figure of) Rousseau, among others, and the history of literature and culture, is already a history of Romanticism and reading Romanticism, a nonclassical history and, as such, is more reliable than its classical alternatives. First, then, there is a quantum-like history of singular, random events, 'whose power, like the power of death, is due to the randomness of its occurrence'. Second, there is, under certain circumstances, a still quantum-like history of organizations of such singular events, or organization of singularities, including a historical organization of them as events. Finally, there is a history, in turn quantum-like, of 'reintegrating in a historical and aesthetic system of recuperation that repeats itself regardless of the exposure of its fallacy', in a process that 'differs entirely from the recuperative and nihilistic allegories of historicism'. In

other words, this history is also a history of the processes that give rise to classical forms of historicism as one of its effects. It is, then, by this multileveled process that a more reliable history may be achieved, and this is how it is achieved by Shelley's poem. By putting the irreducible 'loss' in historical representation, knowledge, or conception into play, both a greater richness of historical representation, knowledge, or conception and a greater reliability of a 'guess' become possible as well. One can of course only speak of 'loss' here if one applies a classical concept of representation. For, we also gain in terms of knowledge that now becomes possible and was not possible previously. But then, as de Man's last sentence tells us, each such 'guess' may be unique, singular. The lessons of such texts or of their grouping together are complicated accordingly, but are hardly made less significant.

5. Conclusion: From Quantum Theory to Romanticism

One may indeed turn the tables and juxtapose classical and quantum physics as classical and Romantic physics, the juxtaposition expressly used by Heisenberg in one of his late philosophical essay 'Cosmic Radiation and Fundamental Problems of Physics' (1975). This is hardly surprising, since intellectually Heisenberg clearly belongs to the same – Romantic – tradition. The essay elegantly, if a bit mischievously, relates the pastoral or (by the landscapes it invokes) the sublime and the epistemological dimensions of Romanticism. Heisenberg says first:

The romantic time had gone, in which the study of cloud-chamber pictures in a mountain laboratory at high altitude could be combined with skiing and mountaineering, or in which balloon experiments could be started from a beautiful island in the Mediterranean with the help of an airplane and a military vessel from the Italian navy, as has been managed by our Italian friends. Certainly the warm sun of the Mediterranean has contributed to the scientific success of the experiment. But this gay time had now gone, and particle research had to be done on the 'matter of fact' atmosphere of huge accelerator establishment.²²

And yet conceptually, cosmic radiation, coupled as it is to 'fundamental problems in physics', at the smallest and the biggest scale, as the phrase 'cosmic radiation' itself tells us is essentially a romantic science. At this point, we indeed can get some conceptual and metaphorical mileage from Heisenberg's appeal to 'magnitudes' [*Größen*] in introducing quantum mechanics. As Heisenberg says in ending his essay:

Cosmic radiation contains information on the behavior of matter in the smallest dimension and it also contributes to our knowledge about the structure of the universe – of the world – in the largest dimensions. These two extreme ends are not accessible to direct observation – they can be investigated only by very indirect deduction, in which the concepts of daily life have to be replaced by other rather abstract new concepts; only then will we learn what such words as 'extreme ends' or 'infinity' can mean in relation to nature. In this sense cosmic

radiation – in spite of any changes in the style of experiments – can still be called a very romantic, very inspiring science.²³

Thus, along with all modern, post-relativistic and post-quantum physics, it is also a romantic science in the epistemological sense here discussed insofar as such concepts as ‘extreme ends’ or infinity or such concepts as ‘dividing’ (including in terms of ‘quantum’) or ‘consisting of’ (for example, ‘elementary particles’), or any concepts are ultimately inapplicable.²⁴ That, however, need not stop science any more than literature or philosophy, only make it irreducibly Romantic perhaps.

Although many of Shelley’s Mediterranean poems, such as *The Triumph of Life*, could be invoked here as well, perhaps his greatest mountain poem ‘Mont Blanc’ is an especially fitting counterpart of Heisenberg’s vision, as discussed in this article. Indeed, ‘Mont Blanc’ may be read as an allegory of the process traced here in the case of Heisenberg’s discovery. The poem first suggests, in its famous opening, a (relatively) classical view of the world, nature and mind, in term of waves, water waves and light waves, in the way Schrödinger wanted, but failed to do, in quantum mechanics: ‘The everlasting universe of things/Flows through the mind, and roles its rapid waves, [...]’ [1–11]. Then, the I (or the eye, physical and the mind eye) of the poem stops to ‘gaze’ [34], at the Ravine of Arve, ‘dark, deep Ravine’, ‘dizzy Ravine’ [12, 34], and Mont Blanc, ‘still, snowy, and serene’ [67], in Chamonix. It gazes at them, as Kant’s ‘poets do – merely in terms of what manifest itself to the eye’, and by suspending, divesting one’s thought of, all understanding or reason. Then, however, in ‘holding an unremitting interchange/With clear universe of things around’ [39–40], it arrives to a kind of quantum-mechanical, Heisenbergian, sense of the world, from its smallest, atomic dimensions (including both wave and particle constitution of light) to its largest cosmic dimensions, and then of life itself (biological and human). This sense is possible and possibly made necessary by the ‘universe of things around’, things that are in principle observable, when one looks at the Ravine and Mont Blanc, and the world, from the geological history of the Earth, to the solar system, to the universe, to life. These things however, material and mental, and this universe can no longer be seen as linked to the classical view of the world, however conceived, the view ‘repealed’ by the ‘great Mountain’ [80]. They appear instead as the products of a ‘power, [...] remote [...] and inaccessible’ [97] and some ‘secret strength of things’ [139], manifest in the landscape observed, thus also making one question an adequacy of all these terms. This ‘power’ and this ‘strength’, however, also gives us our power and strength to do this questioning, and by so doing reach to the unthinkable. Indeed they compelled or even command us to do so, or to act in right ways in the absence of such ultimate knowledge, scientific or ethical.

The secret strength of things
Which governs thought, and to the infinite dome
Of heaven is as a law, inhabit thee!
And what were thou, and earth, and stars, and sea,
If to the human mind’s imaginings
Silence and solitude were vacancy?

[139–44]

Without the incessant workings of these imaginings and things, 'which in principle are observable', but not explainable or even imaginable in their emergence, we could not then reach, as both Shelley and Heisenberg did, the thought of this unimaginable, which – in its 'secret strength', hidden where no form of secrecy or hidden-ness we could know or ever reach – governs nature and mind, and their 'unremitting interchange'.

Notes

¹ Werner Heisenberg, 'Quantum-Theoretical Re-Interpretation of Kinematical and Mechanical Relations', in B. L. van der Waerden, *Sources of Quantum Mechanics* (Toronto: Dover, 1968), p.261. I modify the syntax of the translation and use 'magnitudes' instead of 'quantities' for Heisenberg's *Größe*, which is more accurate and more effective, as will be seen at the end of this essay.

² Jacques Derrida, *Of Grammatology*, trans. Gayatri C. Spivak (Baltimore: Johns Hopkins University Press, 1975), pp.6, 16.

³ Niels Bohr, *The Philosophical Writings of Niels Bohr*, 3 vols. (Woodbridge, Conn.: Ox Bow Press, 1987), vol.1, p.70.

⁴ Immanuel Kant, *Critique of Judgment*, trans. Werner S. Pluhar (Indianapolis: Hackett, 1987), p.130 (translation modified).

⁵ Paul de Man, *Aesthetic Ideology* (Minneapolis: University of Minnesota Press, 1987), p.82.

⁶ I have considered the subject in detail in 'Algebra and Allegory: Nonclassical Epistemology, Quantum Theory, and the Work of Paul de Man', in Barbara Cohen et al, *Material Events: Paul de Man and the Afterlife of Theory* (Minneapolis: University of Minnesota Press, 2001), pp.49–92. The discussion of both Kant and de Man in the present article proceeds along lines different from those of 'Algebra and Allegory', in part given that Heisenberg (rather than Bohr) and the question of history (rather than aesthetics) in de Man are my main concerns here.

⁷ De Man, *Aesthetic Ideology*, p.82.

⁸ Marcel Proust, *The Remembrance of Things Past*, 3 vols., trans. C. K. Scott Moncrieff and Terence Kilmartin (New York: Vintage, 1982), vol.1, p.702.

⁹ Edmund Husserl, *Ideas: General Introduction to Pure Phenomenology*, trans. W. R. Boyce Gibson (New York: Collier, 1972), p.83.

¹⁰ Husserl, *Ideas*, p.83.

¹¹ Friedrich Nietzsche, *The Birth of Tragedy and The Case of Wagner*, trans. Walter Kaufmann (New York: Vintage, 1967), p.97.

¹² Aristotle, *The Complete Works of Aristotle*, 2 vols., ed. Jonathan Barnes (Princeton: Princeton University Press, 1984), vol.1, p.328.

¹³ Heisenberg, 'Quantum-Theoretical Re-Interpretation', p.261.

¹⁴ Indeed no actual observation can provide such (infinite) data, which fact in turn bears crucially on the question of the relationships between mathematics and physics in quantum mechanics. The subject, however, requires a separate and inevitably technical discussion, which cannot be undertaken here.

¹⁵ De Man, *Aesthetic Ideology*, p.51.

¹⁶ De Man, *Aesthetic Ideology*, p.69.

¹⁷ De Man, *Aesthetic Ideology*, pp.132–33.

¹⁸ De Man, *Aesthetic Ideology*, p.133. De Man's reading of Hegel on history proceeds along similar lines, rather than, as is more common, along the lines of continuous models of history.

¹⁹ De Man, *Aesthetic Ideology*, p.133.

²⁰ Paul de Man, *The Rhetoric of Romanticism* (New York: Columbia University Press, 1984), p.122.

²¹ De Man, *The Rhetoric of Romanticism*, pp.122–23.

²² Werner Heisenberg, *Encounters with Einstein, And Other Essays on People, Places, and Particles* (Princeton: Princeton University Press, 1983), p.62.

²³ Werner Heisenberg, *Encounters with Einstein*, p.70.

²⁴ Werner Heisenberg, *Encounters with Einstein*, p.59.

Arkady Plotnitsky is Professor of English and University Faculty Scholar at Purdue University. His most recent books are *The Knowable and the Unknowable: Modern Science, Nonclassical Thought, and 'The Two Cultures'* (University of Michigan Press, 2002) and a collection of essays (co-edited with Tilottama Rajan) entitled *Idealism Without Absolutes: Philosophy and Romantic Culture* (Intersections: Philosophy and Critical Theory 2004). He is currently completing two books, *Minute Particulars: Romanticism, Science, and Epistemology* and *Reading Bohr: Physics and Philosophy*.