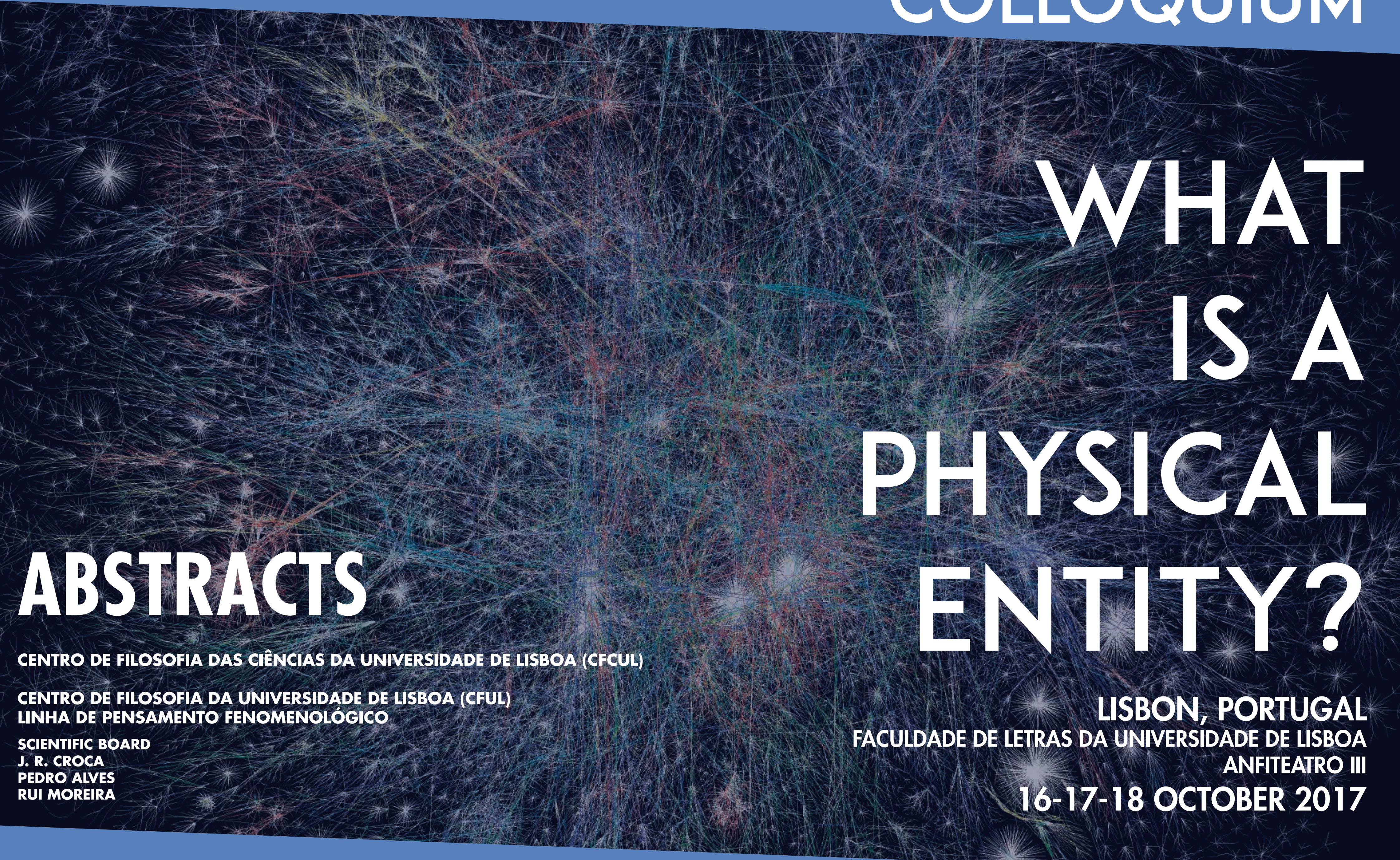

# COLLOQUIUM

# WHAT IS A PHYSICAL ENTITY?

# ABSTRACTS

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# INTERNATIONAL COLLOQUIUM
# WHAT IS A PHYSICAL ENTITY?

## ABSTRACTS

LISBON
FACULDADE DE LETRAS DA UNIVERSIDADE DE LISBOA
ANFITEATRO III

OCTOBER 16TH, 17TH, AND 18TH

CENTER OF PHILOSOPHY OF SCIENCES OF THE UNIVERSITY OF LISBON
(CFCUL)

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(CFUL)

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Amaro Rica da Silva (Dep. Física – IST / CENTRA)
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Arthur Dony (Université de Liège)
Aurélien Dijan (University of Lille)
Carlos Lobo (Collège International de Philosophie / CFCUL)
Carlos Morujão (Portuguese Catholic University - Lisbon) / CEFi)
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Rui Moreira (Fac. Ciências ULisboa / CFCUL)
Thomas De Saegher (University of Western Ontario / The Rotman Institute of Philosophy)
Vasil Penchev (Bulgarian Academy of Sciences: Institute for the Study of Societies and Knowledge: Dept. of Logical Systems and Models)

# ADELINO CARDOSO

**CHAM – FCSH**
**NOVA – UAC**

## ABSTRACT

The scope of Physics constituted one of the strongest and of the most constant interests by Leibniz, who, according to his peculiar way of intellectual progression, successively reformulated the general framework of his Physics, enlarging and reorganising it. Such increase of Physics leads to the creation of a new scientific discipline – the Dynamics – and to a relevant contribution for the emergence of a specific science of life.

Indeed, Leibniz adhered to the Modern mechanism, but he acknowledged its insufficiency either at the philosophical and scientific level. For him, the mechanical view of the universe is valid as phenomenal explanation of motion, but it requires a deeper level, which handles the force as something intrinsic to the bodies themselves. However, the Dynamics reveals to be insufficient for elucidating the vital and immanent dimension of nature. Now, the originality of the leibnizianism lies in the combination of an organicist view, stressing the primacy of the natural function, with a mechanical way of efficiency within the living organisms.

# AMARO RICA DA SILVA

**DEP. FÍSICA - IST**
**CENTRA**

Graduate Degree (Licenciatura) in Physics in 1980 by the Faculdade Ciências Lisboa.

Teaching Assistant at the Physics Dept-IST in 1980.

Master Degree in Physics by the University of Rochester, US in 1985.

Doctoral Degree (PhD) in Mathematical Physics by the University of Florida in 1988.

Assistant Professor at the Physics Dept-IST in 1989.

Researcher at CENTRA-IST, collaborator in Center for Philosophy of Sciences University of Lisbon.

## ABSTRACT

Proper time. Clock hypothesis.

Natural clocks. Special relativity.

Clocks and Simultaneity. Methodologies for "synchronization" of distant clocks. The Lorentz Transformations. Ether and Relativity.

Mie Theory of fields in curved manifolds

# ANDREA MAZZOLA

**CFCUL**

mazzpazz@gmail.com

Since 2009 Andrea Mazzola has collaborated to the research project "What is a physical theory?" coordinated by Prof.. R. N. Moreira, and since 2011 to the project "The foundations of quantum mechanics" coordinated by Prof. J. R. Croca. Actually, is a PhD student at the CFCUL thanks to a FCT scholarship and member of the research group on "Philosophy of Quantum Physics: Nonlinearity and Eurhythmy" coordinated by Prof. J. R. Croca. His focus is on A. N. Whitehead's thought, with special attention to the historical epistemology of the wave-particle duality issues, and its links with the concepts of reality, potentiality, actuality, complexity and teleology.

## ABSTRACT

Whitehead explains the substantialist postulates (points, instants and particle) of the 17th scientific revolution as depending on the fact that at that epoch the only developed science was Euclidean geometry. Besides it, he ascribed to both the traditional idea of matter of classic atomism and the Aristotelian subject-predicate logic and substance-quality metaphysics the introduction into philosophy of a "theory of bifurcation of nature", following which the "entity has been separated from the factor which is the terminus for sense-awareness. It has become the substratum of the factor, and the factor has been degraded into an attribute of the entity". For Whitehead, this distinction is a valid "procedure of mind in the translation of sense-awareness into discursive knowledge", but not an adequate rendering of the ultimate metaphysical character of nature. This, according to him, manifests itself as an "ether of event" everlastingly "moving on"; as an extensive continuum medium quantized by multiple processes of realization which temporise and spatialise it. Trained in mathematical physics, Whitehead deems a "physical" entity as the mark, in the flux of events, of a pattern transmitted across time and space from one event to the other. The endurance typical of what is commonly regarded as a "physical entity" led him to assign to them the term of "society" in which the "genetic relation" supply the quasi-uniform identity to the system. Therefore, the identity of a physical entity is described as the reiteration of an internal regime of activity, as the becoming qua quantized duration required for the expression of the pattern (its local quasi-separable feature), on the one hand, and as functioning as a key for the propagation of its aspect to the events of other regions of the medium (its non-local feature), on the other.

Another aspect of the scientific revolution he stressed is that this was enabled by the "background of imaginative thought" afforded by the mathematical ideas of functionality and periodicity. This abstract ideas illustrated "the underlying analogy between sets of utterly diverse physical phenomena", and supplied the theoretical tools "by which any one such set could have his feature analysed and related to each other". Indeed, Whitehead attributes to mathematics a contribution to natural science that was

unnoticed by the majority of thinkers: to provide an exact theory of the rates of change. Forged by the 19th flowering of algebraic and geometric systems, on the one hand, and of electromagnetism, on the other, Whitehead aimed to melt his expertise in mathematical logic and in mathematical physics in order to get both an axiomatic and a cosmological frame different from the Newtonian. In both his earlier mathematical works and his successive philosophical ones his "constructive task" was "a protest against exempting any part of the universe from change". If according to him the basic notion of physics, like motion, velocity, acceleration, momentum and energy are meaningless at an instant of time devoid of duration, this has to be substituted by that of event. Besides, since the category of quality has to be substituted by that of relation, the basic character of the events is that any event "extend over" other events. The symbolic formalization carried on by Whitehead has as exemplifying counter-side the ontological notion of rhythm, one common to both micro- middle- and macro-scales. A quanta of energy, as well as a molecule of iron, a music note, a biological organism, an ocean tide, a planet and a star are periodical systems that need some "lapse of time" for functioning, for manifest themselves as entities and for express their individuality. Each of these systems have "to be conceived as modifications of conditions within space-time, extending throughout its whole range". Moreover, these periodically, rhythmically pulsing systems, these "states of agitation" are analyzable in a "focal region" and in an external, but not separated stream, since "for physics, the thing itself is what it does, and what it does is this divergent stream of influence".

Following Whitehead conceptualization the physical entity should be analytically conceived as the manifestation of: a) an internal regime of activity or, in other words, a modulated internal production of energy and forces - this activity "synthesises" the data from the past conveying their "real potentiality" towards the adjustment which bodes the maximum of intensity available for the situated actual entity; b) an objective patter, where the "pattern may be essentially one of aesthetic contrasts requiring a lapse of time for its unfolding. [...] Thus the endurance of the pattern now means the reiteration of its succession of contrasts. […] But when we translate this notion into the abstractions of physics, it at once becomes the technical notion of "vibration"; c) a field of external expression for the properties displayed by the specific mode in which the actual entity selectively receives, enjoys and transmits its environmental factors.

Summarizing, for Whitehead a "physical entity" is a partial and abstract characterization of a much more ontologically complex entity: the event as situation for the association of "actual occasion". Perhaps, the Eurhythmic Physics proposed by Lisbon scholars is making the incipient steps towards the return to a realistic interpretation of quantum issues, and from that towards a more comprehensive understanding. Perhaps, if in the future physics will reach a theoretic frame able to translate its quantitative notions and coefficients into qualitative, meaningful ones, i. e. if a semiotic physics will born, then other natural entities' proprieties will be accounted for by it. Indeed, it seems to me more realistic to credit that diverse sciences should ever collaborate to describe natural entities, so that no one single science could identify its "entities" as the ultimate concrete ontological ones. The "physical" functioning of an entity may be for example related with its other modes of functioning, namely the aesthetic, the semiotic, the biotic, the social-economic etc. Plausibly, a "physical entity" will never be a complete and exhaustive rendering for a natural entity in all its bewildering and indefinite variety of relationships.

# INDIVIDUALITY THROUGH RELATEDNESS: A LEIBNIZIAN FRAMEWORK FOR QUANTUM MECHANICS

**ARTHUR DONY**

**UNIVERSITÉ DE LIÈGE**

## ABSTRACT

The purpose of this paper is twofold. First, it aims at showing how Leibniz's ontology provides an understanding of Nature that crucially departs from the classical view of modern science, in which physical entities are defined by their separability and their intrinsic identity. Second, focusing on his metaphysics of relations, it aims at investigating the fruitfulness of Leibniz's ontology in approaching some core issues of Quantum Mechanics, especially those concerning holism and non-separability. In this context, a particular emphasis will be placed on the problem of the individuality and distinctness of physical entities within the interconnected Nature that both Leibniz and Quantum Mechanics portray.

In the first part, by way of introduction, I shall briefly outline the classical ontology underlying the Newtonian framework of modern science. Conceived on the model of particles, the basic entities constituting the world are, according to this picture, objects subsisting *per se* and existing apart from others: what is primarily real are indivisible, permanent and self-contained unities, upon which rests the reality of all compound things[1]. I refer to this view as the "atomistic" conception: regardless of the exact nature of the elements considered as fundamental (be they material points, or mathematical ones), these are conceived as being *discrete* entities possessing *intrinsic* qualities. Within this framework, the relations between physical entities are regarded as external to them, insofar as they are not essential to the related terms.

While Leibniz's ontology has often been associated with this classical view, by examining his theory of individual substances and his doctrine of universal connection, I shall argue in the second part of the paper that this is not the case. As a matter of fact, Leibniz explicitly rejects the idea of ontologically independent entities[2]. Crucially,

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[1] See I. Newton, *Opticks or a Treatise of the Reflections, Refractions, Inflections and Colours of Light*, I. B. Cohen (ed.), New York, Dover, 1952, Quest. 31, p. 400.

[2] "All substances are co-requisites for each other" (A VI, iv, p. 1800).

he conceives of beings as relational entities, their nature being fully determined by their relations to all other beings. According to the structure of the divine decrees whose primary object is the harmonic unity of Nature, every single thing that exists in the universe is essentially dependent upon and related to the whole complex and to each individual entity constituting it[3]. Moreover, Leibniz also rejects the idea of intrinsic natures. On his view, an individual entity is primarily defined by its "mirroring" nature[4]: all its properties originating from its relation to the extraneous multiplicity, like a glass bead reflecting and enfolding the surroundings in itself, it has therefore nothing but relational properties. Indeed, it is one of Leibniz's most enduring and far-reaching theses, that *any* change in a relation between several individual entities necessarily modifies the *internal* properties of *all* the related terms[5].

In light of this, the parallel with entanglement phenomena – arguably the most distinctive feature of Quantum Mechanics[6] – does present itself. As is known, entanglement phenomena can generally be described as phenomena where the states of distinct entities cannot be fully specified without reference to each other and to the whole complex in which they enter. In such cases, it is not possible to assign an absolute value to one parameter, independently of the assignation we make to another related one – hence their non-separability. Yet, as I will have shown, likewise it is precisely a key idea of Leibniz's ontology that "a single state of a substance can be exhaustively described only if one takes into account the whole substantial series and the whole world, according to a corresponding law"[7]. In the third and final part of the paper, I shall thus propose a reconsideration of the issues of holism and non-separability in Quantum Mechanics in the light of Leibniz's ontology. To this end, I will use two major strands of contemporary philosophical interpretations that have been developed in the context of Quantum Mechanics: the so-called "Ontic Structural Realism" (M. Esfeld[8]) and "Quantum Holism" (J. Ismael and J. Schaffer[9]). While their arguments differ in some important aspects, both theories hold that the relational structure of reality has to be seen as fundamental, and consequently reject the idea of individuals ontologically independent and that of intrinsic natures.

By confronting these recent philosophical developments with Leibniz's ontology, my intention is not only to offer a new perspective on the Leibnizian approach with reference to these ontologies of Quantum Mechanics, but also to point out how Leibniz's thought can, in turn, highlight the renewed understanding of Nature yielded by Quantum Physics. Within this context, a particular attention will be given to the following questions: What is it for two related physical entities to be distinct? How can we account for their diversity within a holistic framework? Or, to put it another way, how can we reconcile their individuality with their non-separability? As an attempt to answer these questions, I shall argue in favour of a conception of individuality defined in terms of relatedness: the individuating feature of a physical entity is to be found in (and only in) its relational properties.

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[3] "There is no term which is so absolute or so detached that it does not involve relations and is not such that a complete analysis of it would lead to other things and even to all other things" (A VI, vi, p. 228).

[4] See for instance A VI, iv, p. 1542.

[5] See for instance A VI, iv, p. 1746.

[6] Cf. E. Schrödinger, "Discussion of Probability Relations Between Separated Systems", *Proceedings of the Cambridge Philosophical Society*, vol. 31, 1935, p. 555.

[7] S. Di Bella, *The Science of the Individual: Leibniz's Ontology of Individual Substance*, Berlin, Springer, 2005, p. 340.

[8] M. Esfeld, "Quantum entanglement and a metaphysics of relations", *Studies in History and Philosophy of Modern Physics* 35B, 2004, pp. 601-617.

[9] J. Ismael, J. Schaffer, "Quantum Holism: Nonseparability as Common Ground", *Synthese*, forthcoming.

# AURÉLIEN DIJAN

**UNIVERSITY OF LILLE**

Since 2013, PhD student at the university of Lille-3, preparing a PhD on the history of the concept of horizon in contemporain phenomenology.

## ABSTRACT

My presentation is an attempt to shed light on the very particular link between the constitutive task of Husserl's phenomenology and the theme of the horizon, as it first emerges in the 1907 "Thing and Space" lessons. I will show that the thing must be considered, from a Husserlian perspective, as the unity of a multiplicity of perceptions synthesized through an horizon, and that the existence of nature is phenomenologically based on the motivational horizon of possible perceptions. Considering the bond between constitution and horizon within the local framework of the constitution of the thing, we will then be able to begin to address the general questions both of the nature of Husserl's phenomenology and of the function the often underrated concept of horizon fills in it.

# CARLOS LOBO

**COLLÈGE INTERNATIONAL DE PHILOSOPHIE**
**CFCUL**

Carlos Lobo, né en 1964 à Lisbonne, est directeur de programme au Collège International de Philosophie et membre du Centre de Philosophie des Sciences de l'Université de Lisbonne. Ses recherches relèvent d'une phénoménologique rigoureuse et ouverte. Elles se poursuivent dans un dialogue constant avec les figures de l'épistémologie, de la philosophie et des sciences contemporaines, sans occulter les champs classiques des questions relatives à l'affectivité, l'action ou l'esthétique. Il a récemment publié : « *Digging out the roots of affective fallacy* » (Eikasia, Septembre, 2016) ; « *Some reasons to repent the question of the foundation of probabilité theory following Gian-Carlo Rota's way* » dans *Philosophers and Mathematics* (Springer, 2017); « Le maniérisme épistémologique de Gilles Châtelet. Relativité et exploration de l'a priori esthétique chez Husserl selon Weyl et Châtelet »; *Revue de Synthèse*, 2017, N° 138; « Husserl's Reform of Logic. An Introduction », *New Yearbook of Phenomenology and Phenomenological Research*, NY, 2017; "Renforcement de l'évidence et modalisation de la croyance ou les stratégies de Fernando Gil", Fernando Gil (Eds. O. Capparos, E. Beauron), Garnier, 2017; Traducteur, il a édité *L'éthique et la théorie de la valeur*, de E. Husserl, PUF, Paris, 2009, ainsi qu'une édition critique de Hermann Weyl, *Philosophie des mathématiques et des sciences de la nature*, MétisPresses, Genève, 2017.

## ABSTRACT

Afin de cerner les limites et les points de contact entre le problème philosophique et le problème physique et mathématique de la *nature des entités physiques*, il n'est pas inutile de revenir sur un moment historiquement important qui reste, aujourd'hui encore, porteur de prolongements et de retournements dont nous n'avons peut-être pas encore pris toute la mesure. Il s'agit de l'interprétation que Weyl et de Broglie respectivement proposent du principe d'exclusion Pauli, au tournant des années 1950. L'un et l'autre y voit un approfondissement et une complexification du principe d'individuation prévalant jusqu'alors dans la physique classique. Ces interprétations qui ne sont pas nécessairement divergentes s'inscrivent dans un horizon critique plus vaste qui touchent aux sources mêmes d'une approche idéaliste, et plus largement aux modalités de prise en charge des questions philosophiques par la science ou de l'implication du philosophique dans la science. Chez l'un et l'autre, cette interprétation est indissociable d'un nouveau partage du subjectif et de l'objectif et d'une critique des usages naïfs de la forme de l'espace dans la constitution de l'objectivité physique, nécessaire pour échapper aux interprétations naïves des probabilités et de leurs espaces associés.

L'un de ces moments est représenté par de Broglie et correspond à la célèbre rétractation sur sa propre rétractation après le congrès de Solvay de 1927. Son ouvrage de 1959 (*Tentative d'interprétation causale et non linéaire de la mécanique ondulatoire (La théorie de la double solution)*, Gauthier-Villars, Paris, 1959) permet de comprendre le sens et les raisons de ces revirements. La trajectoire intellectuelle de De Broglie, partant de la théorie audacieuse, mais, équivoque, de « l'onde-pilote », jusqu'à celle dite de la « double solution », en passant par la période de rétractation consécutive au congrès de Solvay de 1927 semble avoir pour point de fuite une interprétation idéaliste, encore à construire, de ce même principe (*op. cit.* p. 88 sq.). D'un point de vue épistémologique, il permet de suivre le partage fin entre construction mathématique et position de réalité physique, résumé sous le titre de « double solution ». Cette théorie conduit de Broglie à compléter la dualité

onde-corpuscule par un dualisme des ondes (double solution) : l'une purement *subjective et probabiliste* représentée par la fonction *psi* de Schrödinger ; l'autre objective *et* physique correspondant à ce qu'il nomme l'onde u (« L'interprétation de la mécanique ondulatoire », *Le Journal de Physique et le radium*, Tome 20 Décembre 1959, pages 963-979).

La théorie de l'onde-pilote présentée en 1927, abandonnée après critiquée par Pauli, ne représente qu'une forme équivoque et dégénérée de la théorie de la double solution (ci-après TDS) (op. cit. p. 93) qui est résumée (op. cit. pp. 85 à 93) ainsi que dans un article contemporain (« L'interprétation de la mécanique ondulatoire », Le *Journal de Physique et le radium*, Tome 20 Décembre 1959, pages 963-979). La question de la théorie physique unitaire (relativité et mécanique quantique) reste cependant à l'arrièreplan. Ce qui intervient en force, c'est un partage du subjectif/objectif au sein de la construction théorique (*op. cit,* pp 87-88). Contre l'interprétation probabiliste (« orthodoxe »), la TDS repose sur une généralisation de la dualité onde-corpuscule et le coupable de l'onde *psi* et d'une onde *u*. L'interprétation « orthodoxe » qui tend à transformer en réalité physique une pure entité « formelle » (fictive et abstraite), est rejetée car les coordonnées n'ont pas de signification pour la fonction *psi*. C'est donc succomber à une étrange illusion de de doter la fonction *psi* (et l'onde qu'elle représente) une signification objective physique. Cette critique se comprend, si l'on retrace la genèse mathématique de cette fonction (Lagrange, Jacobi, Hamilton) qui est indissociable de la construction de cet espace abstrait qu'on nomme « espace de configuration ». Il comporte autant de dimension que le système physique envisagé comporte de « corpuscules » (libres), doté chacun de coordonnées égales à toutes les coordonnées des corpuscules du système. Une trajectoire du point représentatif correspond dans ce cadre à un état du système. L'interprétation de cette fonction comme figuration symbolique d'un processus dans l'espace à trois (ou quatre) dimensions est surprenante et absurde. Il n'est certes pas *a priori* exclu que les deux puisse coïncider, comme c'est le cas en physique classique. Mais ils ne le peuvent en mécanique quantique, du moins dans son état actuel, où le recours à l'espace de configuration est une nécessité. De Broglie n'en indique pas moins un horizon : la nécessité de dépasser nos concepts usuels de l'espace physique, celle de corpuscule, et par suite celle d'entité individuelle au profit de conception plus adéquates.

Abordant l'interprétation du principe de Pauli, De Broglie est conduit à distinguer entre deux niveaux d'individuation : l'un au sein de l'espace abstrait (espace de configuration) où l'état d'un système est représenté par un « point dont les coordonnées sont respectivement égales à toutes les coordonnées des corpuscules du système », et l'évolution du système « par le déplacement de ce point représentatif dans l'espace de configuration ». Dans ce contexte, la fonction *psi* revêt une signification purement *symbolique et subjective*. C'est dans le passage de cette identification abstraite à la localisation de l'entité physique qu'intervient le principe de Pauli. Ce dernier est indissociable de l'introduction du quantum d'action, et de l'ensemble des autres ingrédients du formalisme quantique (relations d'incertitudes de Heisenberg, fonction d'onde, etc.)

La genèse comme les applications du *principe de Pauli* signalent une modification profonde du principe d'individuation prévalant jusqu'alors en physique (y compris dans le cadre de la physique relativiste). L'individuation du corps par un espace - ou un espacetemps – s'estompe au profit d'une individuation du système. Individualité et système sont deux idéalisations complémentaires (*La physique nouvelle et les quanta*, 1937, p. 274). En mécanique classique deux corpuscules de même nature sont individués par l'espace ou par leur localisation dans l'espace de permutation. Des différences de localisation des corpuscules individuels font des systèmes différents. En mécanique quantique, les corpuscules perdent cette individualité au profit d'une caractérisation globale des systèmes et de la fonction psi qui leur est associée. Pour tout système comportant des couples de corpuscules identiques, il existe toujours une fonction *psi* symétrique ou antisymétrique par rapport à tous les couples de corpuscules. Le système sera symétrique ou antisymétrique selon que la fonction psi est l'un ou l'autre. Il est impossible qu'il en aille autrement. Si le principe d'exclusion de Pauli est en parfaite cohérence avec les autres ingrédients du formalisme quantique, et qu'il a reçu nombre de confirmations empiriques, son « origine physique » reste mystérieuse selon de Broglie.

C'est dans le contexte d'une tension entre métaphysique et physique mathématique, qu'il convient de situer l'interprétation weylienne du principe d'exclusion de Pauli et de la mécanique quantique. Profondément marqué par une tradition philosophique idéaliste (Leibniz, Kant, Fichte et Husserl) Weyl associe explicitement le *principe de Pauli* au principe leibnizien des indiscernables. La physique mathématique classique a fait de l'espace euclidien le principe d'individuation physico-mathématique par excellence de corps physiques élémentaires (des atomes) par ailleurs indiscernables. On estime que deux atomes sont suffisamment individués s'il est possible de leur assigner une place spatio-temporelle unique (*Philosophy of mathematics and natural science*, Princeton U. Press, 1959 p. 167). Par contrecoup, il était inévitable que Leibniz ait été conduit à ne voir dans les atomes interchangeables et dans l'espace-temps de la physique classique *deux idéalisations complémentaires* [sic] (*PMNS*, p. 97 et p. 131), qui sous-tendent le déterminisme et l'exactitude postulés par la théorie de la mesure classique. La mesure au sens mathématique est une application du principe (transcendantal) de « déterminabilité complète », lequel pose que tout être réel (possible) est intrinsèquement individué par une série de déterminations (de prédicats). Par suite l'interprétation « classique » et « déterministe » des probabilités (mécanique de Laplace ou thermodynamique de Boltzmann-Gibbs) suppose l'indépendance des états possibles d'un système ou des éléments d'un système. Cette violation du principe des indiscernables n'est pas moindre dans le cadre de la physique relativiste, en dépit d'un assouplissement certain, quant aux conditions d'automorphisme permettant le transport d'un point en un autre, d'une variété riemanienne (*PMNS*, p. 97). C'est ainsi que se trouve maintenue l'indiscernabilité des agrégats pour autant qu'ils soient de même constitution (*PMNS*, p. 244) ou de deux individus dans le même « état » (*PMNS*, p. 245). Alors qu'en « mécanique classique », le principe de détermination complète postule l'existence d'un « état d'une masse (ou d'une charge) ponctuelle(s) » complètement descriptible « par sa position et sa vitesse » et s'articule intimement au principe causal de détermination de tous les états successifs à partir d'un état donné, la mécanique quantique voit dans un état, « une superposition » d'états possibles, le seul état physiquement déterminable et mesurable.

Les états complets d'un individu (électron) forment une variété discrète dont la statistique (de Fermi-Dirac) propose simplement le dénombrement. Cet arrière-plan d'états possibles superposés marque une extension, en physique, du principe des indiscernables, que Weyl nomme pour cette raison même « principe de Pauli-Leibniz ». Encore convient-il de souligner deux limites importantes par rapport à son pendant métaphysique. (1) Ce principe ne s'applique qu'aux électrons supposés par ailleurs interchangeables – « égaux», mais pas « identiques », c'est-à-dire identiques spécifiquement, mais non individuellement (*PMNS* , p. 238) et non aux photons (qui n'ont pas d'individualité ou d'identité, au sens mentionné) ; le principe de Pauli (ou plutôt, la règle de construction devenue principe, une fois compris ce qui la fonde) interdit que deux électrons (ou plus généralement fermions ») soient dans un même état individuel. (2) Il se borne à caractériser les états ondulatoires superposés dans le cadre d'une théorie probabiliste où le principe d'indépendance des états possibles est nié (*PMNS*, p. 262 et p. 283). La « réduction », au cours de la mesure, projette n'importe quel objet (ou système) quantique (fermion ou boson), sur un des états dont est composé, l'état dans lequel il se trouve avant la mesure (superposition d'états correspondant aux diverses valeurs propres de la grandeur que l'on mesure).

Dans le premier cas, contrairement à ce qui se passe dans le second, il n'y a pas d'action exercée sur l'objet (ou le système).

Il est la « nature » de l'électron (la valeur demi-entière de son spin) d'obéir au principe de Pauli. Cela résulte d'un théorème (« connection spin-statistique »), qui associe un type de statistique (de Fermi-Dirac pour les fermions, de Bose-Einstein pour les bosons) à la quantification du spin (par valeurs entières, pour les bosons, ou demientières, pour les fermions). Mathématiquement, cette négation s'exprime par des tenseurs antisymétriques (*PMNS*, p. 262) : « Le principe d'exclusion de Leibniz-Pauli, d'après lequel il n'y a pas deux électrons qui puissent être dans le même état quantique, devient compréhensible en physique quantique, et c'est une conséquence de la loi d'antisymétrie » (*PMNS*, p. 263). C'est pourquoi la « probabilité primaire » (*primary probability*), (*PMNS*, p. 198 et p. 263) exprime « certaines quantités physiques de base et ne peut en général être déterminée que sur le fondement de lois empiriques régissant ces quantités » (*PMNS*, p. 263).

Au lieu que la probabilité se détermine sur la base d'un quadrillage préalable d'un espace ou d'une répartition préalable d'entités « rigides » placées dans un espace homogène ou inhomogène, isotope ou non, se profile, sous le titre d'« espace de jeu », un tout autre « espace », dont l'essence mathématique demande encore à être saisie. Dans son approche moderne (ensembliste), l'axiomatisation des probabilités fournit un cadre admirable pour la construction d'un « espace de probabilité ». En consonance avec Husserl qui, pour prévenir les interprétations les plus répandues, avertit que la « probabilité comme la certitude sont des expressions subjectives », Weyl rappelle que la détermination du type d'entité, sa « typification » pour ainsi dire, procède d'une décision *subjective arbitraire*. Or, le « choix » du niveau de découpage ontologique conditionne (de manière non causale) la délimitation et définition de **l'espace de jeu** dans lequel on effectue le dénombrement des possibilités, l'établissement de leurs dépendances ou indépendances mutuelles et la mesure de la probabilité. La détermination de ce qu'est l'élémentaire ne peut faire l'économie de ce résidu de subjectivité que sont le choix et la décision : c'est « notre décision de considérer telles ou telles choses égales ou différentes [qui] influence le compte des cas "différents" sur lequel est fondée la détermination des probabilités » et qui détermine la nature de ce qu'on appelle, élément, événement, et par suite le sens physique de ce qu'on désigne comme fonction de probabilité. Dans le cadre de l'a priori corrélationnel, cela exclut tout autant les **interprétations subjectivistes des probabilités** – dont le corollaire physique est la thèse des variables cachées, et le présupposé épistémologique, un objectivisme déterministe –, que les **interprétations naïvement indéterministes**.

# CARLOS MORUJÃO

**PORTUGUESE CATHOLIC UNIVERSITY / LISBON**
**CENTER FOR PHILOSOPHICAL STUDIES (CEFI)**

cmorujao@fch.lisboa.ucp.pt

Carlos Aurélio Ventura Morujão is Full Professor at the Portuguese Catholic University and, since 2013, Director of the Center for Philosophical Studies (CEFi). He has published extensively, in Portugal, Spain, France, Germany, Brazil and the USA, about Phenomenology and Classical German Philosophy (especially Kant and Fichte). His last book is entitled Caminhos da Fenomenologia, Lisboa, Universidade Católica Editora. 2015.

## ABSTRACT

The paper addresses the Kantian notions of impenetrability and divisibility of matter, focusing on the *Critique of Pure Reason* (1781) and the *Metaphysical Foundations of Natural Science* (1786). The paper aims to show the transcendental framework Kant built in his critical period to study natural phenomena and analyzes the a priori validity of the above-mentioned notions and their relation to physical experience. Finally, the paper addresses the problematic relations between impenetrability and divisibility, on the one hand, and the two fundamental natural forces – attraction and repulsion –, on the other, that, following Newton's mechanics, Kant puts at the origin of every natural, celestial or earthly, phenomena.

# CHRIS DEWDNEY

**UNIVERSITY OF PORTSMOUTH**

## ABSTRACT

The question of the nature of things has a history as long as that of people. One has Platonic Ideas and Forms, the noumena as distinct from the phenomena as things displaying themselves to the senses and Kant's unknowable "Ding an Sich" (thing-in-itself) (1). The "natural attitude" assumes there are things in nature that we can come to know through experiment and observation, whereas naturalistic phenomenology emphasizes that it is consciousness that constitutes things in the world of nature (2). The history of ideas concerning the relationship between our knowledge and some supposed independent external world is vexed and many doubt the usefulness of such a simplistic distinction. I do not want to enter at this level debate here, instead I wish to focus on how quantum theory has impacted upon the debate and contrast the idea of the quantum object with that familiar from classical physics. The Bohr – Einstein debate of the 1920's (3) can be seen as a clash of philosophical traditions. Einstein believed that physics is about a well-defined reality; things have properties that are independent of measurement, whereas Bohr believed that "there is no quantum world, there is only a quantum physical description". For Bohr physics does not reveal nature it is only concerned with what we can say about nature.

In this contribution I will examine the contrast between the classical, well-defined, observation-independent world of objects envisaged in Newtonian physics and that of quantum theory. However, the contrast is not straight forward as the nature of things in quantum theory has been a matter of great controversy from the very beginning. Quantum theory is seen by many as the fundamental theory from which the classical world must emerge (itself a non trivial problem), but Bohr's approach was founded on the independent and necessary existence of the classical world (itself responsible for the definite individual results of measurement). Many authors have used the quantum formalism and its predictions as variously demonstrating that "reality does not exist", "human consciousness brings about the definite world", "the world is not individual but multiple in its existence" and so on. Each approach tries to show how quantum theory changes understanding of the nature of things that exists in classical physics. The fact that there are many different interpretations of quantum theory indicates that quantum

theory alone proves none of them. The interpretation of the formalism is underdetermined by the evidence. Even the approach that may be seen as the minimal approach, that which argues that quantum theory is simply a predictive schema - a way of calculating the statistics of measurement results (shut up and calculate!) - makes strong (albeit tacit) philosophical assumptions.

If one wishes to contrast quantum theory with classical theory, in order to find out what is new in quantum theory, then it seems obvious that an approach that casts the formalism of quantum theory in a form as close as possible to that of classical theory would best reveal the similarities and differences. This is what was done by Louis de Broglie (4) in proposing the wave-nature of matter (in 1927) and, later, David Bohm (in 1952) (5). In the de Broglie-Bohm theory a well-defined quantum world emerges that, in contrast with orthodox approaches, has no special role for human observers. However, the nature of the quantum world revealed in de Broglie-Bohm theory has distinctly non-classical features. The quantum mechanical wave function, and its role in determining the behavior of quantum systems, is at the heart of the novelty. This new kind of field is defined on configuration space rather than physical space and although quantum “entities” – point-like particles and extended fields – exist, just as in classical physics, their behavior is governed by the evolution of the wave function. The configuration-space wave function gives rise to what Bohr referred to as the “unanalyzable and indivisible nature of quantum phenomena”. In de Broglie-Bohm theory, quantum phenomena are analyzable in terms of constituent parts, but quantum phenomena nonetheless reveal a “wholeness” expressed through “contextuality” and consequently nonlocality.

In this contribution I will discuss some key quantum phenomena describing the behavior of fields and particles in de Broglie-Bohm theory in order to bring out the novel “nature of entities” in this approach to quantum theory. I shall review the wave-particle duality in interference (6), the quantum measurement process (7), the Einstein-Podolsky-Rosen experiment (8) and the exchange of energy between a quantum field and matter (9).

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(3) Bohr N. (1949). From Albert Einstein: Philosopher-Scientist. Cambridge University Press.

(4) de Broglie, L. (1927) *La structure atomique de la matière ed du rayonnement et la mécanique ondulatoire.* Comptes Rendus Hebdomadaires des Séances de l’Académie des Sciences (Paris), 184, 273-4 AND *Le mécanique ondulatoire et la structure atomique de la matière et du rayonnement.* Le Journal de Physique et le Radium (6), 8, 225-41.

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# CLAUDE VISHNU SPAAK

**UNIVERSITY OF LISBON (FCT)**

Claude Vishnu SPAAK has a phd from the University of Paris-Sorbonne (2014), where he completed his thesis. He holds the French "agrégation de philosophie" (2007). His current research as a FCT postdoctoral researcher at the University of Lisbon focuses on the phenomenological the problem of matter. He has just published a book, Matière et mouvement, Paris, Hermann (Le Bel Aujourd'hui), 2017. His doctoral dissertation is about to be published in 2017 at Springer, in the collection Phaenomenologica, under the title *Interprétations phénoménologiques de la Physique d'Aristote chez Heidegger et Patočka*.

## ABSTRACT

After a brief description of Heisenberg's conception of Quantum Mechanics and the way it disrupts the fundamental presuppositions of modern physics, even putting contemporary physics into a new paradigmatic epistemological framework, this presentation goes on to show why, according to Heidegger, not only does Heisenberg's account in fact remain within the framework of modernity, but what is more it misses out the paradigmatic shift of contemporary science where it really stands: the annihilation not only of an ontology of nature, but of human openness to the world under the pressure of technology which disposes of all entities in the infinite process of production and exploitation. Heisenberg, on the contrary, in his anthropological relativization of natural phenomena to the way they are accessed through the measuring experiments set to observe them and, through these technological devices, to the cognitive powers of human scientific reason, remains in a Kantian, or crypto-Kantian model which is in line with the tenets of modernity, or at least late modernity as it is structured by the Kantian Copernican revolution of critical philosophy. In the unfolding of this confrontation between Heidegger and Heisenberg on the status of contemporary physics, we wish to address a few questions : 1) can the current practice and theoretical assumptions of today's science, which largely endorses a naturalist reductionist approach, remain satisfied with the relativistic depiction of Heisenberg (and more generally of the Copenhagen School), where the very possibility of an ontology of nature seems to be ruled out in principle in light of the epistemological, methodological and technical constraints of Quantum Mechanics ? 2) Can the Heideggerian appeal to the Greek understanding of nature (*Phusis*), in order to regain access to the things themselves (*phusei onta*), be of any help to solve the greatest problem of naturalistic science, i.e. how to allow for a strong (ontological) sense of emergence of individual beings (or natural entities), understood as complex holistic structures with a temporal endurance, without flushing out this possibility in a reductionnist approach that dissolves all individualities in the physico-quantic continuum ?

# EDOUARD MEHL

**UNIVERSITY OF LILLE**

After a PhD (on Descartes, method and science) under the supervision of Jean-Luc Marion (Paris-Sorbonne, 1999), Edouard Mehl has been associate professor in the University of Strasbourg (France). He is now working as a full-Professor in the University of Lille, teaching modern philosophy and history of science. He is currently achieving a book on the birth of modern cosmology, from Copernicus to Descartes (to be published in Presses Universitaires de France, 2019).

## ABSTRACT

If we ask what is a physical entity, it means, at least, that we are not really sure to know the answer : we are not even sure that a correct answer is possible, or we can doubt that what we know as such… is truly such as we know. It means that maybe the way these so-called "physical entities" are known is not the way they are. Therefore it must be established that "les figures et les mouvements… sont bien les vrais principes" (Descartes). As we will see, this demonstration relies on the fundamental statement that "l'étendue est l'essence du corps" (quantitative dimension of something is not an accident but the very essence of the *res corporea*). The aim of this talk is to show that Descartes' does not only (in fact : not at all) amend the Aristotelian concept of "ousia physike », but, rather, substitutes the traditional concept of substance with the res extensa, whose concept is pure and primitive, and has its origin in the «stereoma» of the Book Genesis (Gn 1, 4).

# CAN THE FLAT PHYSICALIST TELL US WHAT IS A PHYSICAL ENTITY?

**EREZ FIRT**

**TEL AVIV UNIVERSITY**

## ABSTRACT (VIDEO CONFERENCE)

In this paper, I would like to suggest that physicalist versions which resort to the physical sciences to tell us what is the ‘physical’ might have difficulties overcoming a set of problems, brought into the center of attention due to the rise of the physics of the micro world. I demonstrate these difficulties and problems by introducing a physicalist approach and exposing its weaknesses.

Physicalism is the thesis that everything is physical, or that everything supervenes on the physical. As much as this is a metaphysical doctrine, Physicalism is unique in that it is closely related to the physical sciences . This close relation is often expressed by the claim that what there is in the world, i.e. the physical , is what physics says there is. Alas, since the Quantum revolution, physics has no exact way of describing the most fundamental physical entities. This is not shocking news to physicists, as they are obviously aware of the interpretational problems of quantum mechanics, of which the most notable is the measurement problem. I believe that most of them overlook, or are agnostic about, these issues and accept the "benefits" of computational precision (as expressed in David Mermin's words: "shut up and calculate"). These issues are nothing new to philosophers as well. Physicalism is facing multiple philosophical problems, from which I focus on the following :

> There is no clear-cut criterion for 'physical', i.e. we cannot provide a clear account of the border between the physical and the non-physical.
>
> There is much vagueness revolving the question of the correct version of physics that one should employ in order to describe the most fundamental physical entities. This is sometimes known as *Hempel's dilemma* : are our physical principles based on current physics, in which case, as history teaches us, they are almost surely (at least partially) false; or are they based on some future version of physics, in which case they are vague, since this version does not yet exist , or on the final complete (future) version of physics, in which case we risk the trivialization of Physicalism.

We do know that our vague concept of a physical entity is due to our current quantum understanding of the micro world. We also know that many physicists believe that quantum mechanics is incomplete , and so it appears that this specific problem is closely related to our subject matter.

From the problems stated above it seems that we cannot hold a physicalist stance without addressing some of the issues mentioned. One of the options to face Hempel's dilemma is dubbed 'Flat Physicalism'[1]: this view refers to Physicalism as a scientific hypothesis rather than a metaphysical stance. Proponents of this view take the case of Statistical Mechanics and Thermodynamics as a paradigm for the wa y fundamental physical theories will account for all higher order theories, in physics and in the special sciences. Our flat physicalist is a physicist whose project is to address and explain the problems of current physics (e.g. the measurement problem, the ontological status of the wave function, dark matter and energy, quantum gravity etc.). Once the physicalist formulates a version of physics which addresses all open issues, her work is done. At this point, according to Hemmo and Shenker, her physicalist project can either succeed or fail. In case of success , her version of physics is supposed to explain everything, i.e. the low-level fundamental physical theories will provide explanation s to all high-level theories of the special sciences. However, in case of fail ure, our flat physicalist will need supplementary non-physical theories to explain parts of reality tha t elude her version of physics, which she will then bind to her physical theories through an identity relation . Under this description there seems to be no problem of a future complete physics that includes the mental , thus making the proposition 'the mental is the physical' analytic. This future version of physics is a scientific theory that can be falsified and refuted.

However, Hemmo and Shenker do leave some issues unattended: By not postulating a final complete version of physics, they manage to avoid the problems of trivialization and the question of whether there will ever be a final, complete physical theory. However, in case her scientific project fails , the flat physicalist will have a set of non -physical theories which she cannot account for using her best fundamental physical theories. She will then have to rely on nothing else but her belief in the explanatory powers of future physics. This may feel a bit like scientism, since our flat physicalist strongly believes that her future physical theories will have a special privileged status, such that they will no doubt be able to explain the ontological claims of non - physical theories. So, in case the flat physicalist project fails, the physicalist has two options: She can declare Flat Physicalism false, or hope for (in a rather dogmatic inclination ) a better future physics. But even in case her project succeeds, i.e. future physics does explain everything, our present flat physicalist is in a rather peculiar position: She actually believes that by solving the problems of current physics, we shall ac hieve the physicalist goals, e.g. to explain the mind physically. Alas, there is nothing that indicates that formulating a robust theory of quantum gravity for example has anything to do with the mind.

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[1] See Hemmo, M. and Shenker, O. Under Review. "Flat Physicalism". *Philosophy of Science.*

**FERNANDO BELO**

**CFUL**

## ABSTRACT

# UNE QUESTION D'INSPIRATION PRIGOGINIENNE : QU'EST-CE QUE L'ÉNERGIE, LA FORCE ATTRACTIVE ET L'ENTROPIE ?

> "dans la physique actuelle,
> nous ne savons pas ce que c'est l'énergie"
> (Feynman)

> "qu'est-ce que la gravité? [...]
> quel est le mécanisme intrinsèque qui l'origine?
> [...] Newton n'en a pas élaboré d'hypothèse
> personne après lui n'a proposé aucun mécanisme"
> (Feynman)

Pré-scriptum : l'auteur de ce texte travaille en philosophie depuis environ 60 ans, mais sa première formation a été en ingénieur civil, à l'I. S. T. de Lisbonne (1956).

## 1.

Une question que l'on peut poser à la science qui s'en occupe, la Physique, c'est celle de savoir *qu'est-ce que l'énergie* ?; on sait qu'elle se conserve dans l'univers et se dégrade, selon les deux principes de la Thermodynamique, mais aussi qu'elle est susceptible de constituer des stabilités instables (Prigogine), secret entropique de l'évolution des vivants et de l'histoire des humains[1]. Dans un texte cité au §2, le physicien Nobel réputé Richard Feynman disait que "dans la physique actuelle, nous ne savons pas ce que c'est l'énergie" (p. 95). Il faudra donc questionner la Physique et

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[1] La phénoménologie scientifique supposée ici (blogue *philoavecsciences*) considère quatre grandes scènes historiques : celle de la gravitation (cosmos), de l'alimentation (vie), de l'habitation (sociétés humaines) et de l'inscription (savoir défini occidental), leurs éléments étant caractérisés respectivement par le noyau atomique, l'ADN, les unités sociales disciplinant la sexualité et l'alphabet avec définitio. Le virage phénoménologique par rapport à la philosophie européenne a été le fait de Husserl, Heidegger et Derrida, la différence (phénoménologique, ontologique et avec *a)* placée *avant* la substance. On dira plus loin comment c'est Galilée et Newton qui ont débuté cette déconstruction.

la Chimie avec des yeux instruits par Prigogine, allant au-delà de son propos qui a manqué d'une philosophie adéquate. Toutefois interrogeons d'abord le mot lui-même que le physicien anglais Thomas Young est allé chercher en 1807 au vocabulaire philosophique d'Aristote pour remplacer les "forces vives" des physiciens classiques. La pair *dynamis / energeia* répond dans sa *Physique* à deux situations du mouvement, de l'altération d'un vivant, animal ou humain : *dunamis*, celle qui précède le mouvement mais correspond à ce qu'il en a déjà la capacité, la 'puissance' (traduction habituelle) ou possibilité, 'il peut' (verbe *dunamai*, pouvoir) changer, ayant y compris la force de ce changement (d'où la 'dynamique' newtonienne en tant que théorie des forces) ; *en-ergeia*, la situation qui correspond à 'l'acte' (traduction habituelle) de ce mouvement effectué, (-*ergon*) travail sur soi (*en-*) ; puisque mouvement est dit *kinêsis*, d'où 'cinétique', on comprend que les physiciens soient allés chercher cette paire aristotélicienne pour dire les énergies potentielle / cinétique. Il y a toutefois une différence entre les deux physiques, car chez Aristote il s'agit de la substance (*ousia*) elle-même qui se meut, s'altère, tandis que dans notre physique il s'agit de la différence mesurée, relative à l'énergie, entre deux positions de graves, par exemple dans le champ de la gravitation : dans un barrage, la différence entre le niveau de l'eau du réservoir et la position plus baisse de la turbine, c'est l'énergie potentielle, tandis que l'énergie cinétique est celle du mouvement de l'eau tombant effectivement du premier niveau vers le second.

### La labeur dans la connaissance scientifique

**2.**

On pourrait penser que, antérieure à la vie, la matière dont s'occupent Physique et Chimie, la matière 'vraiment substantielle', connaît une stabilité authentique sans des oscillations instables. C'est d'ailleurs ce que Prigogine semble avoir pensé lui-même quand il parle de "la stabilité des atomes de notre univers tiède", comme s'il postulait qu'ils étaient inaccessibles à la 'production d'entropie' qu'il avait découvert dans la chimie du métabolisme cellulaire (et lui a valu le Nobel de Chimie en 1977) et cherchait par la suite dans des turbillons et d'autres phénomènes plus ou moins marginaux, tout en disant parfois que sa nouvelle conception était destinée à l'ensemble de la Physique. Pour venir à la question, on peut avoir recours au fameux texte *Leçons sur la Physique* du Nobel Richard Feynman[2], dont la pédagogie a tellement innové que l'on pourra peut-être le lire dans sa logique de 1961-62, sans tenir compte des découvertes postérieures, croyant que les 'fondements' de la Physique dont il s'occupe n'auront pas changé ni qu'il y eût des textes de divulgation si clairs.

**3.**

Pour adapter la perspective entropique de Prigogine au-delà du métabolisme celulair, à la Biologie animale et aux sciences relatives aux humains, il a fallu dénoncer *le préjugé aristotélicien substantialiste dans les paradigmes de ces sciences* : 'corps propre' dans les Biologies au lieu *d'être au monde*, 'population d'individus' dans la constitution des sociétés au lieu des paradigmes de leurs usages dans les unités sociales. La question dès lors est celle de savoir si l'on peut, et comment, 'dé-substantialiser' les atomes et les molécules qui constituent les graves et les astres. En lisant le texte de Feynman, ceci impliquera *privilégier le motif du champ de forces attractives sur les corps ou les atomes qui y sont assujettis*. Il s'agit d'un motif paradoxal en Physique, puisque, si l'on prend l'exemple du système solair et de ses planètes, ce sont les astres qui s'attirent réciproquement, le soleil au foyer principal, *le champ n'étant 'rien' de substantiel*, que le jeu entre elles de ces forces d'attraction, tout en étant ce jeu qui soutient le système dans sa stabilité, reconnue depuis les anciens Égyptiens et Chaldéens. Ce paradoxe ne permet pas de décider entre les astres et le champ, puisque celui-ci n'existe pas sans eux, mais c'est ce qui décide le préjugé substantialiste que les empiristes ont hérité d'Aristote à leur insu, en allant au champ 'après' les astres, à partir de leurs substances et masses. Pour poursuivre, il nous faudra poser une question épistémologique préalable : pourquoi le laboratoire est indispensable à la Physique ?

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[2] Que je citerai d'après l'édition portugaise.

**4.**

Ce que cherche le laboratoire, *c'est l'alliance entre savoir et technique*, entre définition et labeur, il cherche à éprouver les définitions et arguments philosophiques hérités des Grecs et des Médiévaux[3]. Ce qu'il fait est 1) *enlever* un phénomène donné de sa scène de circulation *aléatoire*, 2) lui déterminant (délimitant, définissant) le mouvement en *des conditions de détermination* par des techniques de mesures appropriées, 3) à cette connaissance acquise devant se suivre un mouvement de *restitution théorique* du phénomène connu à la scène d'où il a été enlevé, puisque c'est la 'réalité' extra-laboratoriale que, par des étapes laboratoriales, la théorie cherche à connaître. De même qu'en géométrie et en astronomie, les chiffres mathématiques, entre équations et mesures, rendent possible une exactitude plus grande que celle des définitions en langues structuralement polysémiques (ce que la mathématique n'est pas) : cette exactitude – dans des marges d'erreur, elles se répètent telles quelles dans les autres laboratoires – correspond à une *stabilité* que les philosophies n'ont jamais réussi ni d'ailleurs les théories scientifiques elles-mêmes qui interprètent les résultats des expérimentations laboratoriales. C'est que celles-ci ont un point faible, elles sont fragmentaires (comme tout problème d'algèbre classique, chacun avec son équation), elles ne rendent possible de connaître avec exactitude laboratoriale à chaque fois qu'un aspect déterminé du mouvement d'un phénomène ; c'est à la théorie, héritière de la philosophie, que revient l'unification de la connaissance, toujours approchée, *instable* donc, puisque un 'phénomènes entier' ne peut venir au laboratoire et reste indéterminé dans sa scène aléatoire[4]. Exemple fameux : Newton a découvert les équations de la force de gravité sans imaginer celle-ci, ce que l'on ne sait pas encore selon Feynman, ni l'énergie ni le pourquoi de l'inertie.

**5.**

Une question décisive du laboratoire peut être illustrée à partir de la fameuse expérience de Galilée démontrant le mouvement uniformément accéléré avec une petite balle roulant par la rainure d'un plan incliné. N'ayant pas encore des horloges capables de mesurer ces temps, Galilée utilisa un sceau d'eau qui s'écoule pendant le temps de la chute et qu'il mesure ensuite, "les différences et proportions entre les poids donnant les différences et proportions entre les temps"[5]. Mesurer le temps en grammes d'eau ou en secondes, c'est pareil, *le physicien ne sait expérimentalement que des différences, pas des 'substances'* ; sur le temps, il définit et argumente, en faisant de la théorie, c'est-à-dire, de la philosophie ; il faudra dire le même de l'espace, de la masse, de la force, de l'énergie, de l'intensité de l'électricité, comme atteste la conventionnalité (arbitraire) des 'conventions' qui définissent les unités des diverses 'dimensions' (ce mot souligne qu'en physique on ne travaille que sur des mesures). Les théories évoluent historiquement, tandis que les expérimentations, hors de la précision des techniques de mensuration, continuent valables : par exemple, si la physique de Newton a été réélaborée par Einstein pour des phénomènes à vitesse proche de celle de la lumière, elle continue valable scientifiquement face aux vitesses de la majeur des phénomènes d'ingénierie courante sur terre. Or, avec les techniques de mensuration, c'est la technique qui est entrée dans le noyau des sciences physiques et (bio)chimiques, c'est pourquoi elles aient comme effet des inventions techniques les plus diverses, témoignant ainsi de la *stabilité* de ces sciences, tandis que les scientifiques discutent de leurs théories, témoignant donci de leur *instabilité* : leur grand problème est justement le 3) du paragraphe antérieur, le geste de restitution théorique du savoir fragmentaire acquis laboratorialement sur le phénomène, restitution à la scène aléatoire d'où il a été enlevé, hors du laboratoire donc, du savoir sur le phénomène entier, puisque c'est sur celui-ci que la théorie doit verser. Les

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[3] Héritage reconnu par le grand physicien qui fut Feynman : "ce qu'on appelait d'habitude philosophie naturelle, d'où est dérivé la plupart de la science" (p. 74), tout en croyant d'ailleurs comme Newton que la Physique est son équivalent moderne.

[4] Les règles que les sciences découvrent, de même qu'une automobile est projetée au laboratoire pour se mouvoir dans l'aléatoire du trafic.

[5] Galilée, D*iscours et démonstrations mathématiques concernant deux sciences nouvelles*, introd., trad. e notas por M. Clavelin, 1970, A. Colin, p. 144

techniques laboratoriales sont une part du phénomène d'élévation entropique des sciences exactes, de même que les 'envies' des scientifiques qui, dans la définition de 'paradigme' de Kuhn, sont 'attirés' (*attract*)[6] et liées aux 'envies' des collègues du même paradigme par son apprentissage. A la *stabilité* correspond le cours normal des paradigmes selon Kuhn, ce que l'on pourrait appeler leur *homéostasie laboratoriale*, en contraste avec leurs crises, manifestation de *l'instabilité* en de fortes polémiques, souvent pendant des générations.

**6.**

On peut retourner maintenant à l'héliocentrisme. S'il a été donné au génie de Newton de comprendre la stabilité héliocentrique du système, en termes du principe de l'inertie et de sa découverte des forces de gravité comme attraction des corps dans la raison directe de ses masses et inverse du carré de leur distance – c'est-à-dire qu'il n'y serait pas arrivé sans ces deux motifs fondamentaux de sa Mécanique –, ce qui est étonnant c'est que sa démonstration n'ait pas été faite selon eux mais plutôt selon les lois de Kepler (qui avait utilisé les mesures de Tycho Brahe, anti-copernicien) dans lesquelles ne jouent que les espaces et les temps des parcours des orbites des planètes et les raisons entre les surfaces respectives. *Il est parti donc du système en tant que 'champ' théorique*, Newton ayant d'ailleurs avoué, aveu répété par Feynman trois siècles plus tard, qu'il ne sait pas expliquer ce qui est la force de gravité tant qu'attraction à distance[7], de même que l'on ne sait toujours pas aujourd'hui, selon Feynman, quel est la cause du principe d'inertie (qui tient un corps en mouvement quand aucune force ne joue sur lui, p. 114), dont les effets peuvent toutefois être mesurés et calculés. On peut dire que cette manière 'non substantialiste' de démontrer l'héliocentrisme joue bien avec ce que l'on peut déduire de l'affirmation de Galilée en mesurant le temps en unités de poids : il ne connaît que "des différences et des proportions" entre des mesures de temps, et non pas le temps en soi, non pas les substances (les nou-mènes, dira le newtonien Kant). Or, il arrive que Feynman procède de façon inverse à Newton quand, pour définir charge électrique, il part des charges vers les champs : "nous avons ainsi deux règles : (a) les charges engendrent un champ et (b) les charges en champs restent assujetties à des forces et elles se meuvent" (p. 60). 1° les charges, 2° le champ, 3° les forces ! Un autre exemple : au premier chapitre, il argumente longuement sur les atomes de l'eau, vapeur et glace, sans jamais parler des forces électromagnétiques perdues dans la vaporisation ou gagnées dans la solidification. On retrouve la difficulté dans sa conception de la force comme interaction, celle de la gravité étant une interaction à distance (p. 57), ce qui semble signifier que la force est pensée à la manière des forces habituelles de la Mécanique, du genre balle de billard sur une outre balle de billard, action et réaction, ce que l'on peut appeler 'forces locales'. Il va jusqu'à caractériser la force électromagnétique par la "propriété d'aimer repousser au lieu d'attirer" (p. 58), il considère seulement les charges du même signal et non point celles de signal contraire, d'attraction, celles qui justifient que les atomes aient des électrons attirées par les protons, donc qu'il y ait des molécules et des graves, de la glace, de l'eau et du vapeur ! Or, *les forces fondamentales de la Physique, nucléaire, électromagnétique et de la gravité*, constitutives des atomes et de leurs noyaux, des molécules, des graves et des astres, *les seules dont il y a des champs, sont des forces attractives*, et c'est là peut-être la raison par laquelle nous ne savons pas les imaginer : notre expérience intuitive est celle des 'forces locales', tellement importantes dans la Mécanique newtonienne. Étant donnée son attention si forte au détail qui change les perspectives, on ne peut attribuer ces choses comme dues à l'inattention de Feynman, cela ne peut qu'être inscrit dans la force elle-même du paradigme (attractive !) qui institue les physiciens en tant que tels (donc qu'il ne faille pas attendre de leur part une grande attention à ce texte).

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[6] Thomas Kuhn, *La structure des révolutions scientifiques*, [1962], Flammarion, 1983, p. 31.

[7] Feynman dit que "Newton n'a pas élaboré des hypothèses, satisfait d'avoir découvert ce qu'elle faisait, sans s'intéresser par son mécanisme. Personne dès lors n'a pás proposé aucun mécanisme" (p. 128). Au fait, ce que Newton a dit c'est qu'il n'était pás capable de fictionner (*fingere* en latin, feindre), imaginer une hypothèse explicative de cette étrange force à distance: "je n'ai pas encore réussi à déduire des phénomènes la raison de ces propriétés de la gravité et je ne me figure aucune hypothèse (*hypothesim non fingo*)" (Newton, *Principes mathématiques de la Philosophie naturelle*, trad. de Mme Châtelet, Paris [1756], édition fac-simile de A. Blanchard, 1966, pp. 178-179).

## Énergie, force et entropie

### 7.

Si les grands génies de la Physique, de Newton à Feynman, ne sont pas arrivés, en partant des *‘substances’*, à imaginer ce que sont les forces attractives, l’énergie et l’inertie[8], il me semble qu’il ne s’agit pas d’attendre un futur super génie qui en sera capable. Il est plus sensé penser que c’est le problème qui est mal posé : pourquoi ne pas partir de ces motifs inexpliqués pour mieux comprendre ce que sont les dites ‘substances’ ? Puisqu’ils continuent de ne pas être compris, et sans avoir aucune prétention de les ‘comprendre enfin’, on peut dire que, de même que l’on parle du *principe d’inertie*, ces motifs pourraient avoir un statut, disons, de *principes laboratoriaux*, c’est-à-dire, de principes d’une philosophie (d’une théorie) qui doit faire face à l’expérimentation de mouvements, des principes nécessaires à la compréhension de toute analyse de laboratoire[9]. Ces motifs, qui ont structurés depuis le début la Physique classique, en rendant manifeste que ses inventeurs étaient aussi des philosophes habiles, constituent en effet le motif fondamental de *champ* ; dé-substantialiser, ce sera donc considérer théoriquement forces et énergie comme étant épistémologiquement (non pas chronologiquement !) préalables aux ‘substances’, à l’atome, molécule, grave, astre, charge électrique, les trois forces jouant ensemble et l’énergie étant ce qui, par inertie, se répand sans elles. On ne ‘part’ pas de l’atome, à la façon de Feynman, puisqu’il n’y a pas ‘l”atome, ‘la’ molécule, ‘le’ grave : avant tout, ce qu’il y a ce sont les champs des astres dans lesquels les trois forces agissent. Dans le cas du système solaire, les orbites des astres sont stables du fait du champ de forces de la gravité qui les *retient*, champ qui consiste en eux-mêmes en mouvement inerte vis-à-vis les uns des autres[10]. Les graves dont un astre est fait sont eux aussi *retenus* par le champ des forces de gravité, ainsi que, à leur tour, ces graves sont faits de molécules que des forces électromagnétiques *retiennent* ensemble, leurs atomes devant, eux, leur stabilité à la *rétention* de protons et neutrons dans le noyau par des forces nucléaires. Quel est le sens de ce ‘retenir’ quatre fois souligné ? *La stabilité* de ce qui est retenu et qu’il la perdrait en n’étant plus retenu : l’explosion de l’essence liquide dans le moteur d’une voiture est l’exemple de la fin d’une telle rétention par des forces électromagnétiques et, en conséquence, que ses molécules, devenues gazeuses, se répandent sous forme d’explosion, de même que, *mutatis mutandis*, les protons et les neutrons des bombes nucléaires qui explosent parce qu’on leur retire les forces nucléaires, et aussi se répandent des photons quand des électrons en mouvement perdent un peu des forces qui les retenaient. Si une fusée envoyée sur la lune ou une sonde sur marte, après avoir quitté le champ de la force de la gravité qui les retenait sur la terre, suivent sans avoir besoin de plus énergie que celle qui les a chassé (on ne pourrait les alimenter dans la stratosphère à égal que jusque lors), elles suivent selon un mouvement inerte, perdues leurs liaisons à des forces quelconques. On peut dès lors *définir une force attractive par sa capacité de retenir ce qui, de son inertie à soi, se répand sans limites*. Or, ce qui se répand de cette façon, ce qui explose, ce sont des exemples essentiels, non pas n’importe lesquels, *d’énergie*. Donc, *ce que les forces attractives font par leur retenir ou lier, c’est créer de l’entropie positive* (Prigogine), c’est-à-dire, de l’énergie interne telle qu’Einstein l’a conçue comme équivalente au produit de la masse par le carré de la vitesse de la lumière[11]. Le mot grec ‘entropie’ (‘se fermer en soi, timidité, honte’) convient à cette ‘énergie’ einsteinienne[12]. Il n’y a

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[8] Feynman souligne très souvent cette ignorance des physiciens de son temps sur des motifs fondamentaux de la Physique: pp. 57, 66, 95, 106,107, 113-4, 128-9, 133.

[9] Sans laboratoires, ces motifs – des forces qui retiennent des énergies – n’existeraient pas, ce qui n’est pas vrai d’espace, temps, vitesse, poids ; sans le champ de la gravité, il n’y a pas des mouvements de graves sur la terre, de même que sans les explosions de forces électromagnétiques ou nucléaires il n’y a pas d’optique, de relativité ou de la mécanique quantique.

[10] La *différence phénoménologique* entre le champ des forces de gravité et les astres est équivalente à la différence entre telle espèce biologique et ses individus, telle langue et ses discours ou textes, telle société et ses populations. Affirmer dans un premier temps la primauté du ‘champ’ sur les astres ne peut se faire qu’en l’effaçant ensuite pour dire que *champ et astres ce sont le même*, l’un n’est pas sans les autres.

[11] C’est sur de l’irradiation électromagnétique qu’il argumente dans le quatrième texte de 1905 (de trois pages) qui établit cette formule.

[12] En ‘entropie’, le verbe *trepô* signifie ‘changer’, avec l’ ‘*-en*’ devient intérieur: ‘changement intérieur’, de sentiments, ici d’énergie interne.

pas que les gaz et les liquides, les airs et les mers, qui sont soumis à des vents, des ondes et d'autres tourbillons, les solides sont eux aussi *instables* selon leur position dans le champ de la gravitation, des rocs soumis à l'érosion, parfois des tremblements de terre ou des volcans nous rappellent que les mots 'terrible' et 'terreur' sont composés à partir de 'terre'. Instabilité chimique aussi, toujours que la proximité entre des molécules rende possible des transformations que la Chimie étudie, comment le fer est oxydé, par exemple. Tout ceci est construit entropiquement au sens de Prigogine, et peut donc être détruit, c'est pourquoi il y a de l'entropie au sens de Clausius, c'est pourquoi il y a une 'histoire' de l'univers, de la scène de gravitation[13].

**8.**

Explosion, expansion, inertie, ce seront donc des contreexemples de l'entropie prigoginienne, ce sont des mouvements de sa dégradation, de l'entropie clausienne qui s'accroît. Mais ce sont aussi des exemples de l'étrange mécanique quantique, dont l'étrangeté principale est justement l'instabilité de sa population de particules des électrons sans bride qui partent comme des balles ou comme des ondes (ce sont des exemples de Feynman dans son dernier chapitre), rares étant les particules qui réussissent à persévérer une fois déliées (proton, électron, photon, presque pas d'autres) ; on ne peut même pas parler d'elles en termes de 'population', motif qui implique durée, ni 'monde' ou 'univers' quantique, même pas 'matière', puisque ces particules n'existent qu'en tant que lumière, des rayonnements ou du courant électrique, ou alors de façon très fugace en des accélérateurs, des laboratoires. Quand le grand physicien multiplie ses avertissements sur la difficulté de comprendre la gravitation en termes de forces électromagnétiques quantiques, tout en regrettant ce que l'on appelle la non unification des deux grandes théories de la Physique du XXème siècle, relativité et quantique, la question que le lecteur peut poser est celle-ci : *quelle est la barrière* entre la grande stabilité de notre univers macro et l'instabilité incroyable, ultra chaotique, de cet étrange micro quantique ? Voici une réponse osée : ce sont *les champs des forces attractives*. D'une part, il n'y a que des particules, fussent des atomes isolés, de l'autre, que des graves et des astres, lesquels, analysés, se révèlent constitués par des atomes et leurs noyaux, par des molécules[14]. Or, comment peut-on dépasser cette barrière ? D'ici vers là-bas, par la désintégration technique des atomes et noyaux (des graves) jusqu'aux particules, en des bombes ou des centrales nucléaires, en des grands accélérateurs. Et de là-bas vers la matière de chez nous ? du big Bang vers les étoiles ? peut-on 'prendre' des protons, des neutrons et des électrons et fabriquer des atomes et des molécules ?

**9.**

Si l'on accepte la conception de science physique proposée ci-dessus (§§ 4-5), il faudra conclure que son noyau dur consiste dans les équations correspondantes aux résultats expérimentaux, qui sont les 'données' qui doivent 'vérifier' dans ces équations leurs 'variables'. Tant que les instruments de mesure ne changent pas, ces équations (variables et données) se *vérifient*, comme on dit, elles sont 'vraies'. Galilée et Newton

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[13] Dans le contexte de la phénomenologie qui est ici au travail, on posera la question de savoir jusqu'où 'l'attraction' par des forces continue de jouer aux niveaux entropiques de la vie et des humains. Au niveau zoologique, les motifs de flair et de faim jouent comme des attractions chimiques essentielles à la reproduction des animaux, de même que les pulsions sexuelles sont des attractions chimiques pour la reproduction des espèces. Dans l'habitation sociale, le motif d'envie répond aussi à l'attraction du paradigme des usages qui 'attire' (Kuhn, généralisé à toute unité sociale), le jeu des désirs et des rivalités, etc. Au niveau de l'inscription, la curiosité est le grand moteur attractif de tout savoir, des apprentissages comme des découvertes et inventions. Entraînement et éducation, ce sont des manières de *retenir* la spontanéité chimique des attractions biologiques, en vue d'y créer de l'entropie, c'est-à-dire, d'en faire une spontanéité habile capable de jouer quand il faut. Voici une façon de justifier aux yeux des physiciens l'audace du propos.

[14] Je serais tenté de dire que la physique des particules est kantienne et celle de l'atome husserlienne. Les pieds d'argile du kantisme, c'est son point de départ sur les 'sensations', comme si elles étaient des 'étants' d'où partir, tandis que Husserl, plus avisé, a assis son édifice phénoménologique sur la 'perception' de la chose, du phénomène, toujours le même malgré les variations possibles des perceptions. La physique des particules, à la façon de Kant, obéit au principe cartésien d'analyser en descendant jusqu'au plus simple et de monter par la suite pour faire la synthèse. Mais ce 'plus simple', sensations ou particules respectivement, subsiste-t-il par soi de façon à être la base possible de la synthèse ?

résistent aux physiques du XXème siècle, c'était surtout leur physique que l'on enseignait dans les écoles d'ingénieurs dans les années 50 du siècle écoulé. Interpréter ces équations et ces expériences fragmentaires dans une théorie, avec leurs définitions de concepts et leur argumentation, quelque chose qui doit exister pour créer le laboratoire lui-même, reste toutefois un travail 'philosophique' (théorique) de physiciens qui définissent et argumentent à fin de comprendre ce qui arrive au laboratoire, puisque les équations ne touchent pas aux 'substances', que (des mesures) des différences et des proportions, comme l'a écrit Galilée[15]. Ceci a des conséquences que les physiciens semblent difficilement comprendre par des raisons philosophiques. Par exemple, que les laboratoires sont irréductibles et donc les équations et les techniques de mensuration de la Physique newtonienne continuent scientifiquement valables, en permettant notamment d'innombrables constructions techniques, même si l'interprétation 'philosophique' venue d'autres contextes laboratoriaux (des vitesses très hautes, des distances ultra microscopiques) révise les anciennes interprétations sans toutefois pouvoir les déclarer 'fausses', comme Feynman fait parfois de façon péremptoire. S'il le fait, c'est une autre conséquence, ce n'est pas en tant que physicien (puisque les laboratoires respectifs sont irréductibles), mais en tant que philosophe (théoricien d'un autre type de laboratoire). Tout autant 'philosophique' sera la prétention que la mécanique quantique soit valable dans toute la réalité extra-laboratoriale, dans notre univers matériel où les vitesses sont 'petites' et les longueurs d'onde 'minuscules', en raison des dimensions macroscopiques des graves. C'est-à-dire que, étant donnée l'irréductibilité des laboratoires respectifs, l'unification si souhaitée des deux grandes théories du XXème siècle ne pourra être que 'philosophique', en incluant la dimension philosophique des sciences. Déjà le philosophe Cornelius Castoriadis évoquait "l'antinomie épistémologique formulée par Heisenberg dès 1935 entre la constatation de la non validité des catégories et des lois de la physique ordinaire dans le domaine microphysique et la démonstration de cette non validité par le moyen d'appareils construits selon les lois de cette physique ordinaire et interprétés selon les catégories usuelles"[16]. Ce qui signifie que l'unification des deux physiques, relativité et quantique, ne sera possible qu'en tenant en compte les laboratoires où elles ont été formulées, leurs instruments de mensuration et leurs respectives différences d'échelle[17], et bien aussi la validité laboratoriale de la physique de Galilée et Newton, dont les équations reviennent quand on réduit les facteurs d'échelle (quand v/c tend vers zéro dans les équations relativistes).

## L'entropie et la flèche du temps contre le déterminisme

**10.**

*Prigogine a découvert le secret de toute évolution, de toute histoire, inventions et découvertes, de ce que l'on appelle la flèche du temps.* À partir d'une situation chaotique menaçant de dégradation, implosion ou explosion, entropie du type

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[14] Je serais tenté de dire que la physique des particules est kantienne et celle de l'atome husserlienne. Les pieds d'argile du kantisme, c'est son point de départ sur les 'sensations', comme si elles étaient des 'étants' d'où partir, tandis que Husserl, plus avisé, a assis son édifice phénoménologique sur la 'perception' de la chose, du phénomène, toujours le même malgré les variations possibles des perceptions. La physique des particules, à la façon de Kant, obéit au principe cartésien d'analyser en descendant jusqu'au plus simple et de monter par la suite pour faire la synthèse. Mais ce 'plus simple', sensations ou particules respectivement, subsiste-t-il par soi de façon à être la base possible de la synthèse ?

[15] La première définition de Newton est celle de "quantité de matière", qu'il designe par les mots 'corps' ou 'masse' et l'on connaît par le poids des dits corps, c'est-à-dire, par mensuration. Il a d'ailleurs commencé en disant que "les Modernes ont enfin rejeté depuis quelque temps, les formes substantielles et les qualités occultes". Quantité (par différences mesurées, comme chez Galilée) et non point qualité: dé-substantialisation.

[16] "Science moderne et interrrogation philosophique", *Encyclopædia Universalis*, vol. Organon, 1975, p. 48.

[17] Tenues en compte dans leurs respectives équations, comme le fait pour la relativité restreinte Laurent Nottale, *La relativité dans tous ses états. Au-delà de l'espace-temps*, Hachette, 1998.

Clausius, comment peut la vie ajourner la mort : comment, de formes très diverses selon le niveau de ladite réalité, est produite cette entropie, sont créées de nouvelles stabilités avec des règles adéquates à des circulations aléatoires, donc instables. Il a permis de comprendre que l'entropie n'est pas que 'non', qu'elle est 'oui' et 'non', sans les opposer (ce qui a toutefois été sa tendance de pensée), puisque la flèche du temps va d'abord au 'oui' et ensuite au 'non', la mort après la vie et sa condition (puisqu'on ne survit qu'en mangeant des cadavres).

**11.**

Récapitulons. Il y a deux formes essentielles de matière sur la Terre. *Matière inerte* en sens classique, faite de l'agrégation de *molécules relativement simples et égales* pour atteindre des dimensions macroscopiques, des solides, des liquides, des gaz : comment est préservée, de la glace à l'eau et de celle-ci au vapeur, la liaison entre les atomes de l'oxygène et de l'hydrogène, qui se révèle plus forte que la solidité et que la liquidité. L'autre, *la matière vivante*, qui, pour arriver elle aussi à des dimensions macroscopiques et former des organismes fort variables, est faite de la composition de *molécules différentes* en leurs fonctions cellulaires et *très complexes*, à base notamment de carbone, et donc assez instables et demandant d'être souvent refaites, demandant constamment de l'alimentation ; quel contraste avec la stabilité et l'impénétrabilité des atomes, dues à leurs noyaux, impénétrabilité qui les rend irrémédiablement *autres* entre eux. Ce que la vie a réussi, cela a été d'inventer un nouveau niveau de *même*, au-dessus de cette altérité empirique radicale : le niveau d'individus *différents* dans la *même* espèce. Or, ce fut dans le métabolisme de la ma-tière vivante que Prigogine a découvert une entropie positive.

**12.**

Il faut croire que le savant ait été emporté par l'importance de sa découverte à opposer son entropie à celle de Clausius, à une exclusion des phénomènes entropiques, à opposer ensuite les certitudes qui ont rendu légendaires les découvertes de ses prédécesseurs, dont un de ses derniers titres proclame la fin. Or, les certitudes de la physique classique, qui sont laboratoriales, restent des certitudes, on l'a dit, ne sont pas devenues des lois simplement statistiques : au lieu de dire que ce sont des lois déterministes, on doit dire que ce sont des *lois déterminées*, c'est-à-dire, déduites dans les conditions de détermination du laboratoire. *Le problème, c'est que l'on a toujours pensé que ce qui était valable au laboratoire était automatiquement valable dans ladite réalité, là, où il y a toujours des incertitudes, dues à la confluence d'effets non dominable qui a justement impliqué la nécessité du laboratoire*. Or, le motif de scène, c'est clair chez l'automobile, éclaire la question : les règles de détail étudiées par les laboratoires correspondent dans le tout théorique à des situations aléatoires, la machine est construite *rigoureusement* dans ses pièces pour suivre *l'aléatoire* de la loi du trafic. De même, l'anatomie de n'importe lequel animal, 'construite' selon la cruelle loi de la jungle qui commande de manger l'autre vivant pour survivre. La loi de la gravité vaut toujours sur la terre, mais la trajectoire de chaque grave dépend de sa position aléatoire dans sa scène. Pour ce qui est de la mécanique quantique, le problème de l'incertitude des mesures concernera le fait que la distinction entre laboratoire et scène dehors disparaît dans un accélérateur de particules (instabilité totale, on ne peut plus parler de scène). Que hors du laboratoire règne la contingence, on l'a toujours su depuis Platon tout au moins, lui qui a placé les entités résultants de la définition dans l'éternité céleste, parce que sur terre il n'y avait que de la contingence, génération et corruption. Mais c'est vrai que dans son sillage et du neoplatonisme du IIIème siècle, où le terrible Augustin a bu, un Dieu absolu s'opposait à cette contingence et a marqué les savants européens, croyants ou pas, d'une conception déterministe qui extrapolait les certitudes laboratoriales (que l'astronomie justifiait) : contre ce déterminisme, Prigogine avait raison. Mais il faudrait un autre argument pour un tel combat. Ce que l'on ne savait pas – ce qui n'a pas été écrit de façon à pouvoir être su de la façon généralisée qui convient à ce savoir –, ce que le maître n'a pas su, lui non plus, c'est que les règles (ou lois), les savoirs scientifiques qui ont nourri le récit légendaire des sciences européennes des quatre siècles derniers, *ne se réalisent pas substantiellement*, on l'a vu chez Galilée, *mais ce sont des règles structurelles de régimes aléatoires de circulation* : rigueur de la machine et aléatoire de sa circulation dans le trafic, rigueur de l'anatomie animale construite pour la chasse aléatoire et pour y échapper, rigueur des règles d’une langue qui rendent possible l’entente dans l’aléatoire d’une conversation ou d’une discussion écrite. *Que les règles soient pour l’aléatoire n’est possible, à chaque niveau des choses, que de par l’entropie prigoginienne.* Comment au-dessus des roches, des mers et des airs, mobiles sans doute mais durant à grande stabilité si les températures ne bougent pas beaucoup, se sont établies des in/stabilités vivantes, éminemment fragiles puisque mortelles, mais faisant de la mort vie, loi de la jungle, en des espèces chaque fois plus complexes qui durent au-delà des générations d’individus mortels qui procréent.

**13.**

Que *les lois scientifiques soient pour l’aléatoire*, c’est, je crois, ce qui réhabilite – sans déterminisme et selon la relativité du savoir occidental en tant qu’historique – *leur vérité et celle des sciences exactes des savant européens*, contre beaucoup de leurs héritiers eux-mêmes qui croient facilement aujourd’hui que leur ‘vérité’ est provisoire, une erreur en sursis. Les techniques sorties de leurs laboratoires nient ce scepticisme.

# GIL C. SANTOS

**CFCUL**

## ABSTRACT

According to a comprehensive relational ontological view, the existence, the identity, the evolution and the causal behaviour of any entity must always be conceived and explained as products of both intrinsic and extrinsic relations. Therefore, properties, taken as ways of being, must also be conceived in these terms, regarding both their instantiation and causal actions. In this sense one should re-evaluate the meaning of the classical distinctions between monadic, intrinsic and extrinsic properties, as well as between internal and external relations, relational properties and relations. The application of this relational view in the domain of Physics implies the impossibility of admitting the existence of one fundamental property, since in that case it would be taken, not as a relational way of being, but as a self-sufficient and ontologically independent entity.

# JAIRO JOSÉ DA SILVA

**PROFESSOR OF MATHEMATICS, UNESP, SP BRAZIL**
**RESEARCHER CNPQ, BRAZIL**

Author of *The Road Not Taken. On Husserl's Philosophy of Logic and Mathematics* (in co-authorship with Claire Hill), London: College Publications, 2013 and *Mathematics and its Applications. A Transcendental-Idealist Approach*, Synthese Library vol. 385, Dordrecht: Springer, 2017.

## ABSTRACT

Since Eugene Wigner's famous paper "The Unreasonable Effectiveness of Mathematics in the Natural Sciences" (*Communications on Pure and Applied Mathematics. 13: 1–14*, 1960) much has been said about the uses of mathematics in science, particularly as a heuristic tool. Wigner thought this is a "gift" we neither understand nor deserve; others, as the philosopher Mark Steiner, go so far as to claim that the fact that mathematics can be used in science as an instrument of discovery puts a problem for the view that man has no special place in the natural scheme of things.

My aim here is to show, first, that the scientific usefulness of mathematics is mysterious only from the point of view of empiricism – the mystery utterly disappears in an idealist perspective – and, second, that the transcendental-idealist approach to mathematical structuralism that I will sketch here can explain to full satisfaction the four main uses of mathematics in empirical science, which I called the representational, the organizational, the predictive and the heuristic. I will also show, in passing, how this approach handles Benacerraf's dilemma and the arguments of indispensability advanced in favor of mathematical Platonism.

# JOÃO PINHEIRO

**CFCUL**

João Pinheiro is a Master's student in Philosophy and a member of the Centre for Philosophy of Science of the University of Lisbon with research interests in the evolution of cognition, Philosophy of Science, and cosmopolitanism. [http://cfcul.fc.ul.pt/equipa/jpinheiro.php].

# JOÃO LUÍS CORDOVIL

**CFCUL**

João Luís de Lemos e Silva Cordovil frequentou a Licenciatura em Física na Faculdade de Ciências da Universidade de Lisboa entre 1995 e 1999, tendo-se licenciado em Ensino da Física e Química - variante Física - na Faculdade de Ciências da Universidade de Lisboa em 2001. Realizou a parte curricular da primeira edição (2003-2005) do mestrado em História e Filosofia das Ciências da Faculdade de Ciências da Universidade de Lisboa. Obteve uma bolsa FCT para doutoramento em História e Filosofia das Ciências na Universidade de Lisboa, (Referência: SFRH/BD/21790/2005), sob a orientação de Olga Pombo e José Croca, em 2012, tendo defendido a sua tese de doutoramento com o título "O que é uma Partícula Quântica? - Implicações Ontológicas e Epistemológicas do Conceito de Partícula Quântica nas Interpretações de Copenhaga e de De Broglie-Croca". [http://cfcul.fc.ul.pt/equipa/jcordovil.php]

## ABSTRACT

In this talk we will begin by introducing the notion of Metametaphysics, the study of the foundational and methodological issues of Metaphysics, *i.e.* of the assumptions made and tools used by metaphysicians, of how one ought to make sense of their purported solutions to philosophical questions (their meaning, knowledge, and comprehensibility), and of what grounds, constitutes, and/or explains existence claims. Having made explicit what Metametaphysics is we will then demonstrate that it plays a central role in assessing what the meaning of *physics* is. Our proposal consists of a survey of different criteria for physicality ascriptions to entities while revealing their metametaphysical frailties, building up to the conclusion that at our present time there is no tenable definition of the physical. Despite the overall pessimism of our criticisms we will conclude our talk on an optimistic tone by presenting some desiderata for any and all working definitions of physics.

# JOSÉ R. CROCA

**FCUL**
**CFCUL**

Ph. D. in Theoretical Physics, Professor and Researcher at the University of Lisbon.

Was initiated on the research on the foundations of Quantum Physics by Professor J. Andrade e Silva one of the most direct collaborators of the great French physicist Louis de Broglie.

His main activity is centered on the Foundations of Quantum Physics. Presently is developing, together with the School of Lisbon Research Group. This international and multidisciplinary Research Group focused his activities mainly in promoting a general complex, integrated and inter-relational nonlinear view on physics, quantum physics and also in the other sciences namely: philosophy, history of science, technology, economics and sociology.

The research on physics is related mainly with the following issues:

Reality of de Broglie waves, theta waves or subquantum waves
Fourier Ontology and Uncertainty Relations

Quantum Tunneling Effect
Principle of Eurhythmy

This research on the foundations of physics in done in a multiple front, from pure theoretical physics, mathematics, philosophy, epistemology to some possible practical application of these novel ideas.

### Awards

Is the recipient of two Prizes: the 2008 T. Galilee Gold Medal, for The Crusading Work Towards the Demise of the Prevailing Scientific Obscurantism, and the FIR Prize 2008, for his Work in promoting REASON, from the International Rationalist Federation.

He is the author of several papers published in international scientific journals related to modern non-linear quantum physics and several scientific books published in Portuguese and English.

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## ABSTRACT

Abstract

The concept of physical particle has undergone an important evolution, at least since the scientific revolution of the XVIIth century till now. Initially the particle was identified with something akin to the Greek atom. Completely independent and existing by itself. With Newton, the concept of abstract point-like particles was introduced in physics. In any case the particles had proper awn identity. With the development of orthodox Quantum Mechanics, the very concept of individual well localized, in time and space, particle was lost. Indeed, in this view of understanding Reality, a quantum particle with a well-definite momentum and energy is omnipresent in time and space. In this way, we went from an absolute localization and individualization to the opposite extreme non-localization and no-individualization.

With the development of Eurhythmic approach to understand Physis, a kind of middle way was introduced. The concept of complex particle was proposed. This complex physical entity sharing, at the same time, a certain degree of localization and non-localization, and also, of individuality and non-individuality.

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# REFERENCE FRAME DEPENDENCE IN ONTOLOGICAL INTERPRETATIONS OF QUANTUM MECHANICS

## JOSEPH BERNAL

**EL PASO COMMUNITY COLLEGE (EPCC)**
**THE PHILOSOPHIC SYSTEMS INSTITUTE (PSI)**

Joseph Bernal is currently an instructor of Philosophy at El Paso Community College and is the present team leader for the Foundation of Physics research group at the Philosophic Systems Institute (PSI). The research group has concentrated its efforts in examining the philosophical foundations of various theories within physics, particularly quantum theory. Joseph's main professional interest has been the connection between metaphysics and epistemological claims in the sciences. As a result, Joseph has focused his research on philosophy of information, philosophy of physics and information theory with the goal of clarifying its role in scientific explanations.

Joseph has presented at a number of conferences in the areas of Information theory (Duke University), Information Loss (Centro de Filosofia da Universidade de Lisboa), scientificexplanations (University of Kansas) and standpoint epistemological approaches to women in computing (University of Texas at El Paso).

Joseph Bernal received a BA in Philosophy and Psychology and an MA in Philosophy from the University of Texas at El Paso (UTEP).

## KEVIN D. VALLEJO

**THE UNIVERSITY OF TEXAS AT EL PASO, PHYSICS DEPARTMENT (FORMER)**
**BOISE STATE UNIVERSITY, MATERIAL SCIENCE AND ENGINEERING DEPARTMENT (CURRENT)**

Kevin D. Vallejo is currently a Ph.D. student in Material Science and Engineering at Boise State University. Kevin's professional interests reside in advancing an understanding of the interaction between experimental science, theory, and their interaction and interpretation. These interests are reflected in Kevin's research on materials at the border of the nano- and meso- scale to observe the manifestation of quantum phenomena on the design and fabrication of devices. Kevin has presented in various conferences in the southern part of the US. Among these he has presented research on ionic liquids and axion electrodynamics. His focus on the practice of science with a philosophical insight have been product of his drive for a better, and better understood, science.

Kevin obtained a BS in Physics from The University of Texas at El Paso and completed advanced graduate coursework in quantum mechanics, solid state physics and electrodynamics. He is now pursuing his doctoral degree.

## ABSTRACT (VIDEO CONFERENCE)

### Background

Various physicists such as Schrodinger, Heisenberg, Einstein, Everett, and DeWitt have debated what is the proper ontological interpretation of quantum mechanics in light of the measurement problem (Auletta, 2000). The result of such a widely debated topic in the field of physics has been a variety of differing interpretations—e.g. mathematical formalism, Copenhagen, epistemic ignorance, statistical, many worlds (Auletta, 2000), relational (Rovelli, 1997). Despite these attempts to explain what quantum mechanics tells us about reality, the answer to the question "what is a physical entity?" remains ambiguous and not well accounted for. This has led some philosophers such as Ian Hacking to propose that experimental research be the basis for ontology as opposed to the formalism (Experimentation and Scientific Realism, 1998).

### Purpose

Interpretations of the measurement problem in quantum mechanics that rely solely on experimental research as foundational for an ontological account, however, fail to adequately explain that the entities they posit and have been largely misguided by being myopic their focus. Questions regarding what entities does quantum theory posit as physical remain difficult to address perhaps due to implied assumptions regarding traditional ontologies. This is because attempting to explain the notion of an entity's being implies the ability to speak of the "thing in itself" devoid of an explicit frame of reference (Husserl, 1970). Traditional concepts of physical entities and failure to make frames of reference explicit resulted in what appears to be an ontological description of entities that are paradoxical at times (e.g. exhibiting reverse causation) and attributes incompatible properties to entities (e.g. particles that are both restricted by and violate locality) (Auletta, 2000).

### Aim

Instead, we propose that in order to reach a proper interpretation and solution to the measurement problem, that avoids the seemingly paradoxical ontology, one cannot simply focus on identifying a proper interpretation from the mathematical formalism. But rather as Slobodan Perovic had stated,

> "…it is important to understand that interpretations, formalisms, and the relevant experiments were closely related aspects of the same endeavor. Disentangling them by introducing rigid distinctions might misguide us in our attempts to reconstruct the relevant views and arguments. Both the development of quantum mechanics and its interpretation were closely dependent on the experimental results: the view of the interpretation(s) arising from the theory, and the theory arising from the experiments, is misleading. It is more accurate to say that all three components informed each other." (2008)

So by providing explicit attention to the relations between the formalism, the relevant experimental research, and interpretation of the phenomena as an ongoing process in constant reassessment. We begin to piece together a more viable notion of entities in quantum mechanics. Specifically, we examine well established experimental research, in particular the quantum delayed choice experiment (Marlan O. Scully, 1982) (Kim, Yu, Kulik, Shih, & Scully, 2000). We propose the phenomena could be better understood by focusing on the relation between the experiment in question, conceptual interpretation and the mathematical formalism. By doing so we reveal that the implicit assumption of entities devoid of frames of reference but instead as "the thing in itself" results in some paradoxical ontological interpretations with entities possessing contradictory properties.

We argue that an entity in quantum mechanics cannot be understood simply as a "thing in itself", but as reference frame ontologically dependent events, as a result of properly analyzing the relationship with the mathematical formalism alongside the relevant experimental research.

### Conclusion

By closely examining the relationship of the formalism and experiments, should shed light on the usually overlooked and rarely explicitly acknowledged importance of some reference frames ontological status, boundary conditions and interactions of so called "physical entities" within regards to the traditional measurement problem.

### Keywords

Reference Frame Dependence, Measurement problem, Quantum Mechanics, Physics Ontology

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# IS SPACE-TIME A DYNAMICAL PHYSICAL ENTITY EMERGING FROM GEOMETRY AND TOPOLOGY?

## LUCIANO BOI

**CAMS**
**EHESS**

**Selected publications on the topic of the Colloquium:**

**Book:**

*The Quantum Vacuum. A Scientific and Philosophical Concept: From Electrodynamics to String Theory and the Geometry of the Microscopic World*, The Johns Hopkins University Press, Baltimore, 2011, p. 222.

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## ABSTRACT

Our talk aims at studying various topics and different issues related essentially to topological quantum field theories and string theory. We present recent work and discuss new ideas and results from these topics. We will focus on the subject of the geometric and topological structures and invariants, which enriched in a remarkable way relativistic and quantum field theories in the last century, starting from Einstein's general relativity until string theory. In the last three decades, new and deep developments in this direction have emerged from theoretical physics. We will stress the crucial fact that many physical phenomena, at the quantum and at the cosmological level as well, appear to be related to deep geometrical and topological invariants, and furthermore that they are physical effects which emerge, in a sense, from the dynamics underlying the geometric and topological structure of space-time.

Topological quantum field theory (TQFT) emerged in the eighties as a new relation between mathematics and physics, and appears as a very rich and promising research program in theoretical physics. Two conceptual points appear to be very significant, and likely promising for physics, in TQFT. The first is the assumption of an effective correlation between knots and link invariants and the physical observables and states of quantum field theories and gauge theories. The second is, on the one hand, the idea of the fuzziness of space-time and of its emergence from the dynamical fluctuations of physical phenomena, on the other, the idea of the geometric and topological nature of physical process at different scales.

We will address the important philosophical point concerning the differences between the "ontology" of classical physics and that of quantum physics. (Here this term stand for the nature and the kind of properties ascribed to the most fundamental physical entities from which a specific theory is built up and also to the mathematical objects by means of which one construct a definite space-time theory or model). One may affirm that Newtonian physics had a clear ontology: the world consisted of massive particles situated in Euclidean space. In that sense, the nature of space played a fundamental role. In the mathematical developments of Newtonian mechanics, however, the role of space is not clear. There is not much difference between the description of two particles moving in $\mathbf{R}^3$ and that of a single particle moving in $\mathbf{R}^6$, nor between that of a

pivoted rigid body and that of a point moving on the group-manifold $SO^3$. In quantum mechanics the idea of space is even more elusive, for there seems to be no ontology, and, whatever wave-functions are, they are certainly not functions defined in space. Still, for about seventy years we have known that elementary particles must be described not by quantum mechanics but by quantum field theory, and in the field theory the role of space is quite different. Although it is an important fact that quantum field theory cannot be reconciled with general relativity, one could emphasize that the two theories have a virtual feature in common, for in both of them the points of space play a central and objective dynamical role. In quantum field theory two electrons are not described by a wave-function on $\mathbf{R}^6$; instead they constitute a state of a field in $\mathbf{R}^3$ which is excited in the neighborhood of two points. The points of space *index* the observables in the theory. The mathematics of quantum field theory is an attempt to describe the nature of space, but it proposes to look at space in a completely different way.

Like quantum field theory, Penrose's twistor theory is a radical attempt to get rid of space as a primary concept. The Connes's programme of non-commutative geometry amounts to a huge generalization of the classical notion of a manifold. Finally, string theory proposed a scheme for making space as an approximation to some more general kind of complex geometric structure whose most striking ingredients seems to be knots invariants, moduli spaces and Calabi-Yau spaces. One very significant difference (maybe the essential one) between general relativity and quantum mechanics lie in the fact that, whereas in general relativity it seems impossible to separate the postulate of (continuous) space-time localization of events and the theory of gravitation from the (inner) geometric structure of space-time, on the other hand, it is precisely these postulate of the indistinguishablity of the physical fields from the space-time geometry that got lost in quantum mechanics. It is particularly contradicted by the Bohr principle of complementarity and the Heisenberg uncertainty relations, which states the impossibility of knowing simultaneously the exact position and velocity of particles (electrons). These relations are indeed based on a model in which the electron jumps quickly from one orbit to another, radiating all energy thus liberated in the form of a global package, a *quantum* of light.

The most important quantum field theories are gauge theories. Studying gauge theories, one realize that to each physical entity and their correlated physical-theoretical model corresponds a local or global structure of differential and algebraic geometry and topology. The so-called dictionary of Yang-Wu (1975) has very well illustrated this important fact. For example, field strength is identified with the curvature of the connection; the action integral is but a global measure of curvature. Certain topological-algebraic invariants in the theory of characteristic classes have been seen to be most appropriate to describe the charge of the particle in the sense of Yang-Mills. More generally, we can establish a direct correspondence from the concepts of gauge field theory to those of the differential and topological geometry of fiber spaces.

We will also suggest the philosophical idea that, fundamentally, physics is but geometry in act, which do not mean at all that physics can be reduced to mathematics. This implies not only that geometry produces mathematical abstract concepts like manifolds, groups, curvature, connections, fiber spaces, etc., but also that it is, in a way, ontologically rooted in reality, because it participate somehow in the properties of physical entities and in the dynamical behaviors of phenomena. In fact, some principles of geometrical symmetry (or, equivalently, some groups) can be transformed into dynamical principles that are in turn responsible for certain changes in the phenomena. Thus, the concept of symmetry is not just abstract, and its mathematical properties have simultaneously an explanatory power and a capacity to generate a world of forces, interactions and energy, so that the mathematical understanding of this world cannot be separated of the understanding of reality itself. On one hand, one is increasingly led to believe that symmetry might determine at a deep level almost everything. Nevertheless, on the other hand, it is not unreasonable to look on topology, like symmetry, as some kind of underlying or unifying principle which helps us to understand complex (macroscopic and microscopic) physical phenomena. Thus, a best comprehension of the interplay between geometry, topology and dynamics might help to reach a better understanding of the complex nature and multivel meaning of physical entities.

**Key words**
topology, geometry, fields, gauge theories, quantum world, string theory, emergent space-time.

**MEIR HEMMO**

**UNIVERSITY OF HAIFA**

## ABSTRACT

As is well known the measurement problem in standard quantum theory casts serious doubts on the possibility of interpreting the mathematical formalism of the theory in a realistic fashion, that is, in a fashion that correlates the formalism with existing physical facts, things, properties, etc. and the way they change over time. The various so-called interpretations of the mathematical formalism of quantum mechanics, such as Bohm's (1952) theory, Everett's (1957) theory and the Ghirardi-Rimini-Weber (GRW, 1986) theory (see also Bell 1987) are attempts not only to solve the measurement problem but more generally to come up with a realistic account of the mathematical theory that provides a clear cut description of what there is in the world and its evolution in time.

In this paper we focus on the GRW theory of spontaneous localization. According to the original GRW theory (1986; see Bell 1987) the wavefunction of every elementary material particle has a fixed probability per unit time (say, $10^{-8}$ per second) to undergo a collapse that localizes the particle in space. The probability that the wavefunction localizes around a given spatial point is given by the modulus squared of the wavefunction just before the collapse at that point. It is crucial to note that the GRW collapses are introduced as genuine stochastic variables. We apply the GRW prescription to the simplest case of a measurement and we show that the stochastic nature of the GRW collapses has anomalous consequence (with substantial probability to occur) in which the GRW theory breaks down in the sense that the localization of the wavefunction becomes ill-defined. In such cases, we show that the GRW theory fails to solve the measurement problem in quantum mechanics and more importantly *ipso facto* it fails to provide a realistic account of *what there is*. That is, in such cases the GRW theory *cannot* say anything about *which physical facts* obtain, including *macroscopic* facts such as pointer readings. We also show that this argument applies to all versions of the GRW theory (regardless of how the wavefunction is interpreted e.g. as describing the distribution of mass density or the probability distributions of flashes). In this abstract we don't provide the details of our argument; in the paper we

show that the GRW theory breaks in a relativistic setting in the same sense that Bohm's theory breaks down in its anomalous cases (see Albert 1992, Hemmo and Shenker 2013).

We show that our argument applies in both the classical and the relativistic settings. In the classical setting we explain how the problem may be partially solved by so-called "measure zero" arguments, given a choice of measure. However, we argue that the measure zero response is inapplicable in the relativistic setting of Minkowski's spacetime, since to circumvent our argument the GRW theory requires the introduction of a preferred Lorentz frame, which implies, in a realistic approach, an *absolute* reference frame. But this "solution" gives no hope for a fundamental realist relativistic interpretation of the GRW theory. In this sense our argument shows that the status of special relativity given the GRW theory is exactly the same as it is in the case of Bohm's theory (although for somewhat different reasons). That is to say, if one accepts the GRW theory, special relativity and Minkowsky's spacetime can only be understood effectively as describing what we can measure rather than as describing what there is. Our argument shows that the GRW theory cannot be coherently and realistically interpreted as a physical theory that accounts of what there is and how it evolves in time *without assuming a preferred Lorentz frame*, and therefore it is *incompatible* with the spirit of special relativity.

This result is very surprising, because as is well known, there is a relativistic version of the GRW theory (called rGRWf) in the framework of the so-called flash ontology (Tumulka 2006). We show, however, that our argument applies to *all* the versions of the GRW theory regardless of how the GRW collapses are interpreted and regardless of the interpretation of the quantum mechanical wavefunction, in particular of whether the wavefunction is taken to describe the distribution of mass density, as in Ghirardi (2016), Bedingham, Durr, Ghirardi, Goldstein, Tumulka, Zanghi (2014); or the distribution of discrete flashes in spacetime in the relativistic formulation by Tumulka (2006). Finally in the light of our results, and given the current state of the art, we discuss in the paper the deem prospects for a realistic interpretation of quantum mechanics that is compatible with special relativity. Since Bohm's theory and the GRW theory drop out as viable options (according to our argument) the only remaining existing alternative as of now is something along the lines of Everett's theory, which is notoriously extravagant and problematic as a realist theory. But this last issue is left for another paper.

**ORLY SHENKER**

**HEBREW UNIVERSITY OF JERUSALEM**

## ABSTRACT

Everett (1957) proposed his “relative state” formulation of quantum mechanics as an attempt to provide a realist interpretation of the mathematical formalism of quantum mechanics (and of course solving the measurement problem). A central notion in Everett's original formulation of his theory is that of an *observer*, in particular the *memory* of an observer and its evolution over time. It is quite natural to understand Everett's notion of an observer in the framework of a *physicalist* approach to the mind-body question. In this paper we examine whether a realist approach and a physicalist approach in Everett's theory are compatible with each other. We argue that these two approaches are *incompatible* in Everett's theory, and therefore one has to choose between them.

Very briefly Everett’s idea was that the Hilbert space mathematical formalism of quantum mechanics “yields its own interpretation” in the sense that nothing need be added to the formalism in order to understand it as describing physical reality. That is, according to Everett the quantum mechanical state of the universe evolves at all times in accordance with the linear and deterministic Schrodinger equation, and its solution at each time gives a complete description of what there is (e.g. physical facts, properties, etc.). Everett argued that after a measurement the quantum state of the universe consists of all components that correspond to the outcomes of the measurement, which have nonzero quantum probability (as fixed by the initial pre-measurement state and the Hamiltonian).

The crucial observation made by Everett was that after a measurement each component corresponding to the observer’s memory of the outcome of the measurement evolves separately in a way that satisfies the Schrodinger equation independently of the other components of the state (each of which exist equally in parallel to each other). Everett calls components of the universal quantum state that satisfy this condition of separate Schrodinger evolution *branches*. In fact, it is this idea that is supposed to replace in Everett’s theory the projection (collapse) postulate put

forward by von Neumann. Everett also attempted to prove that the Born rule probabilities would be the probabilities for measurement outcomes assigned by observers evolving along the branches (see e.g. recent discussions or versions of this last point by Deutsch 1999, Wallace 2012). Whether or not the argument concerning probability is successful is under dispute in the literature (see e.g. X), but we don't address this issue here.

In this paper we focus on the following idea: Our primary question is how Everett's notion of branches explains our *experience* and in particular our experience of determinate measurement outcomes from a *physicalist* point of view. To be specific we assume here a physicalist approach in which mental states, memories, etc. and our experience in general, are to be understood as strictly *identical* to *physical* states. (We shall comment also about other so-called non reductive views as we proceed.) The main argument of the paper is that given *identity* physicalism Everett's theory fails to account for our experience, and in this sense it fails to solve the measurement problem and to provide a realist interpreration of quantum mechanics in general.

Our reasoning goes as follows. In the literature it has been argued (e.g. by Zurek 1993; Zeh 2003, Zurek 1993, X??, and more recently Wallace 2012) that the decoherence interaction of macroscopic systems (such as our brains and measuring devices) with the environment implies that the components of the universal state which correspond to determinate memories and pointer readings (among other things) (almost) don't re-interfere because the different environment states that couple to these components become very quickly almost orthogonal and remain nearly orthogonal for very long times. In this way decoherence seems to justify physically Everett's original assumption that the components corresponding to different memory states of the observer presumably evolve separately and independently of each other and in this sense are indeed branches. We make here the reasonable assumption that the degrees of freedom in the brain in which memories are stored undergo environmental decoherence, but this assumption still needs to be studied. This means that the *reduced* state of the observer at any time shorter than the characteristic re-coherence time of the environment is almost diagonal in Everett's memory basis (for a finite universe). Supporters of Everett's theory who also endorse a physicalist approach may take this result as indicating that memory brain states associated with different superposed components that exist in parallel to each other represent determinate mental states (or experiences) of the observer just because the relative phases between these brain states become almost zero. Here the idea is that the fact that the relative phases vanish in the general superposition case is what physically makes this case identical to the case in which the universal state has only one component. From a physicalist point of view this explains why the experience of an observer associated with just a single component of the quantum state (with amplitude that is neither 0 nor 1) is *identical* with the experience of an observer in cases where this component is the entire quantum state (i.e. has quantum amplitude that is equal to 1).

Let us now phrase our central argument in the paper in the form of a dilemma: In Everett's theory one can either be realist with respect to quantum states, or else physicalist with respect to mental macroscopic physical states (such as pointer states). The reason is that as a matter of physical law environmental decoherence is only approximate at any finite time. *This means that Everett's theory is committed to the physical realization of identical mental states and identical pointer states by different (and heterogeneous) components of the quantum state.* Since decoherence can only be approximate, there infinitely many different bases in which the reduced state of the observer (and of measuring devices) are diagonal to the same degree. In order for Everett's theory to explain our experience this leads to massive multiple realization (not only with respect to mental states but also macroscopic 'pointer' states). This dilemma has the consequence that Everettians can either remain identity physicalists at the expanse of changing quantum mechanics, or else stick to current quantum mechanics and give up on physicalism. Finally we argue in the paper that one cannot circumvent our dilemma by adopting a non-reductive physicalist approach and thsu accepting both physicalism and Everettian quantum mechanics because as we show a non reductive approach which accepts multiple realization gives up both quantum mechanics and physicalism.

# PAULO CASTRO

**CFCUL**

I'm an Anthropologist, informally knowledgeable in mathematics, holding a Ph.D. in the Philosophy of Contemporary Thought. Presently a researcher in CFCUL, in the Philosophy of Nature Sciences Group, my work focuses on Quantum Physics, Nonlinearity and Eurhythmy. I'm interested in Epistemology of Physics, namely, unification requirements for phenomena description at different scales, and emergence phenomena formalization.

## ABSTRACT

The initial development of quantum mechanics was profoundly based on Fourier's framework and on the philosophical conclusions inspired by that same mathematical formalism. Working along his own interpretation of Erwin Heisenberg uncertainty relations, Niels Bohr proposed in 1927 the renowned Principle of Complementarity, the core assertion of contemporary Quantum Mechanics. With Max Born probability interpretation of the wave function, the theory became highly idealistic, even giving human consciousness the power to reify reality. On one hand, Bohr's philosophical efforts to understand reality would impose insurmountable limits to human knowledge about atomic reality. On the other hand, it would take all objects in the quantum realm to be devoided of any realistic substance, fully dependent upon human observation to exist, holding metaphysically in some kind of platonic potential state. As a final consequence, quantum reality stood apart from the macroscopic one, making it unlikely both scales to be described by a same theory.

Only recently, and following the suggestions of Louis de Broglie, was a non linear quantum theory developed using a non Fourier scheme. That is, a mathematical formalism where infinite waves spreading throughout the entirety of space-time were replaced by so called gaussian Morlet wavelets. These were understood as formal representation of undulatory perturbations in a subquantum medium, being thus far limited in space and time. The mathematical consequences of such a formal replacement led to a generalized set of uncertainty relations, from which Heisenberg relations are but a particular case. Furthermore, a similar philosophical approach to Bohr's own way of thinking, once applied to these generalized relations, allows for the formulation of what can be called Completeness Principles about the physical reality. The first one stating that Nature in his diverse aspects is a complete, consistent and intelligible unified structure. The second proposing that Nature can be physically described at all scales using both a causal undulatory scheme and a space-time local scheme, with variable accuracy dependence between the two descriptions, the Principle of Complementarity therefore becoming a particular epistemological assertion taken from the second Principle.

From all this it appears at least conceivable an unified description of physical reality, accepting that not only quantum systems, but all physical systems are objects simultaneously exhibiting corpuscular and undulatory properties.

**Keywords:**
Orthodox quantum mechanics, nonlinear quantum physics, nonlocal Fourier analysis, local analysis by wavelets, Fourier ontology, Heisenberg uncertainty relations, general uncertainty relations, Principles of Completeness.

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# POSSIBILITY OF FORKED PATHWAYS OF ONTOLOGY: SUPERPOSITION AND COLLAPSE AND VICE-VERSA IN AN APORIA OF EMERGING NOTHINGNESS

## PRASENJIT BISWAS

**DEPT. OF PHILOSOPHY,**
**NORTH EASTERN HILL UNIVERSITY,**
**SHILLONG, INDIA**

Prasenjit Biswas is an Associate Professor of Philosophy at North Eastern Hill University, Shillong, India. His latest book is Between Philosophy and Anthropology: Aporias of Thought, Language and Consciousness, Notion Press, 2017. His areas of interest are Continental Philosophy, Phenomenology and Philosophy of Science.

## ABSTRACT

Copenhagen Interpretation of Quantum Mechanics (QM) denies a system having well-defined incompatible properties, while Einstein, Podolosky and Rosen interpretation allows for incompatible properties to be part of a coupled system. A Coupled system has two components having two properties represented by A and B, each can have two values only ( + and – ).But this does not make QM a complete theory and hence Einstein and Bell gave rise to a class of theories called Hidden Variable Theories (HVT). According to HVT, famously stated by Bell inequalities , where inequalities are “observed to be violated”, as per Clauser, Horne and Shimony leading to obsolescence of HVT. As a result, the Classical mechanical understanding of observable and unobservable properties of matter is violated when the system behaves in a quantum way, that is, when numerous superposed states keep arising resembling a froth of bubbles. This turns into ‘a nonlocal temporal correlation of frequency-bin entangled narrowband biphotons with time-resolved detection’ as an experimentally observed state of the so called ‘spooky states’ that do not collapse into any classical and computable state. Aurther Fine provided the much needed explanation for this non-collapsed states by thinking about an ontologically privileged status to these states that are underdetermined or undermined by empirical data, when he argued against any correspondence between hidden stochastic variable and deterministic probability of these variables. This implied once again that superposed particles in non-collapsed states (eg., Schrodinger’s Cat) behave in states of superposition between non-local states and states of observation that also marks a shift from original superposition between entangled states of particles to a nonoriginal superposed states of observation of superposition. This is a superposed limbo that does not allow any consistent ontology, rather any ontologically superposed state is underdetermined by the observed superposition itself leading to an indeterminacy of physical measurement of violation of Bell Inequalities or any other such classical ontology.

The question is, can we have an alternative ontology that is consistent with mathematically and logically preferred expressions of indeterminacy? One might attempt to propose one. Magnitudes like position and momentum are expressed as

operators. For any operator, $A \mid \alpha_i\rangle = a_i \mid \alpha_i\rangle$, where $\mid \alpha_i\rangle$, are the eigen-vectors and $a_i$'s are the so called eigen-values of the operators in that state. By a well-known mathematical technique, we might generate a set of vectors, which would form a special kind of space called Hilbert space. In general any state can be written as a linear sum of one-dimensional vectors in this space. In other words for any state $\Psi$ of the system, we can write

$|\Psi\rangle, = \Sigma\, c_i\, |\alpha_i\rangle$, $c_i$ being complex numbers

A special type of operator, may be defined on this space as $P_{|\alpha i\rangle} = |\, \alpha_i\rangle\langle \alpha_i|$

So when it operates on the state $\Psi$, we get

$P_{|\alpha i\rangle}\, |\Psi\rangle = |\, \alpha_i\rangle\langle \alpha_i|\ |\Psi\rangle = \Sigma\, c_i\, |\, \alpha_i\rangle\langle \alpha_i|\, \alpha_i\rangle = c_i\, |\, \alpha_i\rangle$

This operator effectively "projects" on a subspace $|\alpha_i\rangle$ so they are called projection operators. Finally $\Sigma\, P_{|\alpha i\rangle} = I$ the identity operator. It is so called because when acts on any state $\Psi\rangle$ we get back the state itself.

We now use this operator to show that any operator, Q, can be written as

$Q = Q.I = Q\, \Sigma\, P_{|qi\rangle} = \Sigma\, Q\, |q_i\rangle\langle q_i| = \Sigma q_i\, |q_i\rangle\langle q_i| = \Sigma q_i\, P_{|qi\rangle}$;

given that $Q\, |q_i\rangle = q_i\, |q_i\rangle$

This is the well-known spectral decomposition theorem.

Then any operator A may be written as $A = \Sigma\, a_i\, P_{ai}$, $P_{ai}$ being the projection operators.

If A and B are two non-commuting operators, such that

$A|\, \alpha_i\rangle = a_i\, |\, \alpha_i\rangle$ for i = 1,2,3 and

$B|\beta_i\rangle = b_i\, |\beta_i\rangle$ for i = 1,2,3

Assuming that $|\, \alpha_i\rangle$ form a complete set and so is $|\beta_i\rangle$, any vector, $|\beta_1\rangle$ say, may be written as linear combination of $|\, \alpha_i\rangle$ that is

$|\beta_1\rangle = \Sigma c_i\, |\, \alpha_i\rangle$. Expectation of B in state $|\beta_1\rangle$,

$\langle \beta_1\, |B|\beta_1\rangle = \Sigma\ c^*_1\, c_1\, \langle\alpha_i\, |B|\, \alpha_i\rangle$

But B can be written as $b_i\, P_{bi}$ and $P_{bi}$ is $|\beta_i\rangle\langle \beta i|$, so we get a definite number as result of this exercise. This shows that there is a definite probability of getting a definite value for a particular observable even if the system is in an eigenstate of an incompatible observable. That is, we start with $|\beta_i\rangle$ and get terms like $\langle \beta_i|\, \alpha_i\rangle$. The same exercise can be done in the reverse. Usual interpretation of this is taken as literally, collapsing the wave function as a result of measurement. In the process of reaching this conclusion they invoke:

that due to uncertainty relation, A can not have a definite value in state $|\beta_i\rangle$ and

eigenvalue – eigenvector link, that is, to have a definite value an observable must have probability 1 which is possible only if the system is in the eigenstate corresponding to the eigenvalue . Projection operators are also quantum operators and in case of incompatible observables they do not commute.

Since the expectation of an observable in a state is the probability of the corresponding projection operator, it is only to be expected that quantum algorithm does not produce joint distribution for incompatibles. At the same time the above exercise clearly shows that all the quantum probabilities can be generated by using projection operators alone.

The probability generation method of recording the detectible state of particles does not either lead us to detectible token record or to record of detection of these tokens and there is an emergent incompatibility between detectible and the non-detectibility of the act of detection. So this is a state of Quinean inscrutability that does not allow determination of a value of the quantum variables creating perpetual 'ontologiccal relativity'. What could only be traced here is the 'information exchange' between superposed states that can assume a second order non-collapsed probability waiting to be collapsed as an observable. The paper proposes a deflationary truth asymmetry here as an alternative to an ‘alternative ontology’ whose key proposition would look something like ‘superposed states are observable’ is true if an only if the ‘observed’ superposition is an observable ;while the fact remains that observed superposition collapses into an observable classical state. This asymmetric position that nonclassical states exist because they are observable and as they are observable, they become classical states by violating the laws of determination/measurement can act as a model for the multiverse or parallel worlds at a distance. What is philosophically interesting here is a proliferation of an ontology of collapse that defies stable measurement/interpretation in order to open up many more superposed states in an open-ended manner with a “tendency to display a certain actual property”, over and above the actual properties like position and momentum at a particular instant. This is also something out of nothing in which nothing reigns over something as a metaphysical aporia.

# FINALISM AND EQUILIBRIUM: AN APPROACH OF ARISTOTLE AUTOMATON TO BIOLOGIC THERMODYNAMICS

## RENATO MARTINS

**CFUL**

Renato has a Masters Degree in Philosophy from the University of Lisbon. Renato's main areas of research are related to technology issues such as Cybernetics, Information Theory, Artificial Intelligence and Man-machine interaction in contemporary culture. Often organizes and participates in philosophical forums aimed to general public concerning topics such as modern problematics related to Image, Economical paradigms and Internet culture in daily life. Teacher of Philosophy, Psychology and Citizenship at the Secondary level

## ABSTRACT

Purpose has been a key word for the definition of biological activity in animal behavior as well for directed creativity in human nature. These two operations were modernly studied with similar methodology as the use of a mechanical principle is able to determine future execution in both instinctive and aware goals of the organism. The demonstration of mind proposed by Behaviorism submits free will to the surroundings of a sensitive body immersed in space, but also configuring it's entity in retention and memory as a historic and cultural construction evaluated by tradition. In both cases of animal behavior and human psychic, science qualifies the act of becoming in living organisms as a mysterious joint between volition codified in DNA sequence and will activated by situation demand as outcome from individual singular memory. After long research in DNA, individual memory is still a key point in discovering heuristic models of behavior since it shuffles human faculty of subjectivity. The future and the act of becoming in individual organisms is still faced with contingency as proposed mechanical model for nature isn't able to assure the permanence of its laws. Against the deterministic law conception, vitalism attempted to find hidden qualities and substances *ex-machina* such as the Equifinality in Hans Driesch or the Élan Vital in Henri Bergson. In the middle of the 20th Century two models tried to surpass the remaining occultism in vitalism: Theory Systems and Cybernetics. The first of this conceives steady state as the purpose of an opened learning upgrade organism against modern age mechanical body. Cybernetics sets feedback as purpose. In this conception informational stimulus avoid behavioral loops by controlling the experienced situation with reversed conditions. Theory of Systems inherits the sense of will in the organism, not in the way of random activity but setting the goal in stability and self-organization. Cybernetics considers communication as the factor of the function of the organism and the physical entity is still regarded as receptive and reinforced in its activity for temporarily crisis due to the complexity of entropy. The response of a deficit is made in similar of energy loss: the adding of information coordinates the organism with life's situational need. In a different way, for the Systems Theory the fulfilment of the organism is the beginning of its decay as the closeness of inputs correspond not to the desired equilibrium but to the stationary

state where evolution, creativity and knowledge stops. The organism find confinement in the laws of deterministic physics seeking constant conservation as proposed by the first law of thermodynamics. By the assurance of the second law, diversity demands physical interaction by means of sensitivity or communication leading the organism to its adaptability. Both of responses to the entropy problem, Systems Theory and Cybernetics, withdraw from a Universe governed by laws that might assure the future situations, and deny repetition of events. Contingency is regarded as background force affecting physical biological entities that outcomes disentangled parts, disconnected from a hypothetical hierarchical identity force.

Aristotle denoted the bigger unit overlapping sub-parts working with common frames, proposing the whole as bigger than the sum of its parts – "the whole is a certain type of unity" (Metaphysics, V, 26). As Aristotle defined its order of Nature as a Cosmology of quality that preceded the quantitative physics of modernity, the events which escapes from natural flux couldn't be characterized as exception in a finite and finalistic Universe. Alacrity as a minor act of rebellion towards efficient causality was inscribed in the definition of "Automaton" concerning non-rational purpose and material organic unexpected happenings (Physics, II, 6). This operation was not a kind of vital force inherent to some organ, instead, a not expected action from external nature to the object lead to it. Regarded as an incident that surpassed the original order tended to natural things, the becoming act of the automaton does not turn in a creative process, since the intellection of teleology is a precedent presence in the event, which in time leads to the analogous Contemporary conceptions of regeneration and equilibrium. In this case, we have teleology but not purpose, and the similitude with the controlling method of creative growing of Cybernetics is invalid (Rosenblueth A., Wiener N. & Bigelow J., 1943, Behavior, purpose and teleology). Regeneration without causal chain and finalism without determinism was a topic for the late stage of vitalism in biology resurging the necessity of Entelechy (Hans Driesch, 1908), but the propose of the equifinality problem by Bertalanfy makes the approach of a natural sense and the goal for steady states in organisms as systems. Casual events don't have in contemporary biology a backgrounded controlling intellect that assure organism falls in the harmony of the stars as Aristotle proposed, but, the direction to a stationary state without achieving it concerns the dynamic of the open system to the contingent and disorder world that characterize today physics conception. As Bertalanfy stated there is no choice for a static teleology, nor similar finalism following different paths, nor a code of procedures inside a structure controlled by feedback mechanisms. In the first case determinism continues as the paradigm of nature; in the second genetic code prevails and there's no evolution; in the third intellect organizes directiveness. As System Theory proposes, the Aristotelic teleology regard the goal as something present in the entity, ensuring equilibrium and homeostasis as natural processes for physical entities.

The objective of this communication is to find similarities between Aristotle incidental happenings in the organism with the fortuitous affections of oppositional forces in interactive systems concerning the emergence of conservation and the evolutionary creativity of adaptation.

# RUI MOREIRA

**FCUL**
**CFCUL**

Rui António Nobre Moreira licenciou-se em Engenharia Mecânica, ramo de Termodinâmica Aplicada, pelo Instituto Superior Técnico de Lisboa em 1973, e realizou doutoramento em História e Filosofia das Ciências pela Universidade de Lisboa em 1993 com a tese Contribuição para o estudo das origens do princípio da complementaridade. Foi, desde 1985, Professor Auxiliar no Departamento de Física da Faculdade de Ciências da Universidade de Lisboa. A partir de 2007 é professor da Secção Autónoma da História e Filosofia das Ciências, actual departamento de História e Filosofia das Ciências. É desde Janeiro de 2017 o Coordenador Científico e o Investigador Responsável do CFCUL.

## ABSTRACT

Quantum Physics has been shown to us that we must look at all kind of natural entities from a quite different perspective. From a realistic point of view, we must consider them all as complex structures that react accordingly to the information they change with their environment and, evidently, within their own structural capabilities. Within Louis de Broglie and David Bohm proposal of the existence of a subjacent subquantum medium, and within Croca's eurythmic principle, we dare to propose a new terminology to designate all natural entities, namely physical, chemical, biological, social and finally noetic ones.

**Keywords:**
eurythmy, syngenesis, physionoomas, symphysiogenesis, chemionoomas, synchemiogenesis, symbionoomas, symbiogenesis, socionoomas, synsociogenesis, noonoomas, synnoonoomas

# THOMAS DE SAEGHER

**UNIVERSITY OF WESTERN ONTARIO**
**THE ROTMAN INSTITUTE OF PHILOSOPHY**

I am a 4th year PhD student in the Philosophy Department at the University of Western Ontario and a member of the Rotman Institute of Philosophy. My interests lie in philosophy of physics, especially the foundations of quantum mechanics, as well as the nature of semantic content and the task of interpretation for physical theories. Before Western, I did my Bachelors in Physics at the University of Toronto and then my Masters in History and Philosophy of Science at the Institute for History and Philosophy of Science and Technology, within the University of Toronto. As one might guess, I am Canadian and I grew up just outside of Toronto.

## ABSTRACT

There are plenty of reasons to adopt an ontic view of the quantum state (Brown, 2017), and plenty of standard full interpretations that already assume an ontic construal. A number of proposals fleshing out this ontology of the state are also now available, like wavefunction realism (Albert and Ney 2013), spacetime state realism (Wallace and Timpson, 2010), Deutsch and Hayden's Heisenberg inspired ontology (Timpson, 2003) and Saunder's (1997) relational ontology. However, there is currently no general account of what it means to ontologize the quantum state; there is nothing like a set of criteria for when one has provided such an ontology that rules out some substantive class of proposals. This is despite claims (for example, Maudlin, 2014) that the spacetime state realist ontology in the Oxford-style Everettian approach has not really laid bare what exists. The purpose of this paper is, therefore, to provide a framework for saying when one has presented an ontology of the quantum state. The framework will be constrained by issues with relying on a definition of the physical, the nature of what is actually supported by arguments for the ontology of the quantum state, and the nature of the specific problem (the Maudlin-Wallace disagreement) which a clearer view of the meaning of the ontic construal is supposed to resolve.

A starting assumption in the literature is that the ontology of the state expresses a physical property attributed to an individual prepared system, and, therefore, it seems we have to elucidate what it means to construe the state as a physical property. However, such a construal is part of the project, taken as suspect by van Fraassen (2008), of elucidating a target system when our only knowledge of the system comes from the theory in which it is already expressed. The concern is roughly that, if ontologizing the quantum state is a matter of setting up a relationship between the mathematical state and something physical, and we only have the mathematical significance to characterize physical domain relatum, then it is not possible to define the relation. Using further resources to characterize the physical domain still must address a number of classic arguments that the relation with the mathematical state will be trivially satisfiable or not well defined. For example, Newman's problem and

Putnum's paradox illustrate how almost any physical system could be seen as a model of a given formal structure. The Lewisian solution to problems of this sort is to introduce a pre- established class of things from which we pick the physical relatum in relation to the state. As emphasized in Caulton 2015, the class of things defining what we mean by the physical domain cannot be too large or too small without making the relation with the state basically always satisfied or never satisfied. But, in most definitions of what it means to interpret a theory (that maintain the underlying picture of a relation with the physical), what exactly this domain of the physical should include is purposely left open (Reutche, 2011 explicitly takes note of this) . 'Physical' is taken as a placeholder for whatever a future theory in physics happens to be about because a theory with an interpretation that is only expected to discharge theoretical virtues internal and external to the theory makes no obvious or terribly restrictive presuppositions about the domain of physical things it can discuss.  Thus, the standard conception of interpretation, of which the task of ontologizing the quantum state is a part, seems to require a substantive delineation of what is physical to define any relation we would want to take to be interpretive but cannot be committed to a view of the physical for 'interpretation' to be what discharges theoretical virtues.

Given this deep impasse, I look for a characterization of the task of ontologizing the quantum state where it is not a matter of setting up a relation between the state and some domain of physical things. Luckily, Wallace's numerous discussions of the e-e link (Wallace, 2008 is an example) provide the beginnings of a useful template. What seems to be distinct about ontologizing the quantum state from non-ontic construals is that not all properties of the system are representable with projectors on Hilbert space. For example, being an entangled state is a physical fact about the system in ontic views but there is no projector on Hilbert space that projects onto only states that are entangled. Thus, we have a way of distinguishing when the quantum state is being ontologized from within the formalism of the theory itself: when there is further structure being added to the state beyond whether it is in the subspace of a given projector on Hilbert space. There has to be a clear formal difference in the way some properties are expressed from projectors on Hilbert space for the criteria for having ontologized the state to be determinate. Additionally, there are problems that have to be solved by ontologizing the quantum state in a certain way, so the extra structure needs to be expressed in a particular manner, and, to resolve Maudlin's worry from above, I argue it is sufficient to think of the extra structure that comes with ontologizing the state as extra mappings from Hilbert space to itself that have traditionally been conflated with identity operators.

This way of defining the task of ontologizing the quantum state sidesteps having to explain what makes the properties attributed to the systems physical, which has the issue outlined above, by distinguishing these properties in another way internal to the formalism of quantum mechanics. But there are worries that this view fully explains the role that ontologizing the quantum state is supposed to play in resolving interpretive problems and being supported by certain evidence, so the bulk of the paper argues that it really is extra structure distinguished and defined in this way that is supported and at work in the theory.

# VASIL PENCHEV

**BULGARIAN ACADEMY OF SCIENCES: INSTITUTE FOR THE STUDY OF SOCIETIES AND KNOWLEDGE: DEPT. OF LOGICAL SYSTEMS AND MODELS.**

Vasil Dinev Penchev (born in 1958, Sofia, Bulgaria). PhD (1995), Assoc. Prof. (2003), DSc (2009), Institute for the Study of Societies and Knowledge, Bulgarian Academy of Sciences (http://issk-bas.org/logical-systems-and-models/); CV: http://old-philosophy.issk-bas.org/CV/cv-pdf/V.Penchev-CV-eng.pdf; an e-mail: vasildinev@gmail.com; scientific blogs posting the most publications: http://www.scribd.com/vasil7penchev, http://vasil7penchev.wordpress.com/ .

**Education:**
MSc (Electronics), Technical University – Sofia, 1983.
M.Sc. degree: Sofia, 1978– 1983, Technical University of Sofia, Department of electronics.
Ph.D.degree: Sofia, 1991–1995, University of Sofia ''St. Kliment Ohridski''; Dept. of philosophy; Ph.D. thesis: "Reality as continuity. An approach to the interpretation of quantum mechanics and the special theory of relativity" [1], [3].
D.Sc. degree: Sofia, 2009, Bulgarian Academy of Sciences, Institute for Philosophical Research.
D.Sc. thesis: "The philosophical foundation of civilization approach in history" [8], [9], [11].
Affiliation: Bulgarian Academy of Sciences: Institute for the Study of Societies and Knowledge (2010)
Bulgarian Academy of Sciences: Institute for Philosophical Research (2003-2010)
University of Sofia ''St. Kliment Ohridski'', Department of philosophy (1997-2003)

**Areas of scientific research:**

Philosophy of physics (quantum mechanics and quantum information [2], [3])
Philosophy of computation and information (quantum computer and quantum information [3], [5])
Philosophy of science (ontology and epistemology of science [1])
Philosophy of mathematics (foundation of mathematics [3], [4])
Degrees and academic ranks: Associate professor, Doctor of Science

**A few monographs: (almost all are available in the scientific blogs above):**

[1] Being and Science (Sofia: LIK, 1996).
[2] Physical Paradoxes in a Philosophical Interpretation (Sofia: LIK, 1997).
[3] Philosophy of Quantum Information: Einstein and Gödel (Sofia: IPhR-BAN 2009).
[4] Matematization of History (Sofia: Centre for Social and Humanitarian Research, ISBN 978-954-8481-02-1).
[5] Beyond the Turing Machine: Quantum Computer (Sofia: "East – West", ISBN 978-619-152-155-5).

## ABSTRACT

**Background and prehistory:**

Quantum mechanics was reformulated as an information theory involving a generalized kind of information, namely quantum information, in the end of the last century. Furthermore, quantum mechanics is the most fundamental physical theory referring to all claiming to be physical. Thus, any physical entity turns out to be quantum information in the final analysis.

That deduction can be reproduced very easily:

Any quantum state of any quantum system (what anything is) is a wave function, i.e. a point in the complex separable Hilbert space (which is the basic mathematical formalism of quantum mechanics). Then, any wave function can be represented as a series of quantum bits (qubits).

A quantum bit is the unit of quantum information, and it is a generalization of the unit of classical information, a bit, as well as the quantum information itself is a generalization of classical information.

The philosophical meaning of the generalization from classical to quantum information can be represented not less simply:

Classical information refers to finite series or sets while quantum information, to infinite ones. If a bit represents the choice between two equally probable alternatives, a qubit is the choice between an infinite set of alternatives. The definition of a qubit in quantum mechanics is different, but equivalent to the one suggested here.

**Problem:**

Quantum information as well as classical information is a dimensionless quantity. If it is the overall substance of anything claiming to be physical, one can question how

different and dimensional physical quantities appear both originating from it and reducible to it.

Furthermore, quantum information can be considered as a “bridge” between the mathematical and physical. The standard and common scientific epistemology, on the contrary, grants the gap between the mathematical models and physical reality. The conception of truth as adequacy is what is able to transfer over that gap. One should explain how quantum information being a continuous transition between the physical and mathematical may refer to truth as adequacy and thus to the usual scientific epistemology and methodology.

**A short comment to the problem:**

The two fundamental theorems of Emmy Noether (1918) should be involved. They determine the links between what conserve, e.g. energy, and what change, e.g. time, in any physical system. The product of the former and latter has always the physical dimension of action (what the dimension of the fundamental Planck constant is) and thus, it can be interpreted as the physical quantity of action.

If what is changed is physical action, the theorems of Emmy Noether imply that what is conserved should be dimensionless. Quantum information seems to be an admissible applicant for the counterpart of action.

**Thesis:**

Quantum information is conserved, being the counterpart of the changing action. If the change of action is uniform in time, energy is conserved. However, quantum information is conserved more universally for however the action is changed (i.e. not only uniformly), its counterpart of quantum information is conserved.

**A few corollaries from the thesis:**

1. Quantum information is the real substance of the world for it is conserved always. That conclusion is consistent to the interpretation of any wave function as a value of quantum information and thus as the universal physical substance of the world.

2. What is changed, namely physical action, appears necessarily in virtue of Emmy Noether’s theorems as the counterpart of quantum information once it is conserved always, i.e. universally.

3. Generalizing philosophically, the being (or at least the physical being) appears necessarily in virtue of mathematical laws rather than randomly not needing any “creator” or other “ultimate cause” to be.

4. Quantum information and action are the same seen from two disjunctive viewpoints correspondingly as what is conserved and as what is changed. Thus, they do not need the concept of truth as adequacy necessary to link them over the gap for they are the same by themselves.

**A few arguments for the thesis:**

1. Noether’s theorems imply only that the counterpart of action has to be dimensionless as a physical quantity. Thus quantum information is not more than a possible applicant for it satisfies that condition. However, the contemporary science cannot suggest any other applicant fundamentally different.

2. The fundamentality of quantum mechanics reformulated successfully in terms of quantum mechanics is an argument for it, too.

3. The fundamental Planck constant having the physical dimension of action allows of any physical action to be juxtaposed a natural number, which can be interpreted as a number of bits of information. Quantum information by means of

quantum bits can be interpreted as the choice of a certain number of bits among all natural numbers.

4. Quantum information meaning the number of choices among an infinite of alternatives can be interpreted as the conservation of openness for choice as the necessary condition of any physical change. That openness can be further identified as the openness of the present or in other words, as the availability of the present always as that, in which any physical change can occur.

**Conclusions:**

1. Quantum information can be discussed as the counterpart of action.

2. Quantum information is what is conserved, action is what is changed.

3. The gap between mathematical models and physical reality, needing truth as adequacy to be overcome, is substituted by the openness of choice.

4. That openness in turn can be interpreted as the openness of the present as a different concept of truth recollecting Heidegger's one as "unhiddeness". Quantum information as what is conserved can be thought as the conservation of that openness.