WHAT DOES A NEW SCIENTIFIC SPIRIT MEAN? BACHELARD FROM THE THIRTIES OF THE LAST CENTURY AND THE SCIENCE OF OUR DAYS

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ABSTRACT

My paper relates Bachelard's main epistemological thesis – the *new scientific spirit* – in the 30s and some present tendencies in science.

In its "Noumène et microphysique", from 1931, Bachelard reveals a revolutionary change in the 20th century natural science: the definite proof of insufficiency of the traditional *pattern* of experimental physics of macro-bodies and searching for observable causes – where the *starting* point of the research was the *empirical* observation, where the *end* was to measure the material elements and the values of movements, where the pattern of decomposition were the object and at the same time the aim of researchers – to a complex "intellectualist" model where the most important moments of the research are the (new) theories/new conjectures which no longer assume the logic of isolating the phenomena from their context, where these phenomena are rather *relations* and *effects* than material particles, and where the scientific theory follows just the *relations* and *effects* which constitute the new objects, and not so much the material objects as such as in the Newtonian science. And: where the understanding of this relational reality is the result of mathematical *forms* which are not a simple calculus of visible phenomena, but expressions of the internal deep constitution and laws of existence. In this new type of research, the empirical observation is only a starting point and a moment between the theoretical construction and its mathematical clearer manifestation and proof back and forth.

All these elements are developed by Bachelard and are considered here as a mirror (or, rather, a beacon, or, not in a metaphorical language, a criterion) for the present epistemology as this one is visible in some aspects focused on by the present sciences. Indeed, nowadays – and in the trail of Bachelard – and though there is an inertial tendency to put only physics at the origin of the scientific knowledge of the world (and in this sense, to confront the classical model of Newton and Einstein physics), epistemology considers at least three aspects configuring the scientific outlook and, perhaps, world-view: the sciences of the living, giving us new ways of understanding, including the inanimate material logic as well as its qualitative progress; the inter and trans-disciplinary relations of the scientific steps, giving new realms of the world; the holistic approach as methodology and (practical/technological) representation of the world. Therefore, the evolutionary epistemology – whose early representative was Bachelard – allows us to use the same comparative pattern, but concerning a broader space and leading to more refined perspectives about the world.

KEYWORDS: Gaston Bachelard, Newtonian physics, Cartesian science, quantum physics, mathematics, quantity, quality, scale, philosophy, objects and relations, *noumen*, holism, mater, energy, information.

1. Instead of introduction

In its "Noumène et microphysique", from 1931, Bachelard reveals a revolutionary change in the 20th century natural science[2]: the definite proof of *insufficiency* of the traditional pattern of experimental physics of macro-bodies and searching for causes – where the starting point of the research was the empirical observation (considered as giving all at once the "*a priori* clarity" of thoughts reflecting exactly the observed world[3]), where the end was to measure the material elements and the values of movements, where the pattern of decomposition were the object and at the same time the aim of researchers – to a complex "intellectualist" model where the most

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[2] Gaston Bachelard, *Le nouvel esprit scientifique* (1934), Paris, PUF, 1968, p. 37: there is no transition/continuity between Newton's and Einstein's physics, they are absolutely opposed.

[3] *Idem*, p. 33.

important moments of the research are the (new) theories/new conjectures which no longer assume the logic of isolating the phenomena from their context, where these phenomena are rather relations (or forms)[4] and effects[5] than material particles, and where the scientific theory follows just the relations and effects which constitute the new objects, and not the objects as such. And: where the understanding of this relational reality is the result of mathematical *forms* which are not a simple calculus of visible phenomena, but expressions of the internal deep constitution and laws of existence[6]. In this new type of research, the empirical observation is only a starting point and a moment between the *theoretical* construction and its *mathematical* clearer manifestation and proof back and forth.

All of these were developed by Bachelard and the meanings of these developments constitute the first goal of this paper: actually, as they were for Bachelard too. The second aim here is to put face to face the coherent early quite revolutionary epistemological insight of Bachelard and some present tendencies in science.

From the above scarce spotting, one already may degage at least three aspects emphasised by Bachelard and then becoming cardinal ideas in the second half last century and present-day's epistemology:

- the first is the *possibility* of *revolutionary* transformation in the scientific knowledge (towards the old common modern assumption of progress through "quantitative" acquisitions which only deepen the fathoming of the external, absolutely objective and autonomous object; this object would reveal itself, would be unconcealed – if I may borrow a famous term from Heidegger – through the agency of the benevolent and external to it scientist);
- the second is just that the epistemological (philosophical/ external to science/critical) standpoint is that which shows the revolutionary change of science, and makes science aware of its own state: concretely, this change was just the transition from the above-mentioned naïve realist image about the independent object and its relation with the knowing subject to the, let say, Kantian constructivism tradition where the object is, though objective, subject (and context) dependent; or, more precisely, where "one finds more in the hidden real than in the evident given"[7]; however and though the objective object exists, the *object of science* (as it is revealed by science) is neither absolutely known, it does not superpose to the objective object and nor to the previous illusions about the "empirical block"[8], as well as it is not divided into the knowable evidence and the mysterious thing-in-itself of Kant[9], but it is the result of a permanent process of historical and practical critique of theories, and may be better "expressed through metaphors"[10], only the relations being sure; therefore, the revolutionary change is from the *naïve realism* to the *classical*

[4] As said Henri Poincaré, *La science et l'hypothèse* (1902), Paris, Flammarion, 1968, p. 49.
[5] This relational standpoint belonged also to Aristotle and Leibniz.
[6] Gaston Bachelard, *Le nouvel esprit scientifique*, pp. 63-64: the charge numbers of all particles – where "the *number becomes an attribute, a predicate of the substance*" – give the specific of electrons, atoms and molecules, and of their position in material structures. And "philosophically speaking", this mathematisation of the behaviour and singularity of matter reflects and corresponds to the relational essence of matter: "it is the exclusion of *the same* and the appeal to *the other*. Within the interior of every system, more, for the elements form a system an essential mathematical diversity between the components is needed".
[7] *Idem*, p. 28.
[8] Gaston Bachelard, "Noumène et microphysique", in Gaston Bachelard, *Études*, Présentation de Georges Canguilhem, Paris, Vrin, 1970, p. 13.
[9] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 9: The real that corresponds to the new realism (of second order, passing through the experimentation of the mathematised theories) "is not thrown into the realm of the unknowable thing-in-itself"; "it has a different noumenal wealth".
[10] Gaston Bachelard, "Noumène et microphysique", p. 15.

rationalism which is the idealistic consequent and correlate of the first, and the "*dialectical rationalism*" that unites the subject and the object in a historical critique emphasising the ruptures in the process of science and that only together may the opposite methodologies (as realism and rationalism) explain the world; at any rate, the new physics reveals the *noumen* through the mathematical construction of the scientific objects and laws[11];

- and the third is the *contents* involved in the revolutionary change and emphasised, also, through epistemological analysis: the *manner* to tackle the object and the theoretically analysed *means* of this tackling.

The second aspect was developed by Bachelard as the *mutual dependence* of the object and the subject/the scientist: the latter is object dependent in that as its research, new hypotheses and reasoning depend on the state of the object resulted from the previous decomposition and assumptions. And since science is always critical and its search for a better acumen of the object follows inexorably, it (science) is at the same time a *permanent* refutation of its former "illusions". Concerning the object, Bachelard has transposed into both cold epistemology and warm poetic philosophy the new fact the new science has provided: that the scientific object is not tantamount to the external nature but is constructed and historical.

2. The steps of the scientific growth

Bachelard was one of the first philosophers analysing the development of the modern science in a complex *historical* way[12] and pointing the revolutionary moment of the 20th century physics. His tableau of steps of the modern scientific thinking contains: (1) the *pre-scientific* period covering the classical antiquity, the Renaissance and the transitional moment of the "16th, 17th, and even 18th centuries"[13]; (2) the *scientific* stage from the end of the 18th century to the beginning of the 20th, and (3) the '*new scientific spirit*'" certified in 1905 "when the relativity of Einstein has deformed primordial concepts thought to be forevermore immovable. Starting from this moment, the reason multiplies its objections, discriminates and relates the essential concepts, tries the bolder abstractions"[14]. And, obviously, to this spirit a state of the soul characterised by a sickness generated just by the necessity but the difficulty of this new type of abstracting – and opposite to the simple naïvely curious soul (a childish soul) and to the "professorial" soul, "proud of its dogmatism and immobile in its first abstracting" – corresponds[15].

Science advances through its self-critique[16], and just this process allows both the *accumulation of rectifications* and the *revolutionary changes*[17]. The first aspect emphasises the awareness of contradictions between different theories and different suppositions. And the more the scientists have approached to and exercised the understanding of contradictions, the more the problem to solve them appeared as not only a question of choice between contradictory theories, but also as a possibility to synthesise them in a "third" variant[18]: what in the traditional logic was the absolutely impossible excluded third in the law of non-contradiction, was to become later on the included third etc. But for this overthrowing, the change of existent paradigms of the scientific

[11] *Idem*, p. 19.
[12] Bachelard is a forerunner of Thomas Kuhn.
[13] Gaston Bachelard, *La formation de l'esprit scientifique. Contribution à une psychanalyse de la connaissance objective* (1934), Paris, Librairie philosophique J. Vrin, 1967, p. 9.
[14] *Ibidem*.
[15] *Idem*, p. 12.
[16] *Idem*, p. 13.
[17] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 44: "It is in the moment when the concept changes its meaning that it has more meaning. Then it is, in all its truth, an event of conceptualisation".
[18] *Idem*, p. 11: "the *why not* rationalism".

thinking had to occur. And once born, the new science shows that it is not contradictory to the old one, but only different towards it: because they refer to *different* aspects of reality (macro-bodies, the micro-world).

3. The revolutionary meanings of the new physics of the 20th century

Not things (*choses*) but relations: this is *le mot d'ordre* of the new micro-physics[19], more, of the new science. From this, a multiplication of the ultimate constituents of reality, in fact a multiplication of the forms (in Aristotle's meaning) giving the new "substances"/ quantum *objects*: particle and wave, identity of being and its movement/becoming. However, not the form – related to an "original" and fixed material thing/object – is the cause of the change/movements through which a particle receives or abandons energy, but just this movement is the cause of the form and change of form of matter[20]. The origin of causality is not the form, but movements in their various manifestations.

"Does one need to speak about complementary aspects or about complementary realities?"[21] The question is basic, because it suggests at the same time that the *new forms are not simple qualities of the old ontological objects* as the matter of the traditional "massive, strapped up materialism" "serving as target for the simple criticism of the idealist philosophy" – as latter on has Bachelard punctuated[22] – and that the new discovered objects are the results of a different tackling through the emphasis of not the simple relations of appurtenance of qualities to the old objects but of the *organic constituency of these objects through the medium of relations* as such. And every form – particle or wave – is no longer the "Object" (the immutable and final absolute brick of reality), but rather a means to grasp the relations through which it constitutes. Why this? Because relations are not outside matter/materialism, they are not "more important" than matter, but because they are "material", they cannot occur without matter[23]: as the latter cannot exist without relations. (Only in this sense can we assess that the new physics has "de-materialised materialism"[24]: only the old, naïve materialism). But also because the *scale* of nature is essential for the presentation of forms: "The substance of the infinitely little is superposed to the relation"[25], only the level of "macro-bodies"[26] allows the univocal consideration as solid and measurable. Consequently, somehow "the most obscure metaphysical crux is situated at the intersections of spatial and temporal qualities"[27].

Epistemologically, the "old" science has considered its material objects as given and as the bearers of its consistency, while the relations between objects being hypothetical. The old metaphysics – not in its entirety, of course – and the Newtonian science have considered the material bodies separated from action/movement: these bodies were the bearers of movements, as prime entities which were moved. The new physics overturned this view: matter cannot be

[19] As have considered Bohr (The Copenhagen school) and Whitehead.
[20] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 54.
[21] Gaston Bachelard, "Noumène et microphysique", p. 14.
[22] Gaston Bachelard, *Le matérialisme rationnel* (1953), Paris, PUF, 1972, p. 10.
[23] As discontinuous, mobile, and with waves/radiation as intermediary between molecules, is it (see Jean Perrin).
[24] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 54.
[25] Gaston Bachelard, "Noumène et microphysique", p. 15.
[26] Actually, it is about different species, and scales, of medium-bodies, between the micro/quanta/nano-, and on the other hand the macro-bodies of cosmology. Gaston Bachelard, *Le matérialisme rationnel*, p. 22, mentioned that the medium size common solid bodies whose constitution and movement is explained by the "*méso-physique* ", and not by the quantum mechanics, lie between the entities studied by the "micro-physics" and the "macro" one.
[27] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 50.

described outside movements[28], (energy is "an intermediary between objects and movements"[29] and thus is both a criterion of measurement and of mutual transformations of movements in objects and of objects in movements), only the relations are sure, their results as entities are represented "through metaphors" (this is my formulation, reflecting the fact that atoms and quanta are not seen as such, but only as results/relations)[30], and as phenomena are hypotheses. Accordingly, a gap between the traditional empirical facts as structuring factors of the scientific research and the "new" facts resulted from the quantum mechanics was comprehended: therefore, just this new theory becomes the structuring factor of the following research. The immediate description of reality is transforming thus into a "work phenomenology"[31], the phenomenon as such corresponding to this immediate observation being only an external starting point[32], a moment in the new method, of the scientific research.

Actually, not even the end of research does "highly scientifically" configure the "facts", but rather the *effects* of the relations described during the whole inquiry. These effects are the new phenomena which are not discovered, but constructed, and always both theoretically and practically (with technological means), and thus micro-physics becomes a "phenomeno-technique" (*phénoménotechnique*[33]).

One approaches to the authentic, that is to say the specific manifestation of the object when this one takes the mathematical form inside the quantum theory: only this form reflects the *noumen*, the essential deep correlations of the material world whose phenomena are only appearances[34].

The process of understanding the *noumen* entails the expressing of the unseen moving quanta into unseen mathematical objects (*formulae*) by the instrumentality of visible experiments[35]. At the same time, the experiments as such are not similar to the experiments of the 19th century. Those experiments were a *verisimilar* reproduction, so the confirmation of the sensible reality. In the 20th century science, the *possible* character of experiments is (was) what is important, thus organising the experiments as such. It is about the confirmation of the mathematically constructed reality, and of the *possible* as a means of construction and emphasising of the theoretical reality. Mathematics is not a translation of the sensible reality, but an instrument of construction of the *possible*, illuminating the laws, order, coherence, constitution of reality. But 'order', 'laws' etc. are our concepts, and they reflect the point of view of the subject in front of reality, subject that shows the possible reality through its exercise.

However, reality means *n* possibilities: are these *n* something much more than the *possible* showed by science? On the one hand, yes, and science always discovers new aspects of the possible. On the other hand, science reveals the simplicity and the logic of interdependences and

[28] *Idem*, p. 51.
[29] *Ibidem*.
[30] But this does not mean that there is no material basis of the world; this material basis is transposing through its relations, and from the standpoint of the emphasis of matter the new physics seems to be more efficient. On the contrary, the old fashioned materialism constructed as image of the mezzo-world "tends to limit matter: it refuses to it qualities aloof", Gaston Bachelard, *Le nouvel esprit scientifique*, p. 50. This is an excellent observation that dissolves the 20th century and the present ideas of returning to idealism through the medium of quantum physics. Indeed, the qualities generated by distant relationships – the famous quantum entanglement – do not destruct the idea that there is always a material basis: on the contrary, they fortify it.
[31] Gaston Bachelard, "Noumène et microphysique, p. 16.
[32] As the testimony is for the empirical observation.
[33] Gaston Bachelard, *op. cit.*, p. 19.
[34] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 75: "The particle and the wave are not things related by mechanisms. Their association is of mathematical order; we must understand them as different moments of the mathematisation of the experience".
[35] Gaston Bachelard, "Noumène et microphysique, p. 16.

relations configuring the reality, and the more concrete is this revelation, the nearer is science to reality. Anyway, "the real is only a particular case of the possible"[36]: the real as cognisance, I add.

4. Mathematics as a means of science and as a generator of scientific and ontological objects

In Bachelard's time – and contrary to the mechanistic dogma of measurement as the infallible way to understand the order of the empirical block and to highlight the scientific progress, and this dogma expressed the fear from theoretical interpretation[37] – the problem was to understand mathematics more than a simple means to express the empirical observations/experiments[38]: but as the theoretical description of the complex relations structuring the physical world (as theorems "having mathematical sense before having a phenomenal significance"[39]), a theoretical description more complicated than the usual abstractions as "the perfect gas", and more "organic", thus revealing the inner constitution of the world, than the empirical appearance. Briefly, quantum physics and its mathematical realisation have emphasised a new understanding of the *relation* between the knowing subject and its object[40]. And thus, this new role of mathematics, having only a functional *a priori* in the scientific research, has suggested – and was contemporary with – the *holistic* approach of nature: a holism where the order is not (only) deductively supposed, as in the ancient philosophy, neither is *found* (as in the modern pre-20th century science), but it is abstractly proved[41].

In fact, the mathematical constructions as the essential method of quantum mechanics describing just the relations and their transformations have sent to the schemes/patterns/moving architecture of the quantum reality. And as this reality is the moving result of relations, as the mathematical realism is grounded on relations: both the mathematical and physical notions and quantities are the result of qualities, quotients, parameters, comparisons, transformations, measurements, applications, otherwise they do not exist. In these constructions, the *scale* is which is important: the very little variations detected in experiments may have big theoretical meanings, while very little phenomena detected may send to the creation of new theories. So, the mathematics involved in the quantum physics suggests not only phenomena – as it was the case in Plato's mathematical realism – but also, and more, theories: and thus, the deep constitution of matter. In this respect, the mathematically worked model of atom is more *complex* than it is when it is experimentally grasped, while the perfect gas was a *simplification* of the real ones[42].

The role of mathematics in quantum physics went together with and has led to the change of the intellectual supposition substantiating the scientific research: from the one of the unknown and puzzle-form naturalism where the scientist had to put order by discovering the laws of the functioning of the universe to the supposition of rational/mathematically ordered character of the world, guarantee of its objectivity and organic generation of the laws of nature. As a result, these

[36] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 48.
[37] Gaston Bachelard, "Noumène et microphysique, pp. 13, 14.
[38] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 80: "The mathematical conception of the world was, first, inspired by the intuition of simple forms. This intuition had led to the long-standing resistance against the idea of deformation of the celestial bodies and against the idea of perturbation of trajectories. Determinism is thus a result of the simplicity of the first geometrisation".
[39] Gaston Bachelard, "Noumène et microphysique, p. 18.
[40] As shown later on in Gaston Bachelard, *La formation de l'esprit scientifique. Contribution à une psychanalyse de la connaissance objective*, p. 8: "The science of reality is no longer satisfied with the phenomenological *how*, it searches for the mathematical *why*".
[41] *Ibidem*.
[42] Gaston Bachelard, "Noumène et microphysique", p. 18.

theoretical/abstract/mathematical concepts (as position, simultaneity and composition[43]) and models are those which are to be subjected to scientific experiments, and not the sensible intuitions anterior to conjectures/theories, as in the old science. And these theoretical/abstract/mathematical concepts are calculated, only *after* this calculus they are applied on: however, not the application is complicated, but the theories and concepts as such. These mathematical concepts and theories are no longer considered as pure and finite/simple, and the precision is that which is obtained through their reckoning and which gives their accuracy: precision is no longer a problem of application, but just of the constitution of concepts and theories.

This model of constitution of mathematical concepts and theories is the same as the model of relations between the physical and chemical theories, and the experiments. These ones are, we must repeat, *a posteriori* towards the theories; but on the other hand, they are simultaneous, because the theories are created through experiments: which are not necessarily sensible, but may be reduced to computing and ideal experiments. Actually, "in a science with mathematised concepts, the empirical notions solidarize in a rational manner"[44].

The mathematically worked theories are the verification – re-definition, calculus within the new suppositions – of the old concepts which were plain for the common sense. The concepts were evident because they were/used as implicit synonyms, metaphors and sensible intuitions. But the high mathematics is not intuitive at the sensitive level (for this is it difficult), and its objects – the mathematical concepts – are *forms* which give rise to the *problems* generating and constituting just the new concepts of the natural sciences. The mathematical and mathematically worked scientific concepts are definite within the mathematically demonstrated theories; the data of theories are clear (certainly, there are not the ultimate truth), but the *empirical* reality is much hazy, ambiguous, even mysterious.

Being the result of theories and not of the sensible intuitions and experience, the new science is the result of the theoretical and practical instruments of these theories.

Just through the mathematical calculus, not only the precision of detail, but also the sense of the whole (*totalité*) is reached[45].

Nowadays, the entire progress of sciences with mathematics outlines a better understanding of the empirical world but through the medium of mathematical models/mathematically constructed models of different levels empirical correlations and empirically situated regions: working with these models, it seems that what is constructed is *more real/ more explainable*, intuitively or not, than the direct empirical world/what this world can explain. And it seems that what is constructed is more real if and only if its results are OK: actually, the process of verification as such concerns the models, and not – or only ultimately – the empirical proofs.

The development of mathematics has led to the "science" of architectonics, patterns and correlations of structures, through the medium of computational languages and their mutual help and translations. Actually, the development of mathematics – as informatics – allows the scientific constitution, so not philosophical speculation but demonstration, of the theory of unitary principles in the functioning of the world at all its levels (inanimate, animate, natural, artificial, micro, macro; but perhaps not all these unitary principles may be found at the level of mezzo artificial/cultural world, may they?)

With the whole inertia of "mechanistic" research, the present inter- and trans-disciplinary approaches, developing both a *holistic* tackling of things and the computational mathematics, are more and more important.

[43] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 39.
[44] *Op. cit.*, p. 42.
[45] *Op. cit.*, pp. 47, 125.

As Bachelard considered that the above change of science required a new metaphysics rejecting reductionism and the mechanical simplicity of the discrete, but stitching around the concept of relation, as nowadays a new philosophy of nature constitutes by revisiting its concepts and theories.

5. A new type of discontinuity in science (and philosophy)

The difference between the new mobile science and the previous mechanistic one was and is obvious. For some ones this may be a simple countering of two separated blocks of cognisance. But Bachelard's epistemological *esprit de finesse* has led to the dialectical understanding of the *continuity within the discontinuity* of the new science. The Newtonian physics is conceived as only a particular case of Einstein's physics[46]; as the Geometry of Euclid is only a particular case of a "pan-geometry" where the non-Euclidian one only "outlines the limits of the old thinking"[47]. Or: the new science encloses the old one. This means that the new science is not at all born of the old one (for example, the cosmology of Einstein does not arise from the cosmology of Newton, "because this one was a completed system"[48]), there is no gradual transition between them, but a total discontinuity. And also: that the non-Newtonian thinking absorbs the classical mechanics and distinguishes from this one, shedding light on what was clear in the former.

In this way, the new theory can better interpret the previous history, the historical meanings of the old theory[49].

6. The new relation between science and philosophy

The quantum mechanics generates a labefaction of the traditional metaphysics that corresponded to the physics of observable and near macro/mezzo-bodies and phenomena. That traditional metaphysics had concepts as *metaphors* – both for matter that, as metaphor, in fact does not exist, and for the idealist ideas attacking in an outdated manner with their own obsolete prejudices against a caricature of matter and materialism – and conjectures reducing the complex nature to simplicity and order through immutable laws.

In that metaphysics, the objects and beings were autonomous and their inevitable unity took place only after the demonstration of their identity and only as a *unity of disparate, discrete entities*. This was just the mechanical standpoint of discrete, solid macro/mezzo-bodies. (Even the important discoveries of the 19th century – as Faraday's, Maxwell's, or statistical physics and thermodynamics – were tackled with mechanical models and concerned discrete entities as atoms and molecules).

The old physics was that of Descartes type science (that led obviously to a Cartesian metaphysics, with its main model: the metaphor of the world as a machine). Citing the critique made by Louis de Broglie[50] to the Cartesian science, Bachelard has remarked that this science was based on the presumption of immutable natural laws and the *certainty* given by the *process of knowing*[51]: in Descartes, the representation of the natural phenomena could be mathematically

[46] But this discontinuity does not mean that Newton's and Einstein's physics would be contradictory: they simply refer to different scales, different realities: that of mezzo-bodies and that of micro composition and transformation.
[47] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 12. But "the particular can never evoke the general", p. 48.
[48] *Op. cit.* p. 36.
[49] *Op. cit.* p. 45.
[50] Louis de Broglie, *Continu et discontinu en physique moderne,* Paris, Albin Michel, 1941.
[51] Gaston Bachelard, *Le nouvel esprit scientifique*, p.126 : in Descartes, only the human understanding – through rational processes – can grasp the essence of the material constitution of the world. The material characteristics were volatile – as those of a piece of wax – and the experiments related to the material bodies were more difficult than the understanding of the human soul.

decomposed in figures and measured as limits and trajectories of movements. Or – as not only de Broglie, Bachelard, Le Bon[52], Heisenberg, and later on Ruyer[53] and Feynman[54] have showed – the quantum physics emphasises the *uncertainty* of these representations and measurement, because one cannot measure and precise at the same time the speed and position of a particle, and that (as Einstein explained) there are different images related to different systems of coordinates which present different aspects of reality.

The Cartesian and Newtonian physics conceived the natural world as absolutely following the physical laws – which ought only to be known, and may be known directly and immediately, as the empirical connection with the mezzo-world allowed – and representing thus an absolutely determined/deterministic system. Bachelard has showed that this understanding was a normal/necessary step in the analysis of nature, but that it ignored – and this until the 19th century[55] – both the *perturbations* and *deformations* which are deviations from the laws, and the many possibilities, i.e. the statistical manner to understand the deep down of matter.

The Cartesian science moved in a paradigm of *simple* and decomposable aspects and characteristics which allowed the principle of *mechanism*/mechanical relations between them, and thus the *absolute* unfolding of the natural laws. It allowed also the principle of separability of the essence from the existence of things: obviously, an old principle, but now supported by science.
(In the 18th century, only the living could break the unproblematic mechanistic view. After the living organisms were considered as machines, the biologists have developed the famous stance of vitalism that has promoted the teleological representation and causality: the coherence and persistence of the living organisms were the result of the vital power fuelled by a constitutive *conatus/ desire to persist*. But in front of the clear and harmonious mechanism, vitalism seemed untrustworthy. For this reason, Kant has considered that as concepts/principles, both mechanism and teleological causality were acceptable, the later at least as only intellectual possibility, and that what is not knowable with these principles – and indeed, teleology did not explain too much – will remain the realm of the thing in itself).

But the new physics requires a "meta-micro-physics"[56] that is the result of this new physics and thus has the competence to question the old metaphysical theories, and to highlight the complexity, continuity and interdependence of beings whose identity constitutes from and within the unitary whole through *n* relations. The role of mathematics is just the constitution of this *meta* view from and around the relations[57]. It suggests that the un-determinability of a certain situation of quantum phenomena – and these phenomena are always unique – is not tantamount to indeterminacy, but only to statistical forms of the game of laws.

Quantum mechanics simply shows that its entities – atoms, quanta etc. – cannot exist independently, they have no qualities: while of old, philosophy has showed that there are no entities without qualities. For this reason, the new metaphysics has as pillars the *mathematical number*, able to reveal the constitution of the *noumen*, this "hidden world", and the *quantum physics hypotheses*[58].

[52] Gustave Le Bon, *L'évolution de la matière*, Paris, Flammarion, 1905.
[53] Raymond Ruyer, *Paradoxes de la conscience et limites de l'automatisme*, Paris, Albin Michel, 1966, p. 285: "the domains of micro-physics are not those of the characteristics of the common space-time, because these characteristics are secondary to the micro-physical relations which create them as statistical effects".
[54] Richard Feynman, *The Character of Physical Law* (1967), Cambridge Ma., London, England: The MIT Press, 1985. The new physics does not allow prediction, there are no laws permitting prediction (pp. 145-146).
[55] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 81.
[56] Gaston Bachelard, "Noumène et microphysique", p. 19.
[57] *Idem*, p. 20.
[58] *Op. cit*., p. 22.

Quantum physics draws attention on the fact that things are separable in a relative way: matter may be different from energy, but at the same time it is tantamount to it; the physical and philosophical unity of matter and energy involve the consciousness that this unity is a destruction of the supposed original simplicity of the unity as such.

And since the quantum mechanics "produces"/and not describes the phenomena, the new metaphysics is a "meta-technique" of these artificial productions[59].

As a result, the new philosophy is no longer metaphysics in the sense of first concepts/principles decreed as "founding once and for all"[60] and only on the basis of imaginative and intuitive deduction starting from the immediate empirical world, but it is an interpretation of reality substantiated in the physical and chemical reactions and experiments showing so many problems that not only these sciences but also philosophy has a more and more rich domain to explore.

This philosophy around the scientific thinking emphasises both the manner to approach to and to know the new reality shown by the natural sciences, and the new reality as such: it is, thus, a "second order realism" where the material basis of the world is more convincing through the scientific construction than it was in the empirically proved old materialism[61]. It is about a "*rational materialism*", where the questions come from the *problems* appeared within the scientific inquiries, and are not "the first questions" posed with "stubbornness" – while "science restlessly moves 'the first questions'"[62] – but concern just the meanings of scientific findings related to the forms of reality. And at the same time it is about a "materialist rationalism" where the material constitution of the universe is the result of the new science's constructive approach: an intertwining of realism and rationalism warning each other[63].

Therefore, this new materialism represents an aware critique and outrunning of both the former naïve and mechanistic materialism and the self-illusioning idealism, thus without "pacifying" them but constructing itself as an explicit "materialist phenomenology"[64]. This one annuls only the *excess* of the centrality of consciousness[65] and the cold and neutral distancing of the viewer from objects and matter: in the traditional phenomenology not the *resistance* of these ones was the problem, but the resistance of the viewer, its cultural lenses interposing signs, labels and names between the supposed possible fresh look and the forever exterior "matter", i.e. the consistent reality as the only condition of our existence.

The colour and form of this reality is not (only) a question of external contemplative knowing, but also of the "field of obstacles"[66] posed by "the resistance of matter" in front of its knowledge: just the "complexity and fugacity of phenomena"[67] are that which are decomposed by the new science and its meta-look. There are also epistemological obstacles resulted from the resistance of both the immediate perception and the common-sense (countered by concepts and

[59] *Op. cit*., p. 23.
[60] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 15.
[61] *Idem*, pp. 8, 9, 10.
[62] Gaston Bachelard, *Le matérialisme rationnel*, p. 9.
[63] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 13.
[64] Gaston Bachelard, *Le matérialisme rationnel*, p. 19.
[65] *Idem*, p. 18.
[66] *Ibidem*. But see also Gaston Bachelard, *La formation de l'esprit scientifique. Contribution à une psychanalyse de la connaissance objective*, where the epistemological obstacles in front of the new science made with the mathematical abstracting process are described: the obstacle of the direct empirical experience and first cognisance becoming common opinion, the first generalisations, the wordy obstacle, the unitary and pragmatic cognisance, the substantialist and the animist obstacles, the false strictness.

Actually, one should be careful with the abusive extension of familiar images, of metaphors giving a family likeness, despite – as later on Ricoeur also showed – their heuristic role.
[67] *Idem*, p. 16.

theories), as well as from the resistance of old theories and theoretical prejudices. These epistemological obstacles are not tantamount to errors, and they show the "epistemological rupture" in the history of knowledge and scientific theories. Of course, the epistemological and real obstacles are more than linked, are intertwined. But it is essential to not reduce the latter to the former, or not mutually reduce them: to not erase them. Because: the "situation" of things cannot be described as the exterior, inert and unchangeable object, but as "topology of the obstacles"[68].

Thus, in the new "active materialism" the "persevering consciousness"[69] goes beyond the resistance of matter preparing – but it's a long way to – "materialist projects", or the management of forces implied within the resistance of matter.

Finally, and since chemistry became as revolutionary as the new physics, it sent to and required new philosophical conclusions related not only to the resistance but also to the *mixing capacity* of matter. But these conclusions were and are not easy to yield and thus, at least for a while, philosophy may focus, still remaining within the materialist paradigm, on "the imagination of matter"[70] and the phenomenology of the human understanding of this imagination.

7. Nowadays

a) The relational constitution of things

Already from the second half of the 19th century, the particle-wave constitution of light and, later on, of matter-energy game at the level of atom and quanta have dethroned the basis of mechanistic physics, its particle/solid "last brick" thesis. Instead, the *relational constitution*[71] – and not aspect, not a simple "characteristic" or instead of a characteristic, as the speculative philosophy stated – of reality has become the theory emphasised by all the physical, chemical and biological researches. The inertia of the old substantialist presumption was – and still is – big enough to maintaining in philosophy and education either an out-of-date mechanistic materialism or an idealistic protest against this one, preparing the ground for some pseudo-scientific theories "substantiating" obscurantism.

The revolutionary moment of Einstein's theories has definitely imposed the prominence of relation/contact/reaching/collision/encounter over the "palpable" material particle. This prominence brought about the evidence of the discontinuous[72] over continuum in the formulation of our knowledge of matter: this formulation is mathematized and probabilistic because it involves mathematical objects which are not empirically observable[73] and physical objects which are *systems*

[68] Gaston Bachelard, *Le matérialisme rationnel*, p. 18.
[69] *Op.cit*., p. 19.
[70] *Op.cit*., p. 23.
[71] See also Ana Bazac, „Materia: observaţii epistemologice cu prilejul aniversării modelului atomului al lui Rutherford (II)", *Noema*, XI, 2013, pp. 83-114,
http://www.noema.crifst.ro/nr12.php; http://noema.crifst.ro/nr12.php [Matter: epistemological remarks with the occasion of the anniversary of the Rutherford's model of atom].
[72] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 73: "The two images – of particle and of wave – do not really arrive to meet each other. They are clear only when they are isolated. In short, they both must remain images and not claim that they would represent realities".

"As a result of the wave-particle duality, (Bohr) showed (1913) that there exist discrete sequences of electron orbits. When an atom is excited, the electron jumps from one orbit to another. At this very instant, the atom emits or absorbs a photon the frequency of which corresponds to the difference between the energies characterizing the electron's motion in each of the two orbits…First and foremost, a new formulation, unknown in classical physics , had to be introduced to allow 'quantization' to be incorporated into the theoretical language. The essential fact is that an atom can be found only in discrete energy levels corresponding to the various electron orbits", Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue With Nature* (1978), Foreword by Alvin Toffler, Toronto, New York, Bantam Books, 1984, p. 220.
[73] Bertrand Russell, *The Analysis of Mind* (1921), Blackmask Online, 1999, p. 36 ("we cannot observe infinitesimals").

of all the correlated particulars/all the appearances in different places they occur[74] (because a physical object is a system of its qualities/appearances – and this is the big difference from the traditional view where the qualities were added, one by one, to the essences (in metaphysics)/to objects (in physics) since one could separate the qualities from the objects – and is considered as a single causal unit). However, though the quantum mechanics insists on the discrete and the separate treatment of particles – as before, Kant has separated the world of phenomena (objects of science) from the world on *noumen* (world of philosophy) – in fact, the present science of complexity confirms "the universal connectedness of all particles"[75], and it shows at the same time a permanent process of transformation (emphasising the "laws of change"[76] instead of mechanical cause-effects idealisations), and the theoretical unification of mass, energy and space.

Nowadays, another challenge is in front of scientists: the unification of (matter, energy[77]) and information.

If relations are first of all inside of a same scale world – for example, inside the atom, between electrons and protons, or between atoms – they certainly are the results of other relations inside the same world, as "reactions" to these relations/ to the information these relations suppose and generate. *According to the phenomenon of information, all these relations and "reactions" occur in the most economical way from the standpoint of energy*. But at the same time, a world of specific scale exists inside of and in relation with other worlds of both the same specific scale and of a more comprising, or of lesser, magnitude. As a result, the above principle of the *most economical way* functions through the instrumentality of *information* occurred and generated in the multi complex relations inside same scale worlds and between worlds of different scale. These relations mean what is called biological /natural calculation, and is emphasised by bio-computing. Sometimes the "ultimate" logic of all these information and relations is that of the world of the biggest scale: as the human being as such – with its mind and body – whose *telos* and *conatus*[78] decisively influence the *telos* of organs and of their physical-chemical constituency. This does not mean that the superior world annuls the logic of the other ones: but the *teloi* of the physical-chemical level – dependent on both gravitation and chemical laws of attraction, combination and separation – is intertwined with the *telos* of organs and of the organism, with its human (social, cultural) specific.

b) The constitutive function of the scale

One of the first obvious aspects of the presentation of matter is the *scale* and the specific regularities/laws corresponding to different scalar quantities. However, this aspect that is very convincing for the current scientists was not obvious for the ancient and mechanistic modern Newtonian scientists. For them, either the last bricks of materiality or the macro-laws demonstrated according to the medium-size bodies were the argument of the unitary and unchanged laws in the whole universe.

Only with the new Einsteinian physics based on the context dependency of phenomena and their existence as relations[79], the scale became essential for the occurrence and understanding of

[74] *Idem*, p. 38.
[75] Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos*, p. 96.
[76] Bertrand Russell, *The Analysis of Mind*, p. 35.
[77] This unification began to take place already in Bachelard's time.
[78] *Telos* being the *reason to be* of a thing/an entity (see Ana Bazac, "The philosophy of the *raison d'être*: Aristotle's *telos* and Kant's categorical imperative", *Biocosmology – Neo-Aristotelism*, Vol. 6, No. 2, 2016, pp. 286-304), it is suitable here to consider *telos* and *conatus* as overlapping concepts. Indeed, the first reason to be is to persist. The reason to be of a cell is to function so that to persist.
[79] It is the mathematical and physical demonstration of an idea of Leibniz.

these phenomena. And these occurrence and understanding are not devoid of contradictions/problems.

On the one hand, the size of the discrete is the condition of laws of different orders of quantity. And from this standpoint, one even may state that the different size populations of discrete units are reciprocally autonomous and without connections/incommunicable[80]. Anyway, this standpoint allow us to understand that a system – formed by some different sub-systems – is never reducible to its sub-systems/to the laws governing the sub-systems, but that the sub-systems are depending on the system they are included within[81], though they are the basis of this one. A medium-size object is not reducible to atoms etc.

On the other hand, there is continuity of scalar quantities (as time) and of *information*: thus, though the objects of different "worlds" exist only in the frame of those different "worlds", and though at the same size of the "world" different objects belonging to it interact (as the man seeing the apple in front of him, or the micro-particles for other micro-particles, but not for the objects of other size formed by micro-particles[82]), the laws of *the complex* matter-energy-information[83] allow the *evolution* of "worlds" and their *transformation*: and the *ontological* superposition of different sizes objects and "worlds": a medium-size object, its micro-particles but also the superior systems containing them may exist in the same space and time, although the calibre or dimensions of space and of time at the level of these different scales are different and give different spaces and times[84] (since space and time are also relations): so, at the same time in both the same and different space-times.

And this means that: at least at the constitutive micro-level of objects lying in different "worlds", the communication between different sizes "worlds" may be possible; and the "universal" character of the physical laws has to be revised: not in their universality, but in their insufficiency. But, once more, though the communication between quanta and atoms – at the level of this micro-world – does not constitute the direct causality of the level of medium-size world of objects in which the micro-world obviously exist, but only the "communication"/relations between the medium size objects, nevertheless a generative-transformative relation exists between levels: just through the laws of levels of reality and through the bearers of these law: the strange unity of matter-energy-information pertaining not only to the micro-level. As a result, the levels/"worlds" are not (only) parallel – as Vacariu considers – but also imbricate and overlapped.

And the mind-consciousness problem illustrates the *relations between the levels*: the electrical charges and reactions, and the heat at the physical-chemical level of the brain are manifestations of and at the same time transpose the biological-physiological level of cells and their organisations in the brain and all the systems of the organism; just the superior *telos* of the organism is that which determines ultimately the biological-physiological organisation realised through both the biological means and the physical-chemical ones; *but it is not strange to explain* telos *in terms of information, transmission of information and informational calculation*; and just the biological-physiological organisations and reactions form the level called by Popper "world 2" generating and

[80] Gabriel Vacariu, *Illusions of Human Thinking: On Concepts of Mind, Reality, and Universe in Psychology*, Wiesbaden, Springer, 2016.
[81] Somehow as in Nicolai Hartmann's theory of levels of reality (1940), where the superior level is autonomous towards the inferior levels, the inferior levels are shaped by the superior ones, are only aspects of the superior ones, and are very distinct.
[82] Gabriel Vacariu, *Illusions of Human Thinking*:…, pp. 26, 27.
[83] Does information superpose with matter and energy? Are they *fundamentally* different each other – and not only from the standpoint of human ordering and focusing on different aspects – or are they partially overlapping? And how? The question is open, obviously, but its solving is possible only with scientific means.
[84] Louis de Broglie, *La physique nouvelle et les quanta*, Paris, Flammarion, 1937, p. 104: quantum physics questions the space and continuous time of the classical physics.

constituting "world 3", in its turn influencing, and even strongly, not only the "world 2"", but also the biological-physiological level.

Anyway, just the interconnectedness of levels and things has showed the importance of scale and *scaling*, transitions from one scale to another and their ratios and conditions[85]. (And the first, non-mathematical but demonstrated mathematically, condition is the keeping of the *telos* of the thing scaled (or, at the levels of objects interesting for man, the keeping of the meaning of the object irrespective of the change of its scale)).

c) From Bachelard's view on matter and relation to the present holism through computation (synthesis of matter, energy, information)

Micro-physics begins with a thought and finishes with a problem[86], i.e. with the opening of a new "space" of scientific objects and their knowledge. The history of knowledge shows, however, that there is not a linear evolution from simpler "spaces" to complex ones. For example, the ancient atomism as original unitary form of the existence was anterior to Aristotle's substance as an individualised combination of matter and form (AB, Aristotle better explaining the development of living beings within an inanimate world and their open complexity), as well as Anaximander's *apeiron* as infinite principle or order as basis of the existence was. But J.B.J. Fourier's equation of heat (1811) was an "exotic" construction revealing an *irreversible* process towards the *reversible* processes studied by the 19th century equilibrium thermodynamics[87].

Anyway, Bachelard had as landmarks and stakes of the scientific explanation *atoms and quanta*. Today, these landmarks and stakes are *computation* – mathematical transposition of information related to the states of a system, or a mapping of those states through the medium of information algorithms by the instrumentality of mathematical models – and the constitution and dynamics of the *living systems*, as well as *consciousness*. For example, the cell[88] involves its persistence and functioning as complex *intertwining* of the *levels* of its existence: the physical relations at the level of quanta as well as the electrical and chemical relations – including or perhaps always as fluctuations, and not (only) as "mechanical" responses according to the laws of matter, energy and information (but for the time being we do not know either the laws of information in the living cell or the laws of intertwining of matter, energy and information at the level of cell) –; the laws of populations of cells in the same organ; the laws describing the "encounter" (this is Althusser's term for relation)/spark/clash of cells of different organs etc., and even with the entire organism. Actually, how can we explain the strength of *conatus* of the entire organism – or its *telos* as final completeness end – if we do not relate the cell with the entire organism and, thus, with the external world[89]?

Therefore, the understanding of the cell supposes both *holism* because it means the whole cell as entity with inputs and outputs, with promoting substances and subatomic dimensions, with energy resulting from, helping and constituting the substances, with the architecture/schemes of movement, which all are translatable in computational language, and to proceed *at the lowest level* "according to the laws of physics"[90]. Each mentioned aspect has its "language", the languages are

[85] See Adrian Bejan, James H. Marden, "The constructal unification of biological and geophysical design", *Physics of Life Reviews*, 2008; DOI: 10.1016/j.plrev.2008.12.002
[86] Gaston Bachelard, "Noumène et microphysique", p. 17.
[87] Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos*, p. 12.
[88] The approach of the biological in the new scientific worldview created by the Einsteinian physics was one of the main proofs of fruitfulness of this worldview, see Fritjof Capra, *The Turning Point: Science, Society and the Rising Culture*, 1982 (free downloadable).
[89] See Ana Bazac, "Matter, information and cancer: Notes related to the "Challenging Integralism"", *Biocosmology – Neo-Aristotelism*, Vol. 7, No. 1, Winter 2017, pp. 65-84.
[90] Bertrand Russell, *The Analysis of Matter* (1927), Nottingham, Spokesman, 2007, p. 267.

mutually helping (i.e. transmit each other that there are schemes, which make things to be easier/namely, to save energy and to keep the *telos*), and at the same time computation both describes them in the best manner – obviously, the adequate computational description is a process.

The relation between computation and biology – giving at least the "natural computing" – is mutually useful. Computation borrows from biology models and processes[91], and biology becomes clearer through (actually, it can no longer develop without) its transposition into computational models and information processing. Schemes/laws/models/theories are *sine qua non* for the understanding of concrete biological problems, but these ones are not simple concretisations of models and theories, specified only through mathematical quantities. At the same time, the reciprocal borrowing between informatics and biology supposes previous scientific intuitions and hypotheses, even models inside each domain. Having these intuitions etc., scientists are open to facts provided by other domains. A Romanian example is that of the computer scientist who has borrowed from biology the model of symport and antiport (processes of cell membranes to transport molecules in and out of cells, therefore across the membrane) in order to construct a model of calculation "by communication"[92].

d) From Bachelard's historical constructivism of the scientific object to the present practical interdependence of nature and society

Because Bachelard's historical constructivism was mentioned, it is more interesting to referring to his dialectics of the simple and the complex. Indeed, both the simple and the complex are concepts related to humans' ability to know. In order to achieve cognisance, they have discriminated/differentiated/separated a thing (an aspect, a quality) from the surrounding continuous puzzle. This helped them to see the parts and, when they began to search to understand the logic of the connection of things, they have arrived to the idea of the simple as basic unit/characteristic and to the idea that the complex things were the result of the development of the simple/original.

The classic modern science too was a decomposition and re-composition of things in order to get out of the complex the simple parts and laws of constitution. In its turn, philosophy too – and certainly, from is beginning, because it always was the meta-reflection on the results of the human knowledge which already supposed the anterior process of inferences – (in fact, metaphysics) aimed at revealing the simple as the basis of the composed, and so this was the common epistemological programme of the modern sciences and philosophy.

On the contrary, the new physics shows how complex is the realm of the last constituency of the world: the epistemological programme it has constructed was "metaphysically inductive, reading the complex in the simple, formulating the law from the fact and the rule starting from one example"[93].

This programme has continued and, if the image raised by the present sciences is that of order – a theoretical/constructed one, as Bachelard has pointed before – out of the complex that is a chaos, and obviously if that image was the interaction and unity of theory, experiments or practice, in fact a dominant tendency of the present global practice or relation of man and nature still ignore the complexity and reduces it to simple slogans. The dialogue of sciences (and philosophy) did not

[91] See the huge literature, within which the membrane computing whose founding father was Gheorghe Păun (1998), or also the Romanian professor Ion Petre, working in Finland, who co-authored recently a very promising article for philosophy (A. Ehrenfeucht, I. Petre, G. Rozenberg. "Reaction systems: A model for computation inspired by the functioning of the living cell", pp. 1-32. In: *The role of theory in computer science* (S. Konstantinidis, N. Moreira, R. Reis, J. Shallit, eds.), Singapore, World Scientific, 2017), obviously based on previous international research concerning biological reactions.

[92] Gheorghe Păun, "Some Wonders of a Bio-Computer-Scientist", *Bulletin of the International Membrane Computing Society*, 2016, http://membranecomputing.net/IMCSBulletin/, pp. 241-260.

[93] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 11.

yet lead to a practice based on this dialogue and unity of theory and experiments. The reductionism of practice corresponds to a still dominant fashion in science (in the institutionalised science/in the behaviour of some researchers): that the mathematical formulae and measurements of isolated facts or even presumptions (as in econometrics) would allow universal conclusions; a myth, as Prigogine and Stengers called it. And, to refer again to Prigogine and Stengers, as the new scientific turn has begun with the question of *use* of the action of heat on material bodies – and not with the theoretical question of the nature of heat and its influences – as this turn was to develop toward the unity of science (and philosophy) and practice/the practical use of science (and philosophy): beyond its fragmentary applications.

If we read the complex in the simple, i.e. we no longer reduce the worlds – the quantum is a world, as the world of mezzo-bodies is another one etc. – to simple, last constituents which can be taken in an isolated manner/as if they would evolve alone, the same approach ought to concern the mezzo-world. However, this seems – paradoxically – more difficult. This difficulty is the reason why the ecological outlook and sciences have developed so late and why their conclusions are not followed by practice: for, indeed, isolated and fragmented reparatory strategies are not enough at all. There are global anthropogenic processes, wasting the natural non-renewable resources and generating an irreversible deadly path for humankind[94], and leading to mass extinctions of the living. (Actually, it is not paradoxical: the reason of the above fact is not so much the late understanding of the interdependences between phenomena and the necessity of holistic practical approach, but the capitalist framework that have pressed for this late understanding and forbids the holistic practical approach of the world problems).

In fact, the theoretical and practical problem of the nature-man interdependence has been put with the raising of the Einsteinian type of science – and we know that this type has appeared in the second half of the 19th century with thermodynamics and the *idée-force* (let use Alfred Fouillée's term) of *irreversible* processes – as ecological descriptions[95] and syntheses[96]. It is only a question of – or the main impediment of the just in time development of the holistic point of view was – the social organisation of the 20th century world society. Consequently, it seems that really some present natural processes – certainly, anthropogenically determined, though not always in a contiguous form, but indirectly[97] – have become irreversible.

(By the way, we ought to be careful with the notion of irreversibility. A dialectic process of reversible and irreversible movements and changes exists: at different scales or "epistemological worlds" (this last term is borrowed from Gabriel Vacariu) and their coexistence).

e) From Bachelard's new *noumenology* to the present science of complexity

If even in Kant's critical rationalism only philosophy dealt with the *noumen*/the essence of things hidden by its appearances, by the phenomena tackled by sciences – and this division of labour has corresponded to the classical physics and the backwardness of sciences – Bachelard has

[94] See an early warning: Nicholas Georgescu-Roegen, "Energy and Economic Myths", *Southern Economic Journal*, 41, no. 3, January 1975, http://dieoff.org/page148.htm, wrote that from the standpoint of power economy, "the production of all instruments of war, not only of war itself, should be prohibited completely". (And, obviously, no decision makers heard this. On the contrary, they even promoted misinformation related to the harmful methods and processes they led as means to grow profit. See only Shannon Hall, *Exxon Knew about Climate Change almost 40 years ago*, October 26, 2015,
https://www.scientificamerican.com/article/exxon-knew-about-climate-change-almost-40-years-ago/

[95] Ray Lankester, More Science from the Easy Chair (1913), Lond., Methuen & Co., 1920.

[96] Vladimir Vernadsky, *La géochimie*, Paris, Librairie Félix Alcan, 1924; *La biosphère* (1926), Paris, Félix Alcan, 1929.

[97] Terry P. Hughes et al., "Global warming and recurrent mass bleaching of corals", *Nature*, 16 March 2017, Issue 543, pp. 373–377.

signalled and expressed the possibility of sciences to grasp the *noumen*. He deduced this possibility from the revelations of the new, mathematical and quantum physics that shed light on the *noumenal* aspect of the "micro-cosmos". But at the same time, he showed the necessity of a "meta-microphysics", a philosophy that was to position itself as the critique of the traditional metaphysics[98] and the close partner of the new physics.

Therefore, the new science was not to put philosophy in an insignificant place: on the contrary, we may rather infer that Bachelard was one of the forerunners of the *science-philosophy integration*. Why that? Because: "the *noumenal* level of micro-cosmos is essentially complex". The *noumen* must not be reduced – as in the traditional metaphysics – to the last bricks and, thus, to the simplest principles whose general character configures a static world where complexity is the quantitative accumulation of an immutable determinism. It is, warned Bachelard, "the most dangerous to postulate both the original simplicity and the independence of beings, and the unity of this type of beings"[99]. In other words, the mechanical approach of "final" unity of originally separated and simple entities is simply not real, and to force it as pattern of thinking leads to a very contorted and useless representation.

The *noumen* of the micro-physical world is based on relations and the original unity/interdependence of properties which make the phenomenon: "in this *hidden* world, a simple descriptive character is an illusion"[100]. Both the mathematical findings and evidence and the philosophical concepts, as that or order, cooperate and converge. The *noumen* is "a centre of convergence of notions, mathematically constructed" and experimented in scientific experiments (therefore, it is about a "positive metaphysics"): it is, please observe the openness towards and prefiguring of the present era, "a meta-technique of an artificial nature" since the new science is not a description, but a "production of phenomena"[101].

As a result, the *noumen* is not the simple – as in the age old philosophical ideal – but *complex*: the *ideal of the new science is complexity*[102]. The phenomenon is a fabric of relations, the substance is not simple but a structure of attributes. And there are no simple ideas[103]. Application is complication[104].

f) From Bachelard's conception that truth/the only true intermediary of truth is given by mathematics to the present use of mathematics, including through its "embodiment" as information theory.

Mathematising the new physics means to impose the *possible* as organiser of the new type of experiments. In the 19th century, the scientific experiments were translations of the "philosophy of the *as if*"[105], namely, they were reproductions of the reality of mezzo-bodies, so its confirmation. The 20th century natural science is a confirmation of the mathematically constructed reality and of the possible as a means of emphasising the theoretical reality; mathematics is not a translation of the sensible reality, but an instrument of construction of the possible reality that lights up laws, ordering, coherence, and constitution of reality. But laws, ordering etc. are our concepts, they reflect the point of view of the subject in front of reality, and the subject's exercise to show possible realities. However, reality means n possibilities; more than the possibilities highlighted by scientists? On the one hand, yes, and in this sense science always discovers more and more; on the

[98] Gaston Bachelard, Noumène et microphysique, p. 19.
[99] *Idem*, p. 20.
[100] *Idem*, p. 22.
[101] *Idem*, p. 23.
[102] Gaston Bachelard, *Le nouvel esprit scientifique*, p.110.
[103] *Idem*, p. 113.
[104] *Idem*, p.114.
[105] *Idem*, p. 48.

other hand, science reveals the simplicity and the logic of interdependences/relationships configuring reality. In fact, if mathematics organises the experimental possibilities, it result that "we find the real as a particular case of the possible"[106]. These could have been Bachelard's thoughts.

Anyway, Bachelard[107] has shared the modern thesis – first announced by Galileo – that the mathematical language may translate, and it is the only one that may translate the concrete diversity of things into a universal dynamical structure of forms, somehow infallible; and that this language and structure is au fond the core of the theory which is the basis of our knowledge of the world. Because: the mathematical language and structure cannot be falsified by experience or (controlled) experiments, but only by mathematical refutation. Opposite to the classical mechanics where the mathematical analysis followed the empirical case, the new physics has showed that the empirical observations and experiments would even not exist without their incitement by the highly mathematised theory. Sometimes, the theory is only a mathematical demonstration of a mathematical presumption. Moreover, we choose parameters and presumptions so that the theory is always valid.

But this kind of mathematical theory is not a play. It is a *model* on which one may develop games related to models and structures considered to be universal. At the same time, these structures – at least some ones – are confirmed by a cluster of physical and chemical theories (sometimes too abstract and/only hypotheses) which seem to explain the core of the physico-chemical constitution of the world. And the mathematical model becomes very "concrete" through its scientific theories more related to empirical aspects[108], and then through their technological applications. One of the most revolutionary and relevant transpositions of the mathematical approach was the *information* theory that has described the flux of information as *treatment* of results of interactions, treatment of succession of results and interactions, treatment of feedback and loops types relationships between results, treatment of structures and networks of relationships and interactions. Information – and obviously because and when it is mathematically treated – is a strong epistemological device.

However, the belief that there is only one universal language that would allow a universal truth seems to belong rather to a mechanistic type science. Mechanics measures everything and it infers from the measurements the laws – universal truths – of movements. But the development of sciences brought with it a little strange fact: that we can treat mathematically something, we even treat it technologically /we use it, but we do not know what it is[109]. An example is information: we treat it, but we can define it only in a simple, intuitive reduction of information to the level of communication between a sender and a receiver, as a succession of impulses.

The new physics – more, the new sciences *developed* in the track of Einsteinian physics – allows to advancing toward more refined explanations: where a *new* philosophy constructed on the basis of the development of present sciences, therefore a *new* philosophy and *new* sciences

[106] *Ibidem*.

[107] *Idem*, pp. 24-26.

[108] Poincaré, *La science et l'hypothèse*, p. 128, has pointed that the physical/ rather, physico-mathematical laws and rules are certainly conventions, but not arbitrary: because the empirical experiments have led the scientists who have formulated these laws and rules to formulate and adopt them.

[109] As long ago said Poincaré, idem, p. 123, concerning the definition of physical quantities: "our efforts were fruitless: we are forced to resort to the following definition, that is only a confession of incapacity: masses are quotients which are convenient to introduce into the calculations".

Therefore, we calculate abstract quantities, theories/formulae and demonstrations which encapsulate them, then we apply them, but not this application complicates the step, but the mathematical theories/principles/patterns as such. From a standpoint, the quantity/mathematical dimensions experimented/applied is *a posteriori* towards the mathematical theory; from another, the experiment is made in the same time with the theory, i.e. the theory is created within the experiment/by experimenting, but his experiment is not necessarily empirical, rather it is mathematical, rational.

emphasise the *complex multiple meanings* of information, beyond (but surely based on) mathematical treatment[110].

The same is with other concepts. Consequently, nowadays there is – or must be – a more uninhibited view about the means, languages and patterns of scientific thinking: where the philosophical history of thinking and the philosophically constructed analogies help – and are not a useless ballast – the understanding of novel aspects and concepts; where it is authorized to consider with the same justification both rational intuitions related to hypotheses and theories (and here one experiments theories, not sensible intuitions in their way toward proper theories), and sensible intuitions related to experience – and where the separation of sciences based on sensible intuitions and sciences based on rational intuitions (but here also there are mathematical intuitions and non-mathematical intuitions) is no longer absolute – and where all these intuitions are verified with complex scientific methods; and where the temporary insufficiency of scientific explanations does not lead to anti-science ideology.

8. Instead of conclusions

The new science is an "open/unfinished rationalism"[111].

The *model* of Bachelard's evolutionary epistemology is not only perfectly valid today – for, indeed, the Einsteinian science was not a continuation of the Newtonian one, and a scientific revolution took place the new physics being an accomplishment of the Cartesian epistemology[112] –, but it is a model to fathoming the present (and future) state of sciences. It is not about the taking over of all the contents put by Bachelard in this model, but about the *use* of the model as such, that of evolutionary epistemology applied to present phenomena of the human knowledge. In this epistemology, the scientific spirit continuously constructs itself, and the paradigms once valid are not necessarily reliable forever. In this use, we must be sensitive towards at least three aspects suggested by Bachelard – who has focused only on the intertwining of ontology and epistemology emphasised by the new physics and chemistry – but highlighted by more than the present physics and chemistry. These aspects concern:

- the weight of *irreversible* processes in the world and its understanding;
- the necessity to re-formulate definitions of phenomena as a result of their disclosing as depending on *relations* and on more and more *complex* relations, while both the mathematical and abstract, and the "technological" transposition of these decomposed and complex relations outline a *holistic* world and the necessity of its holistic approach;
- and the interdependence of science and technology/the *practical* character of science, too (besides its theoretical essence).

Bachelard has shown that the old scientific concepts – which were clear only because they were based on the empirical experience of mezzo-bodies – have become *historical*/moments in the history of scientific knowledge: because the new science raises rather problems than clarity (and lesser, clarity once for all). For example, the speed is a plain notion only for the common sense[113]. From the standpoint of the old presupposition of full certainty given by science and rather intuitive for the man based on empirical proofs, the use of metaphors/metaphorical definitions and *post hoc* presumptions concerning the causes and essence of phenomena, as well as of *sensible* intuitions, the scientific notions were clear; these notions were polythetic (having different meanings in a given lay dialogue), but they were considered sufficient. But in the new science, the concepts are re-

[110] See Ana Bazac, "Ontology of information, information theory and technology", *Noema*, XIII, 2014, pp. 195-246.
[111] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 132.
[112] *Idem*, p. 135.
[113] *Idem*, p. 43.

defined, re-put in experiments, re-calculated according to the new theories/suppositions just because the new theories open the way to *problems*. A concept that does not cause *problems* is rather suspected. And, as the new physics has showed, neither the quantum world nor the higher mathematics is intuitive from the viewpoint of mezzo-empirical objects. This is the reason they are so difficult: simply, it is about un-translatability of different sizes worlds. Or, at the same time the new science is progressing and is open (even for the translatability of the worlds): it has plausible theories for aspects that, before, were not explainable according to the direct contact causality in the mechanistic pattern and thus the thinkers have thought that these aspects would be explainable not by science but by philosophy (according to either the theories resorting to deity or to concepts). Consequently, philosophy was an opposite way of explanation towards science. But the new physics and, more, the new science developed on the new physics worldview allow a development of scientific explanations and the reduction of the field of philosophical explanations. This does not mean at all that there is no need of philosophy: but only that philosophy ceases to be the only explanation for some problems.

On the other hand, this new relativistic conditioning of concepts does not mean that sure concepts would not exist. Subject to further research, the concepts and data from the *new* theories (mathematised and demonstrated with the new means) are clear, though to be sure, not the last truth; it is the *real* itself that is not transparent: it is ambiguous, mysterious (as Blaga has said and Bachelard too[114]).

But – and here is a methodological stance – people believe that neither the methods of thinking do not change and nor the content given by these methods. Or, both the methods and the content change, and thus the *structure* of rational cognisance is not the result of accumulations, but just of rectifications and – keep attention – extensions[115], i.e. analogies and their development (including refutation in different domains). The *meanings* of concepts change, and only when changing have a concept its larger illuminating power upon the former meanings and, since the change takes place in a later form and complex society, upon the structural complexity of the real world it reflects.

However, the scientific change occurs not only from the change of methods and concepts, but also from its experimental level. This is the first aspect of the *practical* character of science. The mathematical methods create the new physics "as the microscope creates micro-biology"[116]. Therefore, the requirements of experimenting have led to new material means to realise it, new technology/techno-sciences, and these means have led, in their turn, to new facets of reality highlighted by new sciences/new phenomena created by technologies (the already mentioned *phénoménotechnique*). And again, being the result of (new) theories, and not of sensible experience and intuitions, the new science follows new theoretical and practical instruments of these theories, emphasising three types of objectivity: rational, technological and social, as "characteristics of the new scientific culture, and without which we enter the realm of utopia"[117].

The other aspect of the *practical* character of science is something strange at first sight. Science has a practical consequence through its application in different technologies. But this relation is not (only) direct: why would be science, whose aim is to know/to make theories, interested to be applied? Well, this is because the *ideal*/purpose of science does not concern only the methods and moments of research, but goes farther on: science aims for the *totality* of the world it is interested to understand. Not for fragments of the world, emphasised by different theories and

[114] *Ibidem*: "It is the real, and not the cognisance, that which bears the mark of ambiguity".
[115] *Idem*, p. 44.
[116] *Idem*, p. 45.
[117] Gaston Bachelard, *L'Activité rationaliste de la physique contemporaine* (1951), Paris, PUF, 1965, p. 10.

methodological moments, but for the *totality*[118]. This totality is being watched when science draws attention to technologies in order to realise its theories.

As a result, when this ideal of science is neglected, technology also forgets this ideal. Of course, there is not about "science" and "technology", but about researchers and engineers which are framed in and determined by concrete social relations of power over the instruments of science, technology, society and life. Some thinkers have considered science and technology as if these ones would have their own bodies and will, and as if they would determinate impassibly the scientists and engineers. Heidegger and many others have thought that the main cause of the human estrangement is the excessive and crazy development of technology, and that – as Prigogine and Stengers have showed[119] – this development (of science and technology) is only a foolish manifestation of man's essence to dominate nature[120]. Actually, the reason of the anti-human character of some science-technological results is just the anti-human character of the social relations[121]. Indeed, the Newtonian science has split the world in the part of quantity or "reifying geometry" and the part of quality, as Koyré has showed[122], and the first has generated a scientific legitimating of the pattern of considering the quantities as adversaries and subjects, defeating them by the "more, more, more", but the pattern as such was created by the capitalist system's quest for profit.

But, as Bachelard has developed, the contemporary science is not only open to but also generates a complex view about the world: *materialist/realist*[123] and *quantitatively* analysable, and

[118] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 47: "in the detail of the calculation a kind of consciousness of totality is watching. It is the initial ideal of totality that is prolonging".

[119] Prigogine and Stengers, *Order Out of Chaos*, pp.32-33.

[120] It seems paradoxical, because Heidegger was existentialist and not essentialist: he considered that the human existence is that which generates its essence; but at the same time that though the human attribute to dominate nature was generated by the concrete position of man within nature, ultimately this attribute would embody in the mad development of science and technology. As we know, Heidegger has made total abstraction of the social.

[121] Criticising the Newtonian classical science, some ones have thought that its insufficiency would be tantamount to the insufficiency of science as such, its "conceptual blindness" towards un-demonstrable/not yet demonstrable facts and suppositions, and that the alternative irrational way of conceiving of the world would be the solution. With an ironical *esprit de finesse*, Prigogine and Stengers, *Order Out of Chaos*, p. 35 have observed that the "conceptual blindness is not the main reason for the problems and contradictions our society failed to solve".

At the same time, the quantum mechanics was thought by some ones to open the way to a confluence with religious ideologies, as Fritjof Capra, *op. cit*. has showed and was inclined to.

[122] Alexandre Koyré, *Newtonian Studies*, Chicago, University of Chicago Press, 1968, pp. 23-24, quoted by Prigogine and Stengers, *Order Out of Chaos*, pp. 35-36.

[123] An interesting observation has to be mentioned here. The new physics seemed to shake the *realism* (of science, as the main characteristic of a scientific theory to be true, i.e. to reflect real things; therefore, realism is an epistemological characteristic) / *materialism* known as generated by macro and mezzo bodies (thus being a characteristic of the world/ontological characteristic). Because: the quantum mechanics is based on *unobservable* entities. Epistemologists have discussed the attitude of science towards *unobservable* entities, and have arrived at both realism – considering that science can reflect (truth correspondence theory) those entities in an objective manner/can have objective knowledge about them; and that matter (electrons etc.) exists and may be tackled, and must be more carefully verified, with the specific instruments. The antirealists consider the object (matter, electrons etc.) only indirectly. They focus on the quantum mechanics *theories* which would be: a) only instruments helping the organisation of legitimate propositions referred only to observable things; b) true or false only if they are interpreted abbreviations of the observational propositions, thus related to observable things; c) true or false, but the end of science would not be the quest for truth, but only to provide adequate theories from an empirical standpoint. As a result, the antirealists are empiricists, who consider truth as only the relation between subjects and empirical observable objects. (AB, a strange return to a dogmatism of a revolute type of knowledge, is it not?). (See this interesting epistemological analysis at Silvio Seno Chibeni, « Le réalisme scientifique face à la microphysique », *Revue philosophique de Louvain*, tome 97, no. 3-4, 1999, pp. 606-627).

relational and *holistic*, subordinating the quantitative measurements to qualities, interdependences and play of the intertwining levels of reality. In this framework, science is unfinished, and the not yet solved problems are incited by both theoretical curiosity and practical imperious necessity.

A practical attitude towards science is that of a permanent rational doubt concerning the existing knowledge. Doubt must not lead to epistemological and moral relativism: doubt must be reasonable, because there always are criteria and truths which are real and true in a certain moment of knowledge. Doubt must be rational. But doubt is difficult to be assumed as normal scientific attitude[124], and rationality seems to be weaker in the common spiritual atmosphere constructed by the ones above than the anti-science and irrational positions.

Finally, Bachelard, Einstein and important contemporary scientists have insisted that an essential aspect of the scientific knowledge is the responsibility of researchers towards it. In fact, the lack of responsibility is only the result of the conjuncture: the extra-science conditioning of researchers and science and technology. But science is project[125] : related to science, said Bachelard, but this means related to existence.

References

1. Bachelard, Gaston. "Noumène et microphysique", in Gaston Bachelard, *Études*, Présentation de Georges Canguilhem, Paris, Vrin, 1970, pp. 11-24.
2. Bachelard, Gaston. *La formation de l'esprit scientifique. Contribution à une psychanalyse de la connaissance objective* (1934), Paris, Librairie philosophique J. Vrin, 1967.
3. Bachelard, Gaston. *Le nouvel esprit scientifique* (1934), Paris, PUF, 1968.
4. Bachelard, Gaston. *L'Activité rationaliste de la physique contemporaine* (1951), Paris, PUF, 1965.
5. Bachelard, Gaston. *Le matérialisme rationnel* (1953), Paris, PUF, 1972.
6. Bazac, Ana. „Materia: observaţii epistemologice cu prilejul aniversării modelului atomului al lui Rutherford (II)", *Noema*, XI, 2013, pp. 83-114 [Matter: epistemological remarks with the occasion of the anniversary of the Rutherford's model of atom].
7. Bazac, Ana. "Ontology of information, information theory and technology", *Noema*, XIII, 2014, pp. 195-246.
8. Bazac, Ana. "The philosophy of the *raison d'être*: Aristotle's *telos* and Kant's categorical imperative", *Biocosmology – Neo-Aristotelism*, Vol. 6, No. 2, 2016, pp. 286-304.
9. Bazac, Ana. "Matter, information and cancer: Notes related to the "Challenging Integralism"", *Biocosmology – Neo-Aristotelism*, Vol. 7, No. 1, Winter 2017, pp. 65-84.
10. Bejan, Adrian, James H. Marden, "The constructal unification of biological and geophysical design", *Physics of Life Reviews*, 2008; DOI: 10.1016/j.plrev.2008.12.002.

The author shows that the antirealists speculate on the intermediary moment of theories (between the human subject searching for truth and the object), and considers that it is not licit to throw the possibilities that reality has facets contradicting the habitual physical intuitions.

More specifically, we should mention that antirealists break the truth correspondence from the truth coherence, in fact there always is both correspondence and coherence, theories must correspond and at the same time be coherent; the intermediary position of theories does not annul their truth values because they refer to reality, even though indirectly observable; antirealists draw attention on the proofs of the limits of representation of reality: namely, the objective reality is not as it appears; but the intermediary character of theories and means – as mathematics – does not shake the ultimate empirical proofs of quantum mechanics theories; on the contrary, this intermediary character is a supplementary means to control the material objectivity and the correctness of theories; some perturbations in measurements are not antirealist arguments.

[124] Gaston Bachelard, *Le nouvel esprit scientifique*, p. 113: The Cartesian doubt that had to be the starting point of the pedagogy of metaphysics is not at all easy to teach.

[125] *Idem*, p. 14.

11. Capra, Fritjof. *The Turning Point: Science, Society and the Rising Culture*, 1982 (free downloadable).
12. de Broglie, Louis. *La physique nouvelle et les quanta*, Paris, Flammarion, 1937.
13. de Broglie, Louis. *Continu et discontinu en physique moderne*, Paris, Albin Michel, 1941.
14. Ehrenfeucht, A., I. Petre, G. Rozenberg. "Reaction systems: A model for computation inspired by the functioning of the living cell", pp. 1-32. In: *The role of theory in computer science* (S. Konstantinidis, N. Moreira, R. Reis, J. Shallit, eds.), Singapore, World Scientific, 2017.
15. Feynman, Richard. *The Character of Physical Law* (1967), Cambridge Ma., London, England: The MIT Press, 1985.
16. Georgescu-Roegen, Nicholas. "Energy and Economic Myths", *Southern Economic Journal*, 41, no. 3, January 1975,
17. http://dieoff.org/page148.htm
18. Hall, Shannon. *Exxon Knew about Climate Change almost 40 years ago*, October 26, 2015,
19. https://www.scientificamerican.com/article/exxon-knew-about-climate-change-almost-40-years-ago/
20. Hughes, Terry P. et al., "Global warming and recurrent mass bleaching of corals", *Nature*, 16 March 2017, Issue 543, pp. 373–377.
21. Lankester, Ray. More Science from the Easy Chair (1913), Lond., Methuen & Co., 1920.
22. Le Bon, Gustave. *L'évolution de la matière*, Paris, Flammarion, 1905.
23. Păun, Gheorghe. "Some Wonders of a Bio-Computer-Scientist", *Bulletin of the International Membrane Computing Society*, 2016, http://membranecomputing.net/IMCSBulletin/, pp. 241-260.
24. Poincaré, Henri. *La science et l'hypothèse* (1902), Paris, Flammarion, 1968.
25. Prigogine, Ilya and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue With Nature* (1978), Foreword by Alvin Toffler, Toronto, New York, Bantam Books, 1984.
26. Russell, Bertrand. *The Analysis of Mind* (1921), Blackmask Online, 1999.
27. Russell, Bertrand. *The Analysis of Matter* (1927), Nottingham, Spokesman, 2007.
28. Ruyer, Raymond. *Paradoxes de la conscience et limites de l'automatisme*, Paris, Albin Michel, 1966.
29. Seno Chibeni, Silvio. « Le réalisme scientifique face à la microphysique », *Revue philosophique de Louvain*, tome 97, no. 3-4, 1999, pp. 606-627.
30. Vacariu, Gabriel. *Illusions of Human Thinking: On Concepts of Mind, Reality, and Universe in Psychology*, Wiesbaden, Springer, 2016.
31. Vernadsky, Vladimir. *La géochimie*, Paris, Librairie Félix Alcan, 1924.
32. Vernadsky, Vladimir. *La biosphère* (1926), Paris, Félix Alcan, 1929.