

Ancient atomism and modern physics: the search for the unified theory in the context of (in) determination

O atomismo antigo e a física moderna: a procura da teoria unificada no contexto da (in)determinação

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The Research Group “Physics and Humanities”, based in the Brazilian Center of Physics Research (BCPR), has worked on building dialogues between Physics and Humanities, particularly regarding philosophical questions applied to quantum mechanics (QM). The present article intends to establish the relationship between questions concerning the discussion on chance versus necessity — in the context of ancient atomism — and the most recent theories on the nature of matter and the general state of the universe, notably the implications that the proposition of a unified theory of the world presents for the debate on determinism versus indetermination.

O Grupo de Pesquisa “Física e Humanidades”, radicado no Centro Brasileiro de Pesquisas Físicas (CBPF), vem trabalhando na construção de diálogos entre a física e as ciências humanas, especialmente nas questões filosóficas aplicadas à mecânica quântica (MQ). No presente artigo, pretende-se estabelecer uma relação entre indagações atinentes ao debate acaso versus necessidade — no contexto do atomismo antigo — com as teorias mais recentes sobre a natureza da matéria e sobre o estado geral do Universo, sobretudo as implicações que a proposição de uma teoria unificada sobre a ordem do mundo possui para o debate determinismo versus indeterminação.

Keywords: Chance. Atomism. Modern Physics. Necessity.

Palavras-chave: Acaso. Atomismo. Física Moderna. Necessidade.

Introduction

Is the universe, in the unfolding of its movements, a dynamic whole¹ ruled by necessary laws? Does the intuition in the idea of “law” mean submitting nature to the rule of an inflexible determinism? How to reconcile: (a) the acknowledgement of nature as a place of order and regularity — assumption of all investigations of scientific nature, and; (b) the perception that certain events in the world are triggered and developed frequently

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¹ On the notion of whole, it is worth reviewing the notion of totality proposed by David Bohm. Cf. BOHM, D. *Wholeness and the Implicate Order*. London: *Taylor & Francis*, 2005.

at random (particularly if we have in mind the sphere of action in which humans move)? Is there a way to put in accordance our intuition of time as a succession of distinct events and irruption of the new with the image of a universe where the set of all past events submits irrevocably the present state and the future? Ultimately, how to reconcile our ideas about nature — where intelligibility demands determinism — with our ideals of freedom²?

These dilemmas have accompanied Western thinking since its beginnings³. The first philosophers – called *physikoi* by Aristotle⁴ – appear as an intrepid group. Certain traits distinguish the activity of these thinkers. Starting from a repertoire of similar notions – *physis*, *kosmos*, *arché*, *logos* – they firstly set themselves into the task of investigating reality (i.e., nature, *physis*) through rational procedures (*logos*)⁵. They shared the intuition that nature, despite its multiple and shifting aspects, is an ordered whole directed from an economy of principles. Such an intuition has become a kind of guideline for all further philosophic and scientific investigations, with obvious reverberations in contemporary Physics, as we intend to discuss.

The conception that reality is an ordered whole also reveals that, for Presocratic thinkers in general, the proposed explanations would be valid as long as given according to operating principles internal to nature itself. Nature would represent the last instance, therewith one claims the impossibility of evoking an exteriority able to respond for its internal dynamism. In such case, the world ceases to be a scene of fluctuations which, by the constant intervention of the gods, escapes determination. Asserting that nature is an ordered whole means that it is rational in its movements. Investigating and finding the rationality under which such totality works becomes the task of human reason.

Such assertion of the rationality/intelligibility aspect of nature establishes the primacy of the *one* in thinking. According to this perception, nature is *one* whole (and the whole can only be one). The reason that operates the modalities of transformation is the unifying and totalizing instance.

In the first Ionian thinkers (Thales, Anaximander and Anaximenes)⁶, it is possible to detect a clear alliance between reason and ordinary experience conveyed by the senses. The senses announce multiplicity and motion, highlighting the differences promoted according to the *decree of time*⁷. It falls to reason to answer for the significance of these differentiations in view of the primacy of *one*. It can be said that for these first philosophers there is not yet evidence of contradiction between the unity, presupposed by reason, and the diversity, which manifests itself in time.

² Cf. SIQUEIRA-BATISTA, R.; SCHRAMM, F. R. Bioética e neurociências: os designios da Moira. *Tempo Brasileiro*, v. 195, p. 5-26, 2013.

³ Cf. MONDOLFO, R. *O homem na cultura antiga: a compreensão do sujeito humano na cultura antiga*. Tradução de Luiz Aparecido Caruso. São Paulo: Mestre Jou, 1968.

⁴ Cf. ARISTÓTELES. *Metafísica*. Edição trilingue por Valentin Garcia Yebra. Madrid: Gredos, 1970. 2 v.

⁵ Cf. VALADARES, A. A. A doutrina dos elementos entre a poética e a epistemologia de Gaston Bachelard. *Kriterion*, v. 55, n. 130, p. 463-48, 2014.

⁶ Cf. SIQUEIRA-BATISTA, R. O nascimento da filosofia: uma peça em três atos. *Lugar Comum*, v. 33-34, p. 215-225, 2011.

⁷ Cf. Excerpt from that which is considered the first philosophical sentence of the West, the fragment attributed to Anaximander of Miletus: DK 12 B 1. Cf. KIRK, G. S., RAVEN, J. E., SCHOFIELD, M. *Os filósofos pré-socráticos*. Tradução de Carlos Alberto Louro Fonseca. Lisboa: Fundação Calouste Gulbenkian, 1994.

It is left to Parmenides and his school (the Eleatics) to denounce this contradiction and propose a rupture in this harmonious ideal of science as intuited by the first philosophers. Parmenides claims, and to a certain extent, definitely establishes the primacy of reason as a determinant source of the being. Thereupon, it can be stated that the Eleatic thinking intended to impose the exclusivity of reason and the total disqualification of the senses as a source of knowledge. The consequences of this philosophical movement are: the negation of multiplicity and motion, which therefore constitutes a denial of the very dimension of time. Subsequent philosophies had to face this contradiction that has an air of paradox: maintain the intelligibility of the real, i.e., its radical determination, while at the same time saving the phenomena. Explaining them, instead of simply denying them; uniting the order of reason to the constant come-into-being of the world such as it is given to us.

Based on these brief notes the present article aims to establish a relationship between issues of relevance to the debate chance *versus* necessity – in the context of ancient atomism – and the most recent theories about the nature of matter, emphasizing the implications that a unified theory of the world presents for the discussion determinism *versus* indeterminism.

2 Ancient atomism

Atomism⁸ emerges in the context of the philosophic thinking aforementioned crisis – *keeping intelligibility versus explaining phenomena*. Thereby, the being (matter, the atom) is affirmed as infinite reality, disperse in the non-being (the void, the absolutely intangible). The existence of the void appears as a necessary condition for motion to be thought of. Thus, the conditions of knowledge are assured (the atom and the void as abstract realities), as well as the conditions for the becoming to be thought (disperse multiplicity and motion)⁹. Indeed, the image atomists make of the universe is apprehended in one swoop: it is an infinity of matter disperse in chaotic motion in the infinite void, without further moving force but the one pertaining to the atoms.

Formulated firsthand by Leucippus and Democritus¹⁰, this philosophy represents an attempt to respond the challenge issued by Parmenides and his followers: that it is impossible to reconcile the ordinary experiences of becoming (devir) with the norms of intelligibility dictated by thought in the determination of the real, the latter already understood as that which lets itself to be fully comprehended by reason.

To a certain degree, the atomist enterprise is successful: they were able to develop

⁸ Cf. DIÓGENES LAÉRCIO. *Vidas e doutrinas de filósofos ilustres*. Tradução de Mário da Gama Kury. 2. ed. Brasília: Editora da UnB, 1997.

⁹ Cf. BATISTA, R. S. *Lucrecio e a natureza das coisas: entre o acaso e a necessidade*. Tese (Doutorado em Filosofia)–Pontifícia Universidade Católica do Rio de Janeiro, Rio de Janeiro, 2007.

¹⁰ Cf. DEMÓCRITO. *Fragments et témoignages*. Révision de la traduction de Maurice Solovine, introduction et commentaire par Pierre-Marie Morel. Paris: Pocket, 1993.

an ontology that respects the demands of Eleatics (i.e., of reason) concerning the being; at the same time, they succeeded in offering a coherent intelligible statute to the problem of motion and multiplicity. But, beyond the abstract field of ideas – the invisible that only thought can reach, where one plays with reason and nothing else – Democritus might have failed to concede legitimacy to knowledge. To rational, coherent, legitimate thinking (where the reality of atoms and the void is affirmed) the obscurity of sensible experience is opposed; the latter, due to its contradictory character can not intend to overcome its limits and impose itself as valid: it is taken as *bastard knowledge*. There is no straight line uniting the abstract principles to the coming-to-be in the world and time.

Atomism is resumed in the third century BC by Epicurus¹¹. Out of the immense textual production of Epicurus there remain but three letters, two sets of Maxims and fragments of a work entitled *peri physeos* (*On Nature*). Two centuries later Epicurean atomism is spread to the Latin world from the pen of the Roman poet Titus Lucretius Carus¹². Despite being a late disciple of Epicurus, Lucretius writes that which is considered the greatest philosophical poem of the Western world, *De rerum natura* (*On the Nature of Things*). The position of the commentators is that Lucretius's poem faithfully reconstitutes Epicurus resumption of Leucippus's and Democritus's atomism.

The fundamental theses of Leucippus's and Democritus's atomism are kept almost in full by Epicurus and Lucretius. The universe consists of an infinity of atoms that move according to the same velocity, completely disperse in the infinity of the void. The universe is still a totality, but here the first indetermination trait appears in atomist thinking: the totality, for being infinite, is paradoxically a sum that does not totalize. *The atomist whole is open*.

There's no exteriority to rule the movement of these atoms. The law of nature is the law of chance: it is by chance that atoms collide and give rise to phenomena. Collisions are actually the intelligibility principle of atomist thinking. There is here an important difference between original atomism and the Epicurean version: Democritus imagined the collisions between atoms to be entirely ruled by a necessity of mechanical order, meaning the present state of the universe could be entirely sent, by way of causality, to its previous states. Even in a universe dispersed by its infinite openness, past, present and future would already be totally determined by the succession of movements of the atoms. As a physicist Epicurus is unable to propose a world system that is not intelligible. But, for him, as stressed by Prigogine, *the problem of science, of nature's intelligibility and of man's destiny were inseparable. What could human liberty mean in the determinist world of atoms?*¹³ The solution presented by Epicureans is to incorporate to the movement of atoms a component of indetermination: the atom, in uncertain time and place, deviates from the vertical rectilinear motion that symbolizes the movement of mechanical determination. The declination is characterized as *nec*

¹¹ Cf. EPICURO: *Letras et máximas*. Texto grego, tradução, introdução e notas por Marcel Conche. 5. ed. Paris: PUF, 1999.

¹² Cf. LUCRÉCIO. *De rerum natura*. Texto estabelecido e traduzido por A. Ernout. 4. ed. Paris: Les Belles Lettres, 1975.

¹³ Cf. PRIGOGINE, I. O fim das certezas: tempo, caos e as leis da natureza. São Paulo: UNESP, 1996, p. 17.

plus quam minimum – no more than the minimum – an angulation that occurs to the rectilinear movement of pure determination. The declination, for Epicureans, allows us to think the creation of world(s) as well as living beings free will.

Science – for Epicurus and Lucretius – is the science of the probable: every event takes place within certain limits, but, in any case, in uncertain time and place. Thought determines the principles (atoms and the void) and establishes the necessary conditions for the emergence of organized structures, like the world. There remains, however, a background chance: it would not be admissible that an omniscient spirit in a certain moment in time could override the unfolding of movements (time) and determine the causal chains leading from past to future. Less than the atom – the invincible particle of being – what is proposed in a text like *De rerum natura* is to think “what moves”: the flows, that which flows, the universe flowing, the drift of nature. Lucretius says – as well understood by Michel Serres¹⁴ – with a lot more emphasis, that the most general property of the nature of things is to be fluid. To think multiplicity and motion is to think that in the fluid universe stability arises precisely from its background instability. Here one does not think *from* order and regularity, but *about* the conditions: how to attain *a certain* order and *a certain* regularity. The deviation of the straight line is the abstract observable condition of such becoming (*devir*), i.e., of that which stands as the negation of nothing, never fully coming to be. The nature of things is to be done and to be undone eternally; there is no fatal rationality that informs and directs generation in an absolute way. Nature is just a process, not a process “from” something “to”, solely a process. Nature explains itself in doing itself and undoing itself, not by the being, the substance, the idea, but by a certain monotony that arises from constancy. Everything is always new and everything is always the same, without contradiction or ambiguity.

Variations on the theme of declination end up forming the *leitmotif* of Lucretius poem: deviation, instability, stability, fluctuation, spontaneity, constancy of flows, discontinuity, chance and necessity; all themes are connected, directly or indirectly, to the theme of declination, all cross the different fields of Epicurean philosophy, from Physics to ethics, through the theory of knowledge. Everything that exists, what comes into being – the world, men, knowledge – flows within certain limits in one direction and one sense, both of which are, rigorously, not determined beforehand, but determine themselves in their very motion, in their perpetual flow. There are no previous direction and sense but they occur, strictly, in the immediate relationships, in the meeting of bodies with one another. Lucretius’s Physics can be seen, ultimately, as a theory of equilibrium in fluid media, or still, a physical system of disjunct bodies that reach stability without ever adhering to absolute stability: the equilibrium of bodies is metastable, i.e., from the continued disturbance they form structures that the continued disturbance stabilizes and through continuous disturbance they reach ruin.

This is an alternative rationality, not an irrationality, as the dominant tradition of philosophical thinking in the West would have one believe. The most

¹⁴ Cf. SERRES, M. O nascimento da física no texto de Lucrécio. Tradução de Péricles Trevisan. São Paulo, UNESP, 1997.

important philosophic intuition of atomists – less than the very creation of the term atom – is that the background disorder does not mean chaos but the necessary condition for order to arise and be maintained.

3 Atomism, determinism and modern physics

If modern science has a starting point in the works of Copernicus, Kepler and Galileo, it seems to have reached its highest level with Newtonian Physics. Among many accomplishments Newton achieves something prodigious: to unify, through his theory of gravitation, the Physics of terrestrial bodies with the celestial Physics. This meant, for many, the beginning of the project development – started by the Greeks – of a unified explanation of all phenomena¹⁵. The universe would thus be definitely linked to its name and effectively be *one*. Newtonian Physics has earned the distinction of being the ideal model of thinking sought by the dominant current of thought in the West: an ideal objective knowledge, a matrix capable of illuminating the obscurities of nature and coldly exhaust it. Mathematical formalism enabled to describe, in a quantitative perspective, the force of gravitational attraction between two bodies. This remarkable achievement takes Science a step further, enabling it to predict phenomena and to achieve, by determining a group of variables, the evolution of a set. Such advancement sharpens once more the debate on the issue of determinism.

Laplace – in the early nineteenth century – is convinced that the laws that rule the universe are laws of fully deterministic character. His belief is based on the predictive capacity of scientific theories, in particular Newton's mechanics. Laplace presupposes, based on that, the absolute rule of a set of laws of strictly deterministic character. Through these laws we would be able to predict the entire evolution of the whole universe, past, present and future, once knowing its entire state at a given moment in time.

*“[...] an intellect that, at any given time, knew all forces that animate nature and the mutual positions of the beings that constitute it, were this intellect vast enough to submit his data to analysis, he would be able to condense in one only formula the movement of the biggest bodies in the universe as well as the smallest of atoms: for such an intellect nothing could be uncertain; and both the future and the past would be present before his eyes”.*¹⁶

Laplace's determinism is not, regardless of how much one wants to resist to say so, a scientific position. It is rather a metaphysical assumption: it still means conceiving the world's image as the realm of radical necessity. Chance and indetermination would be like the measure of our ignorance¹⁷. The less we know, the more the phenomena appear to deviate to a regime where the rationality of laws loses efficacy. The discovery

¹⁵ Cf. CHIBENI, S. S. As posições de Newton, Locke e Berkeley sobre a natureza da gravitação. *Scientiae Studia*, v. 11, n. 4, p.811-839, 2013.

¹⁶ Cf. Laplace PS. *Oeuvres completes*. Paris: Gauthier-Villars; 1884. Free translation.

¹⁷ Cf. SIQUEIRA-BATISTA, R.; SCHRAMM, op. cit., 2013.

of a complete and definitive image of Physics seems to be, according to this reading, a matter of skill in handling the Newtonian Theory and, of course, a matter of time.

The period from the late nineteenth century to the first decades of the twentieth century is a critical moment for those who hope for the unification of the laws of nature under the paradigm of Newtonian Physics. Via the discovery-invention of the General Theory of Relativity, Einstein ends up frustrating the spirits who, like Laplace, believe to have the key to reading determinism in nature. Developing the Special Theory of Relativity and, years later, the General Theory of Relativity (GTR)¹⁸, Einstein makes the previous conceptions of absolute space and time collapse, while proposing a new conception of gravity. On the other hand, the development of Quantum Mechanics (QM)¹⁹ – in the first decades of the twentieth century – brings a new order of problems for theoretical physicists. Indeed, fortune in applying the laws of Physics according to the Newtonian matrix did not correspond when the microscopic world – the intimacy of matter – started to be investigated. QM succeeds where Newton conceptions meet frustration again. The price however is to notice a strong component of indetermination beginning to coexist with the advancements in knowledge on the intimacy of matter²⁰, expressed in terms of the impossibility to obtain in a single experiment information concerning the position and *momentum* of a given particle; in other words, in any measurement made there will always be uncertainty²¹, explicit as follows:

$$\Delta x_i \Delta p_i \geq \frac{\hbar}{2} \quad \text{and} \quad \Delta t \Delta E \geq \frac{\hbar}{2},$$

$$\text{where} \quad \frac{\hbar}{2} = \frac{h}{2\pi},$$

h being Plank's constant; ; Δx_i , Δp_i , Δt e ΔE indicate the uncertainties in, respectively, position coordinates, momentum components, time and energy.

The formulation of the uncertainty principle by Heisenberg²², in 1926, represents a significant contradistinction to the determinist conceptions:

“The limit dictated by the uncertainty principle does not depend on the way in which you try to measure the position or velocity of the particle, or on the type of particle. Heisenberg’s uncertainty principle is a fundamental, inescapable property of the world, and it has had profound implications for the way in which we view

¹⁸ Cf. EINSTEIN, A., INFELD, L. *Evolução da física*. Rio de Janeiro: Jorge Zahar, 1962.

¹⁹ Cf. SIQUEIRA-BATISTA, R.; HELAYÉL-NETO, J. A. David Bohm's quantum mechanics. *Vértices*, v. 10, p. 57-62, 2008.

²⁰ Cf. PATY, M. A noção de determinismo na física e seus limites. *Scientiae Studia*, v. 2, n. 4, p. 465-492, 2004.

²¹ Cf. CHIBENI, S. S. Certezas e incertezas sobre as relações de Heisenberg. *Revista Brasileira de Ensino de Física*, v. 27, p. 181-192, 2005. Ver também CINI, M. How real is the quantum world? *Science & Education*, v. 12, p. 531-540, 2003.

²² Cf. HEISENBERG, W. *A parte e o todo*. Rio de Janeiro: Contraponto; 1996.

the world. Even after more than seventy years, these implications have not been fully appreciated by many philosophers and are still the subject of much controversy. The uncertainty principle signaled an end to Laplace's dream of a theory of science, a model of the universe that would be completely deterministic. We certainly cannot predict future events exactly if we cannot even measure the present state of the universe precisely".²³

Indeed, the principle of uncertainty establishes that, if two physical quantities, g_1 and g_2 , are complementary, i.e., its corresponding associated operators G_1 and G_2 satisfy the commutation relation,

$$[G_1, G_2] = i \hbar \bar{G},$$

Then, the uncertainties Dg_1 e Dg_2 in the measurement of these quantities in a certain state of the system are linked by the uncertainty relation

$$\Delta g_1 \text{ e } \Delta g_2 \geq \left| \frac{\hbar}{2} \langle \bar{G} \rangle \right|,$$

where G designates the expected value of G in the given state of the system. The concept herein expressed refers to the situation in which two quantities cannot be known, with maximum accuracy, simultaneously.

The very concept of an “objective world”, which refers to physical processes with space and time as absolute parameters, is called into question given the impossibility of isolating the observer and the observed. Such indetermination would be the boundary, the epistemological limit within which we can move²⁴. Bohr rejects even the existence of “hidden variables” in quantum theory, thereby emphasizing that indeterminism is not a matter of insufficient development of the theory but something intrinsic to it²⁵. Thus, invention and QM radically change the scenario that indicated a trajectory without disruption towards knowledge of the definitive laws that the Laplacian presumption gathered fully under the seal of determinism.

Despite Newtonian Physics being still valid in certain domains of reality – one can actually verify that the overwhelming majority of Physics textbooks begin with the teaching of classical mechanics – it is undeniable that its incompatibilities with the advancements of modern Physics has imposed a paradigm shift. The most advanced theories that seek to explain physical reality are effectively Einstein's GRT and QM. The contemporary drama is however not smaller since there is a blatant

²³ Cf. HAWKING, S.; MLODINOW, L. Uma nova história do tempo. Rio de Janeiro, Ediouro, 2005, p. 95-96.

²⁴ Cf. SIQUEIRA-BATISTA, R.; HELAYÉL-NETO, J. A. The chance is necessary?: the case of the Drunkard's Walk: how randomness rules our lives. Revista Brasileira de Ensino de Física, v. 33, p. 1-1, 2011.

²⁵ Cf. BOHR, N. Física atômica e conhecimento humano. Rio de Janeiro: Contraponto; 1995.

incompatibility between the two theories. As a matter of fact, in the current state of research it is not possible to reconcile GRT and QM²⁶. In any case, Quantum Field Theory achieves at least a partial unification of electromagnetic force, strong nuclear force and weak nuclear force. Gravitational force though – which falls under the purview of GRT –resists entirely to be captured by the unifying formalism that brought together the other three forces. It should be commented here that the unification of the three fundamental fields is achieved through the so-called Standard Model of Fundamental Interactions, also known as $SU(3) \times SU(2) \times U(1)$ Model – which describes how these three interactions of the atomic and nuclear dominium share a common origin, thus the *idea of unification*²⁷.

After decades of difficulties, some physicists see the String Theory²⁸ as a promising path to the predicaments of contemporary Physics, something able to lead to a unified theory. In summary, the String Theory suggests that, contrary to what was always imagined, the fundamental particles are not punctiform objects occupying a place in space, but actually the effect of vibration of a structure provided with extension, without any other dimension though, hence the name string. That which we observe as (or supposed to be) a particle, would effectively be something like a wave located along the string. Due to insufficient experimental resources we are unable to detect them as strings. It is speculated that the strings would be of an order of magnitude around 10^{-33}cm .²⁹

The essential virtue of this theory is double: besides reducing the drastic oscillations predicted by QM in the texture of space-time, the String Theory offers an elegant way out³⁰, that is, an aesthetic one, once we enter an area where available technologies are not enough to provide experimental proof. One thus recovers, in a sense, the primacy of rigorous thinking in connection with an informative rationality that animated much of the philosophical speculation of ancient thinkers. We search for a universe able to meet our aesthetic sense. The notion of symmetry plays an interesting role in this case.

“In Physics, as in art, symmetry is a key part of aesthetics. But unlike the case in art, symmetry in Physics has a very concrete and precise meaning. In fact, by diligently following this precise notion of symmetry to its mathematical conclusion, physicists during the last few decades have found theories in which matter particles and messenger particles are far more closely intertwined than anyone previously thought possible. Such

²⁶ Cf. PENROSE, R. O grande, o pequeno e a mente humana. São Paulo: Editora UNESP, 1998.

²⁷ Considerations on the idea of unification can be found at: HELAYËL-NETO, J. A. et al. Neurociências e física contemporânea: a vida no espaço-tempo. In: ESPERIDIÃO, Antonio V. Neurociências: diálogos e interseções. Rio de Janeiro: Rubio, 2012, v. 1, p. 505-527.

²⁸ Cf. MAGALHAES, D.A. Sobre a importância do modelo de Veneziano para a teoria de cordas. Revista Brasileira de Ensino de Física, v. 35, n. 4, p. 1-5, 2013.

²⁹ ABDALLA, E. Teoria quântica da gravitação: Cordas e Teoria M. São Paulo: Revista Brasileira de Ensino de Física, v. 27, n. 1., p. 147-155, 2005.

³⁰ Referência explícita ao trabalho de Brian Greene, O universo elegante: supercordas, dimensões ocultas e a busca da teoria definitiva. Cf. GREENE, B. O universo elegante. São Paulo: Companhia das Letras, 2001.

theories, which unite not only the forces of nature but also the material constituents, have the greatest possible symmetry and for this reason have been called supersymmetric. Superstring theory, as we shall see, is both the progenitor and the pinnacle example of a supersymmetric framework”³¹

According to what has been said seen so far, we can raise the following questions:

- (1) What implications do the findings and improvements in QM bring to our conceptions about knowledge and its relation to the world?
- (2) Is still it possible to postulate objectivity and determinism after the advancements obtained in the field of quantum reality?
- (3) Does the search for a unified theory still commit us irrevocably to an image of the world radically determinist?

We believe such questions, despite being formulated in this vertex reached by contemporary Physics, are eminently philosophical. We only have, like the Greeks, images of thought which reflect our yearnings for unity. But, we have seen in the case of atomists, particularly Epicurus, that the *unified* image of the laws that rule the *universe* can coexist with a background indetermination.

Besides, the recent theory of chaos postulates that there are variations in the laws when we move from the elementary level to the complex level³². This means that the recognition of an elementary entity’s behavior – its evolution – be it an electron, a quark, an atom of Epicurus (maybe even a string) differs in substance from the knowledge we can have of a complex and composite body, like a cloud or the human psyche. A huge distance separates these scales³³. It remains to be seen if the straight line linking both levels, the elementary and the complex one, is irrevocably beyond the reach of our research capacity, or if in fact this line doesn’t exist at all. There is no consensus among physicists with respect to this debate.

4 Final considerations

The meaning of ancient atomism differs enormously from the Physics developed in the twentieth century. Atomism is a philosophy, something like a “*princeps thinking*”³⁴ that defines the soil upon where the themes of discontinuity, chance and indetermination will develop; something that seems to insistently repeat itself, no matter the scope and accuracy of the instrument of the person who measures, because “the” ultimate, definitive measure always escapes, or rather, it is always awaiting determination, since the final determination is never accomplished.

³¹ GREENE, B. op. cit., p. 167 In physics, as in art, symmetry is a key part of aesthetics.

³² RUELLE, D. *Acaso e caos*. São Paulo: UNESP, 1993. Ver também STEWART, I. *Será que Deus joga dados?: a matemática do caos*. Rio de Janeiro: Jorge Zahar, 1991.

³³ Cf. PENROSE, R. op. cit.

³⁴ DUVERNOY, J.-F. *O epicurismo e sua tradição antiga*. Tradução de Lucy Magalhães. Rio de Janeiro: Jorge Zahar Editor, 1993.

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Artigo recebido em: 6 ago. 2014

Aceito para publicação em: 31 mar. 2015