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Werner Heisenberg and Thomas Aquinas on Natural Indeterminism

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Abstract

When Werner Heisenberg presented his views of the fundamental indeterminism to which his uncertainty principle pointed in the basic levels of reality described by quantum mechanics, he used the Aristotelian technical terms of act and potency, affirming that the quantum system is in potency before the measurement and that the potency was actualised when the measurement took place, speaking thus of a 'new ontology' of quantum mechanics. I argue that Thomas Aquinas' Aristotelian account of indeterminism in nature, through his analysis of the notions of matter as potency and form as act, can provide a suitable framework to understand Heisenberg's philosophical intuition about the nature of quantum systems.

Keywords

Werner Heisenberg, Thomas Aquinas, indeterminism, potency, uncertainty principle, *ut in paucioribus*

Few things could have in common two men who lived eight centuries apart. Thomas Aquinas and Werner Heisenberg, however, share at least two: their understanding of nature as a system which is not determined into the future and the Aristotelian terminology they chose to describe this fact. Certainly, their arguments for this view of the natural world are not the same. Nevertheless, it is my contention that they could be understood as complementary. It is, then, my intention to show how these two men can be put in dialogue and how their respective ideas can find fulfilment in the other's thought.

Around 1927, a young Werner Heisenberg found himself discussing his interpretation of quantum mechanics with Albert Einstein, and more often than desired he heard Einstein's famous reply: "God doesn't play dice with the universe". Many decades later, around 1975, he found his way to answer such a claim: "good science is

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being unconsciously discarded because of bad philosophy".[1] I shall not present quantum mechanics in this paper. On the contrary, I will briefly account for Heisenberg's framework of ideas, aiming to assess Heisenberg's philosophy of nature, which springs directly from his work on quantum mechanics. Thus, I will examine which philosophy he believed to be bad philosophy and what he suggested as a new, good philosophy to understand quantum mechanics.

I need not stress the revolution that Max Plank caused with the discovery of the quantum of action and the new physics which sprung from that discovery. The development of quantum physics by scientists of the statue of Max Plank, Niels Bohr, Albert Einstein, Werner Heisenberg, Erwin Schrödinger and many others required in the early years of the twentieth century a new concept of nature. Abner Shimony puts it clearly:

> In no domain have the results been more dramatic than in quantum mechanics. The theory has been confirmed magnificently since the 1920s as its predictions of atomic, molecular, nuclear, optical, solid-state, and elementary-particle phenomena were shown accurate... The experimental results reveal more clearly than ever that we live in a strange quantum world that defies comfortable, common-sense interpretation.[2]

The basic idea of quantum mechanics, opposed to classical mechanics, is that reality is not linear in its behaviour but discontinuous. In Newtonian physics, for instance, it is possible to determine the future states of a system by knowing its present state. In the new physics of the twentieth century, this was no longer tenable. Classical mechanics has at its basis the contention that all states of a considered system can be measured and known. In quantum mechanics, on the contrary, one must accept that it is impossible to know the exact value of a parameter without measuring it, and one can know it only for that measurement. The most one can do to describe the state of any given system before or after the measurement is to provide a probability for the outcome of that measurement.[3] This particular situation is known as the superposition of states of the system before the measurement,[4] because before a measurement is

[1] Werner Heisenberg, 'Was ist ein Elementarteilchen?' Lecture presented at the Tagung der Deutschen Physikalischen Gesellschaft, 5-3-1975. Reproduced in *Die Naturwissenschaften* 63 (1976), pp. 1–7. In page 5 he affirms: "daß heute in der Physik der Elementarteilchen gute Physik unbewußt durch schlechte Philosophie verdorben wird."

[2] Abner Shimony, 'The Reality of the Quantum World', in Russell, Clayton, Wegter-McNelly and Polkinghorne (eds.), Quantum Mechanics. Scientific Perspectives on Divine Action (Vatican City – Berkeley: Vatican Observatory – CTNS) pp. 3–16, p. 3.

[3] Paul Dirac, *The Principles of Quantum Mechanics* (Oxford: Clarendon Press, 1958), p. 73.

[4] The superposition principle asserts that from any two quantum states of a system further states can be formed by superposing them. Physically the operation corresponds

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made on a quantum system we cannot specify the state of the system: the general state of a quantum system previous to the measurement must be considered as the sum of all possible states that the system can occupy. The probability for the outcomes of the experiment is expressed in the Schrödinger equation, which is fundamental to the understanding how a quantum state evolves in time,[5] and enables us to use the present state of the system to assign probabilities to future experiments.[6]

This puzzling feature of quantum physics is complemented by one further perplexing characteristic equally at odds with classical mechanics. In the moment of the measurement, the system jumps into one state of the many probable states, without any apparent reason to jump into one or another possible state. This, however, happens according to an equation which expresses a precise relation between variables of the system, such as position and momentum. This relation, which accurately expresses the superposition of the system in either the position or the momentum, is called the Heisenberg's uncertainty principle.

This principle, first proposed in February 1927,[7] manifests the very first reason a quantum theory cannot be founded on a deterministic model. This principle says that it is conceptually impossible to determine simultaneously the position and the momentum (or any other pair of conjugate quantities[8]) of one single particle. The product of any pair of conjugate quantities (position and momentum in our example) cannot be smaller than Planck's constant ($h = 6.626 \times 10^{-27}$ erg.sec).

Consider any given body: if one admits that it undergoes a variation in its impulse equal to ΔX and another variation in its position equal to ΔP, the probability of finding it in a future instant corresponding to P, $(P + \Delta P)$ and X, $(X + \Delta X)$ will be proportional to the probability of finding it in the area $(\Delta X \times \Delta P)$, in which ΔX and ΔP can be as small as desired. All this makes sense as we work in classical physics. Things change fundamentally when one enters the domain

to forming a new state that 'overlaps' each of the states from which it was formed. SeeRoger Penrose, *The Road to Reality. A Complete Guide to the Laws of the Universe* (London: Jonathan Cape, 2004), pp. 541ss.

[5] Penrose, *The Road to Reality*, p. 498.

[6] R.I.G. Hughes, *The Structure and Interpretation of Quantum Mechanics* (Cambridge, Massachusetts and London: Harvard University Press, 1989), p. 113.

[7] Published as '*Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik*', *Zeitschrift für Physik* 43 (1927), pp. 172–198.

[8] Conjugate variables are pair of variables mathematically defined in such a way that it is possible to transform them into one-another, through a mathematical operation called the Fourier transform. Some examples of canonically conjugate variables include the following: Time and frequency; time and energy; position and momentum; angular position and angular momentum.

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of quantum physics. Here, the product ($\Delta X \times \Delta P$) loses all meaning when it becomes smaller than Plank's constant: the product cannot be smaller than the constant. The accurate determination of the position involves some uncertainty in the quantity of movement, and the same in the inverse way. Since it is impossible to know absolutely the initial state of a system, it will also be impossible to determine the future of that system. In effect, if $\Delta X \to 0$, then $\Delta P \to \infty$.

According to this principle, the classical assumption that it is possible to know simultaneously the initial magnitudes of a system should be left aside: every determination of one of them would have to be done physically by a procedure which will alter the quantity of its pair, and this alteration increases as the accuracy of the measure of the first magnitude increases. The only possible knowledge of the future will be a probabilistic or statistical knowledge. "The uncertainty principle refers to the degree of indeterminateness in the possible present knowledge of the simultaneous values of various quantities with which the quantum theory deals... Thus suppose that the velocity of a free electron is precisely known, while the position is completely unknown. Then the principle states that every subsequent observation of the position will alter the momentum by an unknown and undeterminable amount such that after carrying out the experiment our knowledge of the electronic motion is restricted by the uncertainty relation."[9]

The mathematical translation of the initial state of the system, expressed in Schrödinger's equation, describes a set of possible future events. This function expresses where the electron could be found in a determinate area, which Heisenberg calls a *cloud of probability*. Nevertheless, it is important to remark that quantum theory asserts that any measurement will result in a specific value for the parameter measured. Quantum theory simply does not allow us to predict the result of the measurement before measuring. This probability, however, does not mean chaos or absolute indeterminism: there is an order of probabilities which define the system as a physical reality. The quantum-mechanical phenomenon is not absolutely indeterminate because it can only oscillate between a range of probabilistic values.

1. Werner Heisenberg's Ontology of Quantum Phenomena

In Heisenberg's thought, this probabilistic character of quantum mechanics required a new image of physical reality consistent with the

[9] Werner Heisenberg, *Principles of Quantum Theory* (New York: Dover Publications, 1930), p. 20.

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levels of reality to which the principle refers. He suggested that the uncertainty principle provides a real epistemological foundation for this new conception of the physical world. Physics, as a part of science seeks a description of nature. This part of science, by itself, can require a new concept of nature, or even reject one; but it cannot, on its own, create a new one. It is necessary to think in the domain of philosophy of nature to reach this new image of nature, which is where Heisenberg's considerations lie when he attempts to explain the mathematical expressions of quantum physics.

The uncertainty principle brings to the forefront the following question: If what quantum theory tells about the quantum world is expressed only in probabilistic terms, what is, then, the ontological status of the quantum world? To answer this philosophical question, Heisenberg, in an attempt to define and differentiate his new ontology, searches for the philosophical roots which were assumed by classical physicists. According to Heisenberg, every interpretation of quantum phenomena different from his own interpretation desires "to return to the reality concept of classical physics, or to use a more philosophical term, to the ontology of materialism".[10] This is the bad philosophy to which he referred in 1975: the materialistic, mechanistic, and deterministic view of nature assumed by classical physicists.

For Heisenberg, classical physics works within a framework of what he calls 'metaphysical realism', and identifies it with the materialistic ontology of the Cartesian distinction between *res cogitans* and *res extensa*.[11] He explains that for the materialistic ontology of classical physics, that which is real is what is actual, what is in act. Reality is itself objectively and fully determinate and actual, independently of any kind of observation or measure of its space and time magnitudes. For this kind of thought, absolutely determinate matter is the only kind of physical reality: the Cartesian *res extensa*. In this sense, being is understood, following the tradition of Parmenides and Democritus, as univocal. This kind of univocal materialistic ontology is what Heisenberg explicitly rejected along his life. This ontology helped to restrict the notion of causality until it was completely identified with that of determinism:

> Thus the concept of causality became narrowed down, finally, to refer to our belief that events in nature are uniquely determined, or, in other words, that an exact knowledge of nature or some part of it would suffice, at least in principle, to determine the future.[12]

[10] Werner Heisenberg, *Physics and Philosophy* (New York: Prometeus Books, 1958 [1999]), p. 129.

[11] Heisenberg, *Physics and Philosophy*, p. 81.

[12] Heisenberg, *Physics and Philosophy*, p. 34.

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Given this picture of nature, according to Heisenberg classical physics could only accept an epistemological indeterminism, because reality is completely determined. Only a problem within our structure of knowledge (or technology) would be the cause of this epistemological indeteminism.

In opposition to this materialistic ontology, Heisenberg, when giving his own interpretation of quantum theory, talks of a new conception of nature: a new 'ontology of quantum physics'.[13] According to this, in quantum physics, besides the actual, the potential is also real, i.e., what is in potency is real. Heisenberg refers to Aristotle's concepts of act and potency to explain the indeterminism found at sub-atomic levels in the following terms:

> One might perhaps call it an objective tendency or possibility, a *potentia in the sense of Aristotelian philosophy*. In fact, I believe that the language actually used by physicists when they speak about atomic events produces in their minds similar notions as the concept *potentia* . . . The language has already adjusted itself, at least to some extent, to this true situation.[14]

According to this new ontology, reality becomes actual in the same instant that it is observed, and it is not actual, but in potency, when it is not observed. In these moments, reality is still potential or indeterminate, open to different actualisations, but is still real. Thus, the quantum system will be ontologically potential (indeterminate) before the observation. Observation gives some causal determination but also some causal indetermination to the system which is being observed. Hence, Heisenberg adds, the transition from the 'possible' to the 'actual' takes place during the act of observation. That is, as soon as the interaction of the object with the measuring device, and thereby with the rest of the world, occurs.[15]

As stated above, this potency is mathematically expressed in the Schrödinger equation. The indeterminism is expressed, then, in the superposition of probabilities where the particle is to be found, which is really wherever it can be found. Thus, it is in potency in every place of that superposition of probabilities, and it will be actualised in this or that place by the observation. The Schrödinger equation, then, contains statements about possibilities or tendencies (*potentia* in Aristotelian philosophy), and these statements are completely objective.[16] Hence, it implies a tendency, a real objective potentiality, of nature to act in some way, always within the parameters of Heisenberg's uncertainty principle.

[13] Cfr. Heisenberg, *Physics and Philosophy*, p. 185.
[14] Heisenberg, *Physics and Philosophy*, p. 180–181.
[15] Cfr. Heisenberg, *Physics and Philosophy*, p. 54.
[16] Heisenberg, *Physics and Philosophy*, p. 53.

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With this interpretation Heisenberg abandons the Parmenidean/Cartesian materialistic ontology to embrace a new ontology for quantum phenomena: the ontology of act and potency. He moves from the rigid mechanism of Cartesian ontology to a richer Aristotelian ontology. According to Heisenberg, developments in quantum mechanics have given rise to a more subtle concept of reality than that based in classical physics. The univocal notion of being assumed in classical physics should be left aside for an analogical notion of being.[17] This thought opens a path for a new development of the concepts of philosophy of nature of act and potency, which I will present through the lens of Thomas Aquinas' philosophy.[18]

2. Thomas Aquinas and Indeterminism in Nature

Natural things, in Aquinas thought, have a tendency to act in a particular way, according to their particular kind of being. Thus fire heats, and water wets. This is what Aquinas means when affirming that natural things are determined to act *ad unum*.[19] However, a natural thing may not accomplish the effect which its nature has determined it to accomplish: *in corporibus invenitur esse defectus aliquando ab eo quod est secundum cursum naturae*.[20] In saying this, Thomas explicitly rejects a rigid determinism in nature, i.e. the

[17] It is important to note that Heisenberg has not written on this topic in any other papers, thus he has not gone deeper into this concept of 'potentiality' or 'tendency' in his philosophical interpretation of quantum phenomena. But it is also necessary to say that this work on which we have worked, *Physics and Philosophy*, is a mature work after which he moves to different questions in physics and in philosophy.

[18] In his *Introduction* to Heisenberg's *Physics and Philosophy* edited in 1958, F. S. C. Northrop says in page 16 that "it would be an error, therefore, if the reader, from Heisenberg's emphasis upon the presence in quantum mechanics of something analogous to Aristotle's concept of potentiality, concluded that contemporary physics has taken us back to Aristotle's physics and ontology." This is certainly a strong claim, and it is a shame that Northrop does not expand on what he understands by "Aristotle's physics and ontology", although I have my suspicion that it assumes an incomplete reading of the history of science. However, I must admit to agree with this claim to a certain extent. There is no need to "go back" if one can understand that the notions of act and potency are as important today as they were for Aristotle and even Thomas Aquinas.

[19] SeeRichard Connell, *Nature's Causes* (New York: P. Lang, 1995), p. 241: "Inanimate entities and their properties are similarly determined in their behaviour; and so we see why and in what sense necessary propositions can be formed about entities that can either exist or not exist. Natural activities are determined to one alternative." Stephen L. Brock, 'Causality and Necessity in Thomas Aquinas', *Quaestio* 2 (2002), pp. 217–240, p. 220, expresses this by saying that "it cannot be denied that St Thomas does associate causality with necessity."

[20] Thomas Aquinas, *Summa Contra Gentiles* III, 64.

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position that whenever there is a cause a certain determinate effect necessarily follows.[21]

Natural things are contingent in their being, i.e. they can or can not be. Hence their actions are contingent, given that anything acts according to its being: they can act or not, but besides, they can act according to their nature or they can fail in their natural actions. A recognition of the fundamental metaphysical facts that natural actions flow from their nature, and that all things have a certain admixture of imperfection, leads one to see how there can be contingency in the natural world.

Thomas distinguishes between events which happen always,[22] those which almost always happen and those which happen almost never, but do happen: *ea enim quae sunt alicuius speciei, perveniunt ad finem illius speciei ut in pluribus: ea enim quae sunt a natura, sunt semper vel in pluribus, deficiunt autem in paucioribus propter aliquam corruptionem*.[23] Those which occur *ut in pluribus* were in their causes as almost determined, and there were no impediments in the process of causing them. These refer to the actions of every single natural being. In addition, Thomas also mentions events which occur less frequently or *ut in paucioribus*, and these are those events which are not determined at all in their causes, but they happen *per accidens*, or *propter aliquam corruptionem*.[24] Events which happen *ut in pluribus* or *ut frequenter*, refer to every single action of every

[21] Thomas Aquinas, *De Malo*, 16, 7, 14.

[22] Events which occur *ut semper* are, for Aquinas and Aristotle, those which take place in the heavens: the movement of heavenly bodies. For Aristotle and Aquinas, heavenly bodies cannot fail in their actions because their forms actualise all the potentiality of matter, leaving no potency to another form. Thomas Aquinas, *Summa Theologiae* I, 84, 3, 1: *materia coelestium corporum est totaliter completa per formam, ita quod non est ei potentia ad aliam formam*. See also *Summa Contra Gentiles* II, 30.

[23] *Summa Contra Gentiles* III, 39. See also *Summa Theologiae* I, 63, 9, co; *In I Peri Her.*, XIV, 172; *De Veritate*, 3, 1, co; *De Malo*, 1, 3, 17; *In II De Caelo et Mundo*, 9, 4; *In VI Metaphysicorum*, 2, 16; *In VI Metaphysicorum*, 3, 22; *Summa Contra Gentiles* III, 99.

[24] In all these cases (*ut semper*, *ut in pluribus*, *ut in paucioribus* y *ad utrumlibet*), Thomas is talking of secondary (natural) causes, which act according to their own power. He does not understand them to be the primary cause, neither to be acting with the power of the primary cause. That is why contingency is distinguished from miracle. See *De Malo*, 16, 7, 15: *voluntas divina est universaliter causa entis, et universaliter omnium quae consequuntur modum necessitatis et contingentiae. Ipsa autem est supra ordinem necessarii et contingentis, sicut est supra totum esse creatum. Et ideo necessitas et contingentia in rebus distinguuntur non per habitudinem ad voluntatem divinam, quae est causa communis, sed per comparationem ad causas creatas, quas proportionaliter divina voluntas ad effectus ordinavit; ut scilicet necessariorum effectuum sint causae intransmutabiles, contingentium autem transmutabiles*. Besides, God creates natural agents to act contingently. See *In I Peri Herm.*, XIV, 197: *ex ipsa voluntate divina originantur necessitas et contingentia in rebus et distinctio utriusque secundum rationem proximarum causarum: ad effectus enim, quos voluit necessarios esse, disposuit causas necessarias; ad effectus autem, quos voluit esse contingentes, ordinavit causas contingenter agentes, idest potentes deficere. Et secundum harum conditionem causarum, effectus dicuntur vel necessarii vel*

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single natural agent. In these, *per se* contingent, there is a place for a mitigated determinism, because the agent may or may not produce the effect. With this mitigation Thomas does not want to affirm a total indeterminism, but rather a not so rigid determinism in nature, because the expected effect may not be produced by the cause.

2.1. Events which occur ut in paucioribus

The argument as to why a cause could fail in the production of its natural effect is set in the terms of the hyle-morphic composition of natural beings. Thus, Oscar Beltrán argues that for Aquinas the question is not resolved in terms of extrinsic terms, but according to the very same nature of things. That is, the possibility of an impediment as an extrinsic fact claims its foundation in the intrinsic order of things.[25] So, although natural causes are necessary insofar as they are determined to one alternative, they are nonetheless the source of a contingency, one that follows on their (limited) necessity.[26] Thus, the events which happen *ut in paucioribus* have their ultimate root in the material potency which is an intrinsic co-principle of every natural being. It is worth investigating in some depth Thomas' account of these events, so as to be able to offer proper complement to Heisenberg's thought on quantum mechanics.

For Aquinas, the failure of the causal relation can occur due to three features: 1) pertaining to the cause in itself, 2) the patient in which the agent acts, or 3) the encounter of many agents.[27] As Thomas asserts in his *Commentary on Aristotle's Metaphysics*:

> *Si igitur ea quae hic sunt contingentia, reducamus in causas proximas particulares tantum, inveniuntur multa fieri per accidens, tum propter concursum duarum causarum (1), quarum una sub altera non continetur, sicut cum praeter intentionem occurrunt mihi latrones. (Hic*

contingentes, quamvis omnes dependeant a voluntate divina, sicut a prima causa, quae transcendit ordinem necessitatis et contingentiae.

[25] Oscar Beltrán, 'La doctrina de la contingencia en la naturaleza según los comentarios del Card. Cayetano y S. Ferrara', *Studium* 6:11 (2003), pp. pp. 41–75, p. 51: "Para Santo Tomás la cuestión no se dirime en términos meramente extrinsecistas, como el puro hecho de darse siempre o no darse nunca, o el de no poder ser o dejar de ser impedido, sino, valga subrayarlo, *conforme a la naturaleza intrínseca de las cosas*. En resumen, la posibilidad del impedimento como hecho extrínseco reclama su fundamento en el orden intrínseco." See also *Summa Contra Gentiles* III, 86: *Impressiones enim causarum recipiuntur in effectibus secundum recipientium modum. Haec autem inferiora sunt fluxibilia et non semper eodem modo se habentia: propter materiam, quae est in potentia ad plures formas; et propter contrarietatem formarum et virtutum.*

[26] Connell, *Nature's Causes*, p. 242.

[27] See Connell, *Nature's Causes*, p. 242: "The actions of natural agents can be sometimes defective because of extrinsic active causes or because of inadequately prepared materials or because of an indisposition resulting from a stray, incidental active cause."

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enim concursus causatur ex duplici virtute motiva, scilicet mea et latronum) tum etiam propter defectum agentis (2), cui accidit debilitas, ut non possit pervenire ad finem intentum; sicut cum aliquis cadit in via propter lassitudinem. Tum etiam propter indispositionem materiae (3), quae non recipit formam intentam ab agente, sed alterius modi sicut accidit in monstruosis partibus animalium.[28]

2.1.1. Propter concursum duarum causarum

The first reason for the occurrence of things not expected is the concourse of a series of causes. Aquinas, talking about events which occur casually or by chance, identifies the fortuitous concourse of many independent causes which originates the casual event with the *ens per accidens*.[29] The *ens per accidens* cannot be called a *ens per se*[30] because the *ens per se* only occurs where there is formal unity: "*quod autem est per accidens non habet causam quia non est vere ens, cum non sit vere unum*".[31]

The encounter of different series of independent causes in a time and place cannot be reduced to a cause *per se*. According to Aquinas *manifestum est autem quod causa impediens actionem alicuius causae ordinatae ad suum effectum ut in pluribus, concurrit ei interdum per accidens, unde talis concursus non habet causam, inquantum est per accidens. Et propter hoc, id quod ex tali concursu sequitur, non reducitur in aliquam causam praeexistentem, ex qua ex necessitate sequatur*.[32] In natural beings, due to the fact that there are many beings all acting at the same time, it can happen that two or more of them act upon the same patient, a fact which can be considered accidental, because there was no reason for that to happen: the concourse of many causes cannot be explained by other natural principles because *id quod est per accidens, non est proprie ens, neque unum; unde impossibile est quod id quod est per accidens, sit effectus per se alicuius naturales principii agentis*.[33] That is, given that what is *per accidens* is not properly speaking something with an internal unity, it is not possible for this *ens per accidens* to be the effect of a *per se* natural agent, with formal unity. Thus, the event so produced can be considered as caused in a purely accidental way and thus, it

[28] Thomas Aquinas, *In VI Metaphysicorum*, 3. See also *Summa Contra Gentiles* III, 99: *multae enim naturalium causarum effectus suos producunt eodem modo ut frequenter, non autem ut semper; nam quandoque, licet ut in paucioribus, aliter accidit, vel propter defectum virtutis agentis, vel propter materiae indispositionem, vel propter aliquod fortius agens*.

[29] Cfr. Thomas Aquinas, *Summa Contra Gentiles* III, 74.

[30] Cfr. Thomas Aquinas, *Summa Theologiae* I, 116, 1, co.

[31] Thomas Aquinas, *Summa Theologiae* I, 115, 6, co: *quod autem est per accidens non habet causam quia non est vere ens, cum non sit vere unum*.

[32] Thomas Aquinas, *Summa Theologiae* I, 115, 6, co.

[33] Thomas Aquinas, *Summa Theologiae* I, 116, 1, co.

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does not have a cause, properly speaking. We may speak, then, of an accidental cause.

As infinite and indeterminate, the cause *per accidens*, which is the cause of a chance event, lacks formal unity, and thus it is not properly speaking a being *per se*. Besides, by lacking formal unity, it is impossible for us to know and to foresee every single cause that causes that event. Hence, given the proportionality between being and its causes, it is said that the relative cause of the *ens per accidens* is a *causa per accidens*.[34] Everything which is *per se* has a necessary cause. Then, if any cause is not necessary in virtue of an impediment, that which is obtained under those circumstances would not be an *ens per se*, it would rather be *per accidens*, due to its lack of a proper cause.[35] In this way, the concourse of many causes cannot be explained by other natural principles simply because it is an *ens per accidens*.[36]

Since the causal concourse is accidental it does not have a natural determinate cause, and this is why it is impossible to know the entire causal concourse, and impossible to predict which effect will be produced.[37] Or, in other words, the contingent as such is not intelligible.[38] In the causal concourse the plurality of causes is indefinite, and this plurality behaves as the *possibilitas materiae*. From the very moment that a determination is introduced (a specific orientation of the series), there is no more plurality, no more indetermination. The point I am trying to make here is that the fact that there is a causal series is itself by chance. It does not cause chance. It is an effect, a chance effect.[39] The different causal lines which coincide in a time and space are not determined to coincide with each other. So, the causal concourse is accidental, because it has no determinate

[34] Beltrán, 'La doctrina de la contingencia', p. 54: "Todo aquello que es per se tiene una causa necesaria. Luego, si alguna causa no resulta necesaria en virtud de un impedimento, aquello que se origine bajo tal circunstancia no será un ens per se, sino per accidens, ya que propiamente no tiene causa, o la tiene como algo extraño a él. Entonces, habida cuenta de la proporcionalidad entre el ser y sus causas, se dice que la causa relativa al ser per accidens es una causa per accidens."

[35] Thomas Aquinas, *In XI Metaphysicorum*, 8, 13: *Si aliqua causa sit ad quam non de necessitate sequitur effectus, sed ut in pluribus, hoc est propter impedimentum, quod per accidens contingit*. See also *In V Metaphysicorum*, 22, 21–23 and *Summa Contra Gentiles* III, 86.

[36] Thomas Aquinas, *Summa Theologiae* I, 116, 1, co: *id quod est per accidens, non est proprie ens, neque unum; unde impossibile est quod id quod est per accidens, sit effectus per se alicuius naturales principii agentis*.

[37] Innocenzo D'Arenzano, 'Necessità e contingenza nell'aggire della natura secondo San Tommaso', *Divus Thomas* (1961), pp. 28–69, pp. 41–42.

[38] Connell, *Nature's Causes*, p. 253.

[39] Brock, 'Causality and Necessity', p. 228: "The *concursus* will be a mere coincidence."

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cause.[40] It is chance which brings about the material conjunction of causes.[41]

2.1.2. Propter debilitatem agentis

A metaphysical analysis of the contingency and the continuous coming to be of natural beings requires us to admit that they are composed by two intrinsic co-principles, really distinct and different: 1) a principle of being and actuality, of perfection, of determination, which constitutes the being in its own specific essence, and, therefore, determines its nature and its ways of acting, i.e. the form of a thing; and 2) a principle of potentiality, of a purely passive capacity of being, which by itself is indeterminate, indifferent to being or not being, indifferent to being this or that, and, therefore, of acting in this way or another, i.e. the matter. This composition means that natural beings are not completely act, pure determination, but a mixture of actuality and potentiality, of determination and indetermination. And, as Aquinas teaches, the origin and principle of defectiveness in the action of natural agents, i.e. of their not accomplishing their causal power, is found in the fundamental potentiality and indetermination of matter: *Aristotelis assignat rationem possibilitatis et contingentiae in aliis autem ex eo quod materia est in potentia ad utrumque oppositorum*.[42]

Thomas, thus, finds the debility of the agent to be one of the roots of indetermination and contingency in the action of material beings. This weakness is expressed in terms of the passive principle by which the material being is composed. Hence, due to this passive principle, the active potency of natural agents could sometimes fail to produce their determined effect because of a lack of 'internal energy' (=*impedimentum ex parte agentis*). The material potency, which in the material compound is the passive potency, generates in the material beings the possibility of 'escaping' from the active potency that would determine them.[43]

2.1.3. Propter indispositionem materiae

Here now we speak of that which is not a principle in the agent. Rather, it refers to that which is intrinsic to the being which receives

[40] Charles De Koninck, 'Réflexions sur le problème de l'indéterminisme', *Revue Thomiste* (1937), pp. 227–252 and pp. 393–409, p. 248. See also Connell, *Nature's Causes*, p. 245: "Chance is a contingent, incidental union of effects coming from two or more determinate agents, none of which is antecedently ordained to the union."

[41] Connell, *Nature's Causes*, p. 246.

[42] Thomas Aquinas, *In I Peri Herm*., XIV, 183.

[43] D'Arenzano, 'Necessità e contingenza', p. 46: "S. Tommaso ammette come fonte di indeterminazione, negli esseri corporei, la 'debilitas agentis', in forza del principio pasivo che, come potenza di contrari e causa di contingenza, ogni essere naturale sublunare (quinde anche l'essere meramente materiale) possiede: la materia prima."

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the action of the agent, i.e. the patient. Even though the agent would act in its determinate way, without any impediment from an external causal concourse or its own deficiency, to be the cause of the expected effect, there is still the possibility that this effect would not be produced because of the being which receives the action.

This possibility to fail in the production of the effect comes, again, from the matter of the being which receives the action, which, as a material being, is also a compound of an active principle, substantial form, and a passive principle of indetermination, prime matter. The form of the patient does not inform completely and perfectly the matter which it informs. That is, it does not complete the total potentiality of the matter. (Because of this fact the natural being can change into something else). Thus, this potentiality, as long as it is free from the information of form, can be, partially, an independent material cause, though not by itself a truly effective cause. Hence, it would leave as unforeseeable the exact way in which the patient would behave given the action of the external agent.[44]

To summarise, although natural agents are necessary because they are determined to one kind of effect, they are nonetheless the root of a contingency following upon their imperfect determination.[45] As matter always takes part in every natural action, the possibility exists that the effect which the agent was ordered in a determinate way to produce by its form, cannot by perfectly effected. Instead, there can be unexpected effects.[46] In the material compound, independently of the perfection of the form, there is always a place for an indetermination which exceeds it. The source of this indeterminism is matter, which can make an effect which was not necessarily determinate in its cause to happen *per accidens*.[47]

Conclusively, the effect which is not totally determinate in its cause could be not produced because of any of these three reasons, or by two of them, or even by all the three at the same time. Thus, the causal concourse can come together with the weakness of the agent or with the indisposition of matter that receives the action.[48] Briefly,

[44] D'Arenzano, 'Necessità e contingenza', p. 47: "Infatti, la forma determinata del corpo materiale non domina perfectamente la materia che tiene sotto di sè: resta quindi la possibilita che la materia, in quanto appunto sfugge dal completo dominio della forma, si costituisca essa stessa, parzialmente, in causa indipendente, rendendo in tale modo imprevedibile la reazine esatta che dovrebbe avere dall'azione dell'agente esterno."

[45] Connell, *Nature's Causes*, p. 242.

[46] Cfr. Thomas Aquinas, *In I Peri Herm*., XIV.

[47] Thomas Aquinas, *Summa Contra Gentiles* III, 86: Haec autem inferiora sunt fluxibilia et non semper eodem modo se habentia: propter materiam, quae est in potentia ad plures formas; et propter contrarietatem formarum et virtutum.

[48] Cfr. D'Arenzano, 'Necessità e contingenza', p. 48. Cfr. Comm. Caietani in *Summa Theologiae* I, 115, 6: *Ratio contingentiae potest dupliciter assignari: uno modo, ex parte complementi; alio modo, ex parte radicis. Radix quidem huiusmodi contingentiae est natura*

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the material cause, as an intrinsic and necessary cause of the nature of physical substances, turns to be a potential and indeterminate feature of nature, which cannot be assimilated in any way to the order of the causes in act.[49] Thus, the action of the natural substances, according to their formal active principle, has to be determined *ad unum*, but, at the same time, under a different aspect, given its material principle, it could enjoy a certain degree of indetermination.[50]

Stephen Brock[51] has recently suggested that the interpretation of Thomas' thought I have presented here, which follows the teachings of Selvaggi, DeKonnick and D'Arenzano, is not correct. He does, however, assert that it appears to be a promising path for a good appreciation of the topics. Nevertheless, he finds that it is not possible to interpret Thomas in this way. Brock understands that any impediment to the production of a determined effect has to be due to an extrinsic cause.[52] However, Beltran's suggestion seems to be more corresponding to Aquinas' writings and spirit: the issue of indetermination in nature needs to be solved in terms of intrinsic causes and principles of natural beings, and not merely in terms of extrinsic conflicting causes.

The question to answer now is why we are in a position to find indeterminism at large within the realm of quantum events. To find an appropriate response I will present a different kind of metaphysical argument, developed mainly by Charles de Konninck and expanded by Filippo Selvaggi.

3. Indetermination and the Hierarchy of Being

Aquinas presents a different side of his understanding of indeterminism in nature through his conception of the hierarchy of being. When he talks about the distinction among separated substances and the possibility of their multiplicity, he introduces the doctrine of the

potentiae inventa in naturalibus, qua et possunt deficere in minori parte, et sunt in potentia contradictoris . . . Complementum vero contingentiae est concursus accidentalis causarum, sive activae et passivae, sive activarum inter se, etc. Et propterea non opposita dixit, sed utrumque assignavit in diversis locis divus Thomas . . .

[49] Beltrán, 'La doctrina de la contingencia', p. 66: "la causa material, en cuanto es intrínseca y necesaria a la naturaleza de las sustancias físicas, se plantea como un factor potencial e indeterminado, que no puede ser asimilado de ninguna manera al orden de las causas en acto."

[50] D'Arenzano, 'Necessità e contingenza', p. 58: "l'agire dei corpi, in forza dei principi attivi intrinseci di operazione, debe essere, per principio metafisico, determinato 'ad unum' e, nello stesso tempo, ma sotto un aspetto diferente, può godere di una certa indeterminazione."

[51] Brock, 'Causality and Necessity'.

[52] Brock, 'Causality and Necessity', p. 235.

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grades of being which can be found in created beings, starting from the separate intelligences closest to the *esse subsistens*, to the forms of the elements, from the closest being to Pure Act, down to the most distant from it. This gradual distinction is given by the *gradus potentiae et actus*.[53] Hence he argues that the higher intelligence has more of act and less of potency, and this mixture of act and potency goes downwards gradually. When he reaches the material world, he argues that there are different forms which have more of potency (*plus de potentia*)[54] and hence are closer to matter. In these, he claims, we also find this gradual order of mixture of act and potency according to the form of the being along the spectrum between pure act and pure potency.[55]

Thus, in this hierarchy of beings, from Pure Act to prime matter, which is pure potency, we find a large number of beings which are composed of act and potency. Those closest to Pure Act would have a greater actuality, and those closest to pure potency would have lesser actuality. As we descend the degrees of being, the corresponding reduction in actuality correlates with an increase in potentiality, down to the forms of the elements, which are the closest to prime matter, pure potency. In this hierarchy, act and potency are mixed in a higher or lower proportion according to each being's relation to either pole. According to Thomas, creation necessarily implies a hierarchical order of degrees in being. The distinct character of each creature, according to its specific nature, follows from the difference in its relationship to God, who is the source of the hierarchy of created being. Thus, conceiving the world as divine creation means seeing each creature according to its own degree of perfection.[56]

Greater or lesser actuality comes from the participated *esse*, received by the essence. Essences which are closer to matter would be those that would have lesser actuality, thus, greater potentiality. The farther the substance is from pure actuality, the greater its potentiality, and thus the greater the possibility of an ineffective action. That is why Thomas says that there are three main spheres of action within reality: 1) that being which is only act, operates always without defect; 2) that which is only potency, pure matter, needs an act to actualise it; and 3) that which is a mixture of act and potency, every natural being, which acts perfectly most of the times.[57] From

[53] Thomas Aquinas, *De ente et essentia*, 3.

[54] Thomas Aquinas, *De ente et essentia*, 3. See also *Summa Contra Gentiles* III, 69; *De Spiritualibus Creaturis*, pro., 1, 25; *Compendium Theologiae* I, 74.

[55] Thomas Aquinas, *De ente et essentia*, 4.

[56] Rudi te Velde, *Aquinas on God: The 'Divine Science' of the Summa Theologiae* (Aldershot: Ashgate, 2006), p. 132.

[57] Thomas Aquinas, *In I Sententiarum*, 39, 2, 2, 4: *In naturalibus invenitur triplex gradus; aliquid enim est quod habet esse tantum in actu; et huic nullus defectus essendi*

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this the first conclusion is that with greater actuality there is more determination in being, and hence in action; whereas with lesser actuality there is a greater indetermination in being and hence in action.

We find, then, in every natural being a passive indetermination, which is essentially an imperfection or – more accurately and absolutely speaking – a lack of perfection in relation to the whole of being. According to the hierarchy of being postulated above, we can say that natural things, as they are farther from Pure Act, they participate less in act: they are less determinate. Hence, they are more potential, and with this their passive indetermination increases. Their material cause is the ultimate source of this indetermination,[58] and because it is potentiality, *pura arrazionalità* according to Selvaggi,[59] this passive indetermination cannot be measured. Since forms are the source of different grades of being, beings are also graduated in the determination of their actions according to those forms. Natural agents will determine their effects to the degree to which they are determinate by their forms.[60]

If we start from the consideration of this passive indetermination, every effect could be uncertain. Every single future event, as an effect, has something uncertain, contingent, and indeterminate because of its material co-principle. To deny this would be to forget matter as a potential principle, from which passive indetermination comes. It is this indetermination which is the cause of the uncertainty of the future. Thus, this passive indetermination will become increasingly greater towards the end of the hierarchy of being, at the level of the elements of matter. It is at this level in which what occurs can only be disclosed experientially, because the passive

advenire potest: aliquid autem est quod est tantum in potentia, sicut materia prima; et hoc semper habet defectum, nisi removeatur per aliquod agens reducens eam in actum: est etiam aliquid quod habet actum admixtum privationi; et hoc propter actum dirigentem in opere recte operatur ut in majori parte, deficit autem in minori, sicut patet in natura generabilium et corruptibilium. See also *De Veritate*, 8, 6, co: *Sicut enim est gradus actus et potentiae in entibus, quod aliquid est potentia tantum, ut materia prima; aliquid actu tantum, ut deus; aliquid actu et potentia ut omnia intermedia*. Also *In De Memoria et Reminiscentia*, 2, 6; *In Boethii de Trinitate* III, 5, 4, co2.

[58] Thomas Aquinas, *Summa Theologiae* I, 83, 3, co: *Est autem unumquodque contingens ex parte materiae, quia contingens est quod potest esse et non esse; potentia autem pertinet ad materiam. Necessitas autem consequitur rationem formae, quia ea quae consequuntur ad formam, ex necessitate insunt*.

[59] Filippo Selvaggi, *Causalità e indeterminismo, La problematica moderna alla luce della filosofia aristotelico-tomista* (Roma: Editrice Università Gregoriana, 1964), p. 153.

[60] De Koninck, 'Réflexions sur le problème de l'indéterminisme', p. 237: "Si les êtres naturels sont hiérarchisés selon le degré de détermination de la forme, ils constituent une hiérarchie de natures. Il y aura gradation dans l'ordre de l'activité : les effets ne seront pas légalement déterminés dans leur cause, mais dans la mesure de la perfection de la nature."

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indetermination is the reason for a fundamental unpredictability in events.[61]

Therefore, we can say that natural things are more or less determinate according to their place in the hierarchy of being, and, as causes, more or less determinate of their effects. Thus, we can talk of a kind of internal tension in the very nature of finite things.[62] This internal tension means that nature cannot be completely determinate *ad unum*. The absence of necessity in the form brings with it the absence of necessity in the effects. Thus, the necessity and physical determination are funded on the act as act, whereas the potentiality and uncertainty are founded on the act as act limited by the potency in which it is received.[63]

4. Conclusion

With these arguments from Thomas' philosophy of nature and metaphysics of act and potency we can now ask what relevance this has towards an understanding of quantum mechanics. Can we say that the physical systems with which quantum physics works are at the lowest grades of the hierarchy of being, and hence those with the less actuality and greatest potentiality among created beings? It is clear that we cannot say that quantum physics is working with the constitutive elements of reality as understood in Aristotelian philosophy. Nevertheless, it does not sound very implausible to affirm that quantum mechanics is working and describing natural things which are great in potency and low in act, possibly reaching those forms of natural beings, which are close to what in the Aristotelian ontology has been called prime matter.

It is my argument that this was Heisenberg's intuition when he said that sub-atomic particles were *in potency* before being observed. Evidently, they cannot be pure potency, as Heisenberg claimed, because they would be primer matter itself, which needs to exist under some kind of formality. As Beltrán teaches, the indetermination of matter is not enough to explain contingency because by itself is pure potency. For sub-atomic particles to be considered in potency, they

[61] Selvaggi, *Causalità e indeterminismo*, p 153: "andrà assumendo proporzioni sempre maggiore, finchè al fondo della scala, al livello degli elemento primordiali della materia, potrà raggiungere un livello anche directamente osservabile nell'esperienza."

[62] I am clearly leaving aside the discussion of human free will.

[63] Selvaggi, *Causalità e indeterminismo*, p. 390: "La necesita e la determinazione fisica sono fondate sull'atto in quanto atto, la probabilità e l'incertezza sull'atto in quanto limitato dalla potenza, in cui è ricevuto."

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need to be under a formal determination, and thus some degree of actuality.[64]

It is precisely because of a being's form that quantum physics can show the existence of a fundamental determinism in every being, even in the smallest quantum system. This determinism is found in the specification – at least generic and qualitative – of the operation of the diverse particles and forces. And this determination is quantitatively exact and rigorously identical for all individual cases.[65] Thus, quantum physics recognises a fundamental determinism in nature, and denies an absolute and exclusive ontological and causal indeterminism.[66] On the other hand, quantum physics is open to experience, by which it cannot deny the existence of a certain causal indeterminism, which as Heisenberg claimed is not reducible to the epistemological order, but which is rooted in the ontological order of things, given primarily by the potentiality of matter.[67]

Here is, as suggested above, where we can find the most direct experimental observation of those events which occur *ut in paucioribus*. According to the principles of quantum mechanics, we can only have a certain probability of predicting an event, but not an absolute certainty. This uncertainty is caused by those three reasons for which, according to Thomas, events *ut in paucioribus* may occur: 1) because of the ontological passive indetermination of the natural being before its observation, i.e. the *indispositionem materiae* or the imperfection of the form of the quantum system; 2) because of the interaction between the observer and the quantum system, i.e. the concourse of two or more causes; and 3) because of the interaction between the two necessary systems for the observation, the observed particle and the light particle or photon, i.e. the *debilitas agentis*.

This is exactly what Heisenberg was saying in denying the possibility of fully knowing the state of a system at a given time in order to predict the future states of that system. Given the perturbation caused by the observation, Heisenberg thinks, the potentiality of the system is actualised. And this in a Thomistic perspective means that the system receives new forms, given that through their forms things are in act. This new form was in the potentiality of matter,

[64] Beltrán, 'La doctrina de la contingencia', p. 69: "La indeterminación de la materia no basta para explicar la contingencia, porque ella de por sí es pura potencia, pura disponibilidad, y no tiene nada propio en virtud de lo cual resistir a la forma sustancial, por débil que ésta sea. Por eso su resistencia o capacidad de impedir ha de asumirse bajo una cierta disposición, que se atribuye a la forma que actualmente posee, y que puede guardar un grado diverso de adecuación con la del agente que pretende obrar sobre ella. Y dicho agente, si se trata de una sustancia natural, aun del orden celeste, sólo puede efectivizar su influjo *ad modum recipientis*."

[65] Cfr. Selvaggi, *Causalità e indeterminismo*, pp. 381–382.

[66] Cfr. Selvaggi, *Causalità e indeterminismo*, p. 386.

[67] Cfr. Selvaggi, *Causalità e indeterminismo*, pp. 386–388.

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and is brought to actuality by the interaction with the measurement device in the observation. Now, given that every potency is potency to contraries.[68] In particular, matter in these quantum systems can take unpredictable forms, which are only predicted probabilistically by the wave-function included in the Schrödinger equation. Although matter is open to the reception of new forms, it cannot receive any form. The system described by the Schrödinger equation could only receive those forms included probabilistically in that equation.

Hence, we can conclude with Selvaggi that at the quantum level there is a real potentiality, which is not pure potency, but it is constituted with a certain degree of actuality and determination. It is, then, this potentiality partially actualised which is the real ontological fundament of the probability which rules the quantum phenomena.[69] Finally, the indetermination in the action is founded in the ontological passive indetermination, given by a form located in the lower levels of the hierarchy of being. And it is in this ontological indetermination by which our epistemological indetermination, presented in Heisenberg's uncertainty principle, is sustained.

Heisenberg's analysis of his uncertainty principle to resist the rigid determinism of classical physics, points towards an analogical understanding of being in terms of act and potency. Aquinas's analysis of determination and indetermination in nature, given by his hierarchical understanding of being offers us a way to avoid the choice between thinking that nature must be either determinate or indeterminate: each being will be a cause according to its degree of being. There is neither an absolute determinism nor an absolute indeterminism in nature. Neither for Heisenberg nor for Aquinas.

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[68] See Thomas Aquinas, *De Potentia Dei*, 3, 4, 14: *in educendo res de potentia in actum multi gradus attendi possunt, in quantum aliquid potest educi de potentia magis vel minus remota in actum, et etiam facilius vel minus faciliter*.

[69] Selvaggi, *Causalità e indeterminismo*, pp. 389: "Abbiamo quindi una reale potencialita, che non è pura potenza, ma è costituita in un certo grado di attuazione e determinazione. Ed è proprio questa potenzialità parzialmente attuata che, a nostro parere, costituisce il fondamento reale ontologico della probabilità a priori che regola i fenomeni quantici."

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