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*The Quantum-Relativistic Creation Of Matter  
And Bachelard's Philosophy*

Bénie sois-tu, âpre Matière, glèbe stérile, dur rocher, toi qui ne cèdes qu'à la violence...  
Bénie sois-tu, dangereuse Matière, mer violente, indomptable passion, toi qui nous dévores, si nous ne t'enchaînons.

Bénie sois-tu, puissante Matière, évolution irrésistible, Réalité toujours naissante, toi qui faisant éclater à tout moment nos cadres, nous obliges à poursuivre toujours plus loin la vérité.

Bénie sois-tu, universelle Matière, Durée sans limites, éther sans rivages, – Triple abîme des étoiles, des atomes et des générations, – toi qui, débordant et dissolvant nos étroites mesures, nous révèle les dimensions de Dieu.

Bénie sois-tu, impénétrable Matière, toi qui, tendue partout entre nos âmes et le monde des Essences, nous fais languir du désir de percer le voile sans couture des phénomènes.

Bénie sois-tu, mortelle Matière, toi qui, te dissociant un jour en nous, nous introduiras, par force, au coeur même de ce qui est.

Sans toi, Matière, sans tes attaques, sans tes arrachements, nous vivrions inertes, stagnants, puérils, ignorants de nous-mêmes et de Dieu.

Toi qui meurtris et toi qui penses, toi qui résistes et toi qui plies, toi qui bouleverses et toi qui construis, toi qui enchaînes et toi qui libères, -Sève de nos âmes, Main de Dieu, Chair du Christ, Matière, je te bénis.

– Je te bénis, Matière, et je te salue, non pas telle que te décrivent, réduite ou défigurée, les pontifes de la science et les prédicateurs de la vertu, -un ramassis, disent-ils, de forces brutales ou de bas appétits, -mais telle que tu m'apparais aujourd'hui, dans ta totalité et ta vérité.

Je te salue, inépuisable capacité d'être et de Transformation où germe et grandit la Substance élue.

Je te salue, universelle puissance de rapprochement et d'union, par où se relie la foule des monades, et en qui elles convergent toutes sur la route de l'Esprit.

Je te salue, somme harmonieuse des âmes, cristal limpide dont est tirée la Jérusalem nouvelle.

Je te salue, Milieu divin chargé de Puissance créatrice, Océan agité par l'Esprit, Argile pétrie et animée par le Verbe incarné.

– Croyant obéir à ton irrésistible appel, les hommes se précipitent souvent par amour pour toi dans l'abîme extérieur des jouissances égoïstes. – Un reflet les trompe, ou un écho.

Je le vois maintenant.

Pour t'atteindre, Matière, il faut que partis d'un universel contact avec tout ce qui se meut ici-bas, nous sentions peu à peu s'évanouir entre nos mains les formes particulières de tout ce que nous tenons, jusqu'à ce que nous demeurions aux prises avec la seule essence de toutes les consistances et de toutes les unions.

Il faut, si nous voulons t'avoir, que nous te sublimions dans la douleur après t'avoir voluptueusement saisie dans nos bras.

Tu règues, Matière, dans les hauteurs sereines où s'imaginent t'éviter les Saints,- Chair si transparente et si mobile que nous ne te distinguons plus d'un esprit.

Enlève-moi là-haut, Matière, par l'effort, la séparation et la mort, – enlève-moi là où il sera possible, enfin, d'embrasser chastement l'Univers !

Pierre Teilhard de Chardin, *Hymne à la matière*, 1919<sup>1</sup>

## 1. La phénoménotechnique étend la phénoménologie<sup>2</sup>. Towards an experimental physical phenomenology

At the time when Pierre Teilhard de Chardin (1881-1955), a Jesuit theologian and evolutionary paleontologist, wrote his *Hymne à la matière* in 1919, the observations of light-ray deflections, made by Arthur Stanley Eddington (1882-1944) and fellow astronomers, were gradually confirming the 1916 predictions of Albert Einstein (1879-1955) regarding the nature of gravitation based on his theory of General Relativity. It was a period that would lead to great changes in the sciences – changes launched by the newly emerging theories of evolutionary biology, special and general relativity, as well as quantum theory, which brought about a revolution in our conceptions of matter. However, a proper epistemological understanding of such great scientific revolutions and of a quantum-relativistic philosophy of matter had yet to be developed and refined.

While Edmund Husserl (1859-1938)<sup>3</sup> was delineating the purely practical value of scientific knowledge and disseminating his phenomenological method in France during the 1930s<sup>4</sup>, Gaston Bachelard had been reflecting on the cognitive value of the sciences, and formulating his notion of *phénoménotechnique*, as attested by his 1931-1932 paper entitled *Noumène et microphysique*<sup>5</sup> which would pave the way for a major correction to Husserl's phenomenology.

For Husserl, doubt must lead to the suspension of judgment on all previously given philosophies, and the prejudices of scientific theories must also be “placed in parentheses” to return to the world of “pure experience”. Yet we must also question the world of pure experience and the judgments of common sense, which already presuppose a world of which the human being is a part. Hence,

<sup>1</sup> Teilhard de Chardin, P., *Hymne à la matière*, in *Hymne de l'Univers*, Seuil, Paris 1961, pp. 65-67.

<sup>2</sup> Bachelard, G., *La Formation de l'esprit scientifique*, Vrin, Paris 1938, p. 71.

<sup>3</sup> Husserl, E., *Ideen zu einer reinen Phänomenologie und Phänomenologischen Philosophie. Erstes Buch: Allgemeine Einführung in die reine Phänomenologie*, in *Jahrbuch für Philosophie und phänomenologische Forschung*, Niemeyer, Halle 1913, II e III, Kluwer, Dordrecht 1952.

<sup>4</sup> Pintos-Peñaranda, M.-L., *The Introduction of Phenomenology into French 1900-1940*, [https://reviews.ophen.org/2016/06/29/introduction-phenomenology-french-1900-1940/?fbclid=IwAR2iNmKhNRYdk0LD-JQNnd1aQhWPfcR\\_iIW69850T86LAIeER-RqOFDtk4E](https://reviews.ophen.org/2016/06/29/introduction-phenomenology-french-1900-1940/?fbclid=IwAR2iNmKhNRYdk0LD-JQNnd1aQhWPfcR_iIW69850T86LAIeER-RqOFDtk4E).

<https://reviews.ophen.org/wp-content/uploads/sites/7/2016/06/Pintos-Phenomenology-French.pdf> (Last consultation: 6.04.2021).

<sup>5</sup> Bachelard, G., *Noumène et microphysique*, in *Recherches Philosophiques* vol. I (1931-1932), pp. 55-65.

the phenomena of Husserlian phenomenology are not objects or natural phenomena as given to the senses in their contingent existential singularity, but “pure phenomena” independent of their presumed external existence. Such pure phenomena are the “eidetic-transcendental reduction” of natural phenomena to essences (forms-ideas) as captured by an eidetic intuition in human consciousness. Hence, they do not refer to “natural objects” or to those phenomena studied in the natural sciences whose existence we assume as obvious from the standpoint of practical interest, as entities “at-hand” (*Zuhandenheit*) in the world of experience. Rather, we have to consider eidetic objects that present themselves to theoretical intentional acts, to the disinterested theoretical gaze of philosophical consciousness, to a pure eidetic intuition that provides evidence without the need for further intellectual elaboration.

From this pure theoretical intentional stance, Husserl legitimizes physics’ reduction of the world of Nature into a world of mere material things. Any consideration belonging to the affective-emotional sphere, to the ethical sphere of values, to the practical-instrumental sphere of use and interests, or to the sphere of existential sense, is excluded.

On the other hand, Husserl considers the experimental dimension as part of the theoretical one – a subsumption which must be questioned because, even though things spontaneously show themselves as phenomena in human experience, experiments do not allow things to show themselves but rather force things into an exclusive theoretical reduction.

Thus, in addition to Kantian sensible intuition, Husserl posits a categorical intuition (distinct from that of the Kantian intellect) which allows access, beyond empirical intuition, to universal, a priori modes of “objective” being, in which experience is structured. In Husserl’s account, then, we have an eidetic intuition from particular empirical data to the “objective essences” of things (“objective, ontological transcendentals”), because the various modes of being – even if given only to a disinterested theoretical gaze – are not determined by the subject, and are in fact independent of it.

The universality of phenomenology’s phenomena is revealed in the eidetic phenomena themselves, and must not be added from the outside by the subject nor be extrapolated by subsequent induction as in the case of natural phenomena given to the senses, from which it would be impossible to yield universal certainty, and through which a rigorous science could never be derived.

Following the physical revolutions of the twentieth century<sup>6</sup>, Bachelard questions all previous scientific philosophies and theories, as well<sup>7</sup>. However he believes that even experiments, like lived experiences, provide direct access to physical reality, and that their content is therefore not merely theoretical but in fact constitutes the objective correlate of the theoretical intentional acts that translate themselves into experimental actions.

<sup>6</sup> Bonicalzi, F., *Leggere Bachelard. Le ragioni del sapere*, Jaca Book, Milano 2007, in particular, pp. 73-104.

<sup>7</sup> Bachelard, G., *La philosophie du non*, P.U.F., Paris 1940.

Such experiments bring about the emergence of an “artificial” Nature – a Nature that does not give itself in direct human experience, due to its limits. Although such Nature does not pre-exist naturally on Earth, it perhaps does so elsewhere in the universe: it is a Nature, in any case, that we cannot encounter at the macroscopic or mesoscopic dimensions of our human experience. Consider, for instance, the vacuum produced in Robert Boyle’s experiments through the use of a pneumatic pump that sucks air from a certain delimited area. This artificial Nature is actually produced in experiments by means of technical tools and operations.

Already in a 1932 paper on Spinoza, *Physique et métaphysique*<sup>8</sup>, Bachelard had called this artificial nature *Natura constructa* or *Nature factice*, translating into epistemological terms Spinoza’s dual theological conception of *Natura naturans* (God, Nature’s creative agency) and *Natura naturata* (created Nature)<sup>9</sup>. Mathematical thought must be considered as a case of *Natura construens* and its experimental realization as *Natura constructa* (which is nonetheless not detached from *Natura construens*). *Natura constructa* is discussed by Bachelard as a third factor in the dialectics of creation – a perspective resembling John Scotus Eriugena’s more complex, four-sided dynamics of Nature’s one-and-the-same creation: *Natura quae creat et non creatur*, *Natura quae creatur et creat*, *Natura quae creatur et non creat*, *Natura quae nec creatur nec creat*<sup>10</sup>.

It is important to point out that Bachelard understands even mathematical thought as a form of Nature, yet does not assimilate Nature to thought: physics implies a “created”, “natured” thought. Thus, he avoids every idealistic emphasis on a mathematical metaphysics or on a metaphysics of mathematics. Mathematical

<sup>8</sup> Bachelard, G., *Physique et Métaphysique*, in *Septimana Spinozana. Acta Conventus Oecumenici in memoriam Benedicti De Spinoza Diei Natalis Trecentesimo Hagae Comitibus Habiti*, Nijhoff, La Haye 1933, pp.74-84. An Italian translation of *Physique et Métaphysique* under another title, *Metafisica della matematica*, was recently published with two introductory essays: Ienna, G., *Presentazione a Bachelard, G., Metafisica della matematica*, eds. Alunni, C., Ienna, G., Castelvecchi, Roma 2016, pp. 5-23; Alunni, C., *Gaston Bachelard, ancora e ancora*, in Bachelard, G., *Metafisica della matematica*, op.cit., pp. 25-52; Ienna, G., *Natura constructa et phénoménoteknikue. Spinozisme et pensée des mathématiques chez Gaston Bachelard*, in *L'épistémologie historique. Histoire et méthodes*, eds. by Braunstein, J.-F., Diez, I. M. and Vagelli, M., Éditions de la Sorbonne, Paris 2019, pp. 43-58; Abramo, M. R., *Gaston Bachelard e le fisiche del Novecento*, Guida, Napoli 2002, pp. 180-193; Abramo, M. R., *Il razionalismo “induttivo” di Gaston Bachelard*, Università di Messina, Messina 2019, <https://iris.unime.it/retrieve/handle/11570/3147124/253972/M.R.ABRAMO%20I%20Il%20razionalismo%20C2%ABinduttivo%20BB%20di%20Gaston%20Bachelard%20Tesi%20di%20Dottorato%20in%20Filosofia%202019.pdf> (Last consultation: 6.04.2021).

Abramo, M. R., *Bachelard e lo «spazio» della fisica contemporanea*, in Bonicalzi, F., Vinti, C. (eds.), *Ri-cominciare. Percorsi e attualità dell'opera di Gaston Bachelard*, Jaca Book, Milano 2004, pp.81-96.

<sup>9</sup> This distinction that can be traced back to the Persian physician and philosopher Avicenna (Ibn Sina, 980-1037 AD).

<sup>10</sup> Scotus Eriugena, J., *Periphyseon (The Division of Nature)*, Eng. trans. by I. P. Sheldon-Williams, J. J. O'Meara, Bellarmine, Montreal 1987; Scotus Eriugena, J., *Sulle nature dell'universo I-V*, latin text ed. by P. Dronke, It. trans. by M. Pereira, Fondazione Lorenzo Valla, Mondadori, Milano 2012-2017.

reason is always *a posteriori* in physical science, which modifies every *a priori* or assumed notion of mathematics in its hermeneutic circle<sup>11</sup>.

Indeed, there are phenomena which are not direct perceptual manifestations of Nature to human living experience but are, rather, artificially produced through technical experiments. In the mathematical representation of such experiments, the *eidos* of these phenomena emerges and constitutes a transcendental or noumenal object on the ontological level of physical reality, and this “noumenon” presents itself, as in the last Kant of *Opus Postumum*, as a “phenomenon of the phenomenon”<sup>12</sup>.

For Bachelard, the extension of phenomenology into *phenomenotechnique* is therefore necessary<sup>13</sup> in both cases – whether phenomenology is understood from a purely descriptive physical perspective (in the sense still used by physicists today), or whether it is understood as the descriptive eidetic science proposed by Husserl. This is the indication of an experimental physical (hence also mathematical) phenomenology which – from Hugo Dingler onwards – will be further developed by other authors who come from the phenomenological field. There is, therefore, a convergence of positions between Bachelard and Husserl’s followers<sup>14</sup>.

<sup>11</sup> Bachelard, G., *Physique et Métaphysique*, in *Septimana Spinozana. Acta Conventus Oecumenici in memoriam Benedicti De Spinoza Diei Natalis Trecentesimi Hagae Comititis Habiti*, Nijhoff, La Haye 1933, pp.74-84.

<sup>12</sup> Reicke, R., Arnoldt, E., *Ein ungedrucktes Werk von Kant aus seinen letzten Lebensjahren. Als Manuskript herausgegeben*, in *Altpreußische Monatsschrift* 19, pp. 66- 127, 255-308, 425-479, 569-629 (1882); 20, pp. 59-122, 342-373, 415-450, 513-566 (1883); 21, pp. 81-159, 309-387, 389-420, 533-620 (1884); Kant, I., *Opus postumum*, hrsg. Lehmann G. von, Buchenau A., in *Kant’s gesammelte Schriften*, hrsg. von der Königlichen Preußischen Akademie der Wissenschaften, de Gruyter, Berlin-Leipzig 1936-1938, Abt. III, voll. VIII and IX Handschriftlicher Nachlass, Bd. 21 and 22; Adickes E., *Kants Opus postumum dargestellt und beurteilt*, Reuther & Reichard (*Kant-Studien*, Ergänzungsheft Nr. 50), Berlin 1920, reprinted by Topos, Vaduz 1995.

<sup>13</sup> Bachelard, G., *Physique et Métaphysique*, in *Septimana Spinozana. Acta Conventus Oecumenici in memoriam Benedicti De Spinoza Diei Natalis Trecentesimi Hagae Comititis Habiti*, Nijhoff, La Haye 1933, pp.74-84. See also: Rheinberger, H.-J., *Gaston Bachelard and the Notion of “Phenomenotechnique”*, in *Perspectives on Science* (2005) 13 (3), pp. 313–328; Chimisso, C., *From phenomenology to phenomenotechnique: The role of early twentieth-century physics in Gaston Bachelard’s philosophy*, in *Studies in History and Philosophy of Science Part A*, vol. 39, Issue 3, September 2008, pp. 384-392; Alloa, E., *L’apparato delle apparenze. Sul concetto di fenomenotecnica e la sua incidenza sull’estetica e l’epistemologia*, in *Rivista di estetica*, 63 (2016), pp. 36-55; D’Aurizio, C., Palombi, F., *Il senso di una frattura: la fenomenotecnica bachelardiana fra fenomenologia e psicoanalisi, in Il senso della tecnica. Saggi su Bachelard*, eds. by Donatiello, P., Garofalo, F., Ienna, G., Esculapio, Bologna 2017, pp. 1-19; Ienna, G., *Materialismo tecnico. Fra fenomenotecnica ed epistemologie regionali, in Il senso della tecnica. Saggi su Bachelard*, op. cit., pp. 21-36; Castellana, M., *Il pluralismo coerente della fenomenotecnica contemporanea in Gaston Bachelard, in Il senso della tecnica. Saggi su Bachelard*, op. cit., pp. 37-58; Alunni, C., *“La Valeur inductive de la relativité” contre la Phénoménotechnique, in Il senso della tecnica. Saggi su Bachelard*, op. cit., pp. 59-76; Bontems, V., Guy T., *L’étude des lignées phénoménotechniques. De Bachelard à Simondon et aux Micromegas, in Il senso della tecnica. Saggi su Bachelard*, op. cit., pp. 109-120; Galofaro, F., *Semiologia trascendentale e semiotecnica. Discipline regionali e fondamenti del senso tra Husserl, Bachelard, Hjelmslev, in Il senso della tecnica. Saggi su Bachelard*, op. cit., pp. 137-191.

<sup>14</sup> See also: Guidetti, L., *La costruzione della materia. Paul Lorenzen e la “Scuola di Erlangen”*, Quodlibet, Macerata 2008, pp. 49-76.

## 2. Bachelard and Heidegger

Some years later, in 1935, Martin Heidegger started reflecting on the “mathematical metaphysics” of modern physics<sup>15</sup>. In his lectures on Nietzsche (1936-1946), Heidegger<sup>16</sup> then spoke at length about Western modern metaphysics, accomplished by the Nietzschean will-to-power, as realized by the technical dominion over *Physis*.

In a 1938 conference on *Die Zeit des Weltbildes*<sup>17</sup>, Heidegger wrote about modern technique and modern science as defining the “metaphysics of modernity” – a metaphysics which reduced the world to a mathematical representation or construction (*Bild*).

Heidegger also departed<sup>18</sup> from Husserl’s position on technique. Although Husserl maintained his position until the end, attributing instrumental value not only to technique but also to science<sup>19</sup>, Heidegger discussed a non-instrumental, non-technical role of technique, which was revelatory of being. This discourse by Heidegger has always remained strange and abstract to the eyes of his interpreters: yet it becomes understandable if read as a phenomenological, philosophical, elaboration of Bachelard’s notion of *phénoménotechnique*<sup>20</sup>.

Indeed, Heidegger had had access to the volume that included Bachelard’s *Noumène et microphysique*, since the translation of one of Heidegger’s texts had also been published in the same issue of the journal, where Bachelard’s piece had been initially published<sup>21</sup>.

Heidegger could have drawn from Bachelard the idea of metaphysics as linked to the technical dominion over *Physis*, specifically from the equivalence placed by Bachelard, in that essay, between metaphysics and metatechnique (*metatechnique*) as technically, experimentally realized metaphysics.

The metaphysics outlined by Heidegger as realized by “technical dominion” is critiqued as linked to an erroneous meta-technique which conceives of technique in an instrumental and anthropocentric way, ignoring the sense of revelation of reality that emerged in the *phenoménotechnique* of twentieth-century physics – namely, the ontological (“noumenal-phenomenal”) implications of technique.

<sup>15</sup> Heidegger, M., *Die Frage nach dem Ding. Zu Kants Lehre von den transzendentalen Grundsätzen*, Niemeyer, Tübingen 1962.

<sup>16</sup> Heidegger, M., *Nietzsche*, Neske, Pfullingen 1961.

<sup>17</sup> Heidegger, M., *Die Zeit des Weltbildes*, in *Holzwege*, Klostermann, Frankfurt am Main 1950.

<sup>18</sup> Heidegger, M., *Die Frage nach der Technik*, in *Vorträge und Aufsätze*, Neske, Pfullingen 1954, pp. 5-27; Giannetto, E. R. A., *Un fisico delle origini. Heidegger, la Natura e la scienza*, Donzelli, Roma 2010.

<sup>19</sup> Husserl, E., *Die Krisis der europäischen Wissenschaften und die transzendente Phänomenologie*, in *Husserliana, Gesammelte Werke*, Bd. VI, Nijhoff, Den Haag 1954, 1959.

<sup>20</sup> See also: Bonicalzi, F., *Leggere Bachelard. Le ragioni del sapere*, Jaca Book, Milano 2007, pp.145-160; Castelli, E. Gattinara, *Bachelard e Heidegger a confronto su tecnica, scienza e ontologia*, in *Il senso della tecnica. Saggi su Bachelard*, op. cit., pp. 77-94.

<sup>21</sup> Heidegger, M., *De la nature de la cause*, in *Recherches Philosophiques*, vol. I (1931-1932), pp. 83-125 (Fr. tr. by A. Bassey of Heidegger, M., *Vom Wesen des Grundes*, in *Wegmarken*, in *Gesamtausgabe*, vol. 9, ed. by Herrmann, F.W. von, Klostermann, Frankfurt am Main 1976, pp.79-131).

Heidegger here wrote of being as *production* – namely, as an emergent “*Physis*” produced through a mode of technical provocation<sup>22</sup>.

There is no doubt that Heidegger could have been influenced by Werner Heisenberg and Carl Friedrich Von Weizsäcker<sup>23</sup>. But only Bachelard’s epistemology had by then attributed a fundamental, ontological role to technique, so that Bachelard’s influence on Heidegger is very probable.

It is within this philosophical and epistemological context that the problem of “matter” in twentieth-century physics can be better understood.

### 3. A brief history of the pre-modern concept of matter

An almost complete history of the physical concept of matter as “mass” has been outlined by Max Jammer<sup>24</sup>. Although Jammer also takes into account experiments relevant to modern physics, his methodological perspective is that of the history of ideas, aimed more at emphasizing thematic continuity than the historical *epistemological breaks* outlined by Bachelard and the scientific revolutions (considered from Thomas Kuhn onwards)<sup>25</sup>.

A first perception-conception of some sort of “matter” can be linked to the upper Paleolithic period. Matter appears as a divinity, a Great Mother, celestial and terrestrial, from whose principle everything originates. Matter therefore presents itself originally with traits of a living, animated, intelligent being. Matter is a generating force, animal and feminine<sup>26</sup>.

An epochal change then occurs with the so-called “Neolithic revolution”, or rather with the introduction of agricultural techniques and animal husbandry: the human dominion over *physis*, over the Earth, over animals, practiced systematically and methodically, leads to a new perception of matter as inert and passive, as a mere passive power to which mankind gives shape, yet also as a mode of resistance to human male strength. Animals gradually undergo a process of domestication, and there is an attempt – during this patriarchal, male-dominated turn at the root of our “civilizations” – to bring human society itself (like the Earth) under control, while also bringing about the submission and exclusion of women, including the exercise of violence in forcing them to generate.

<sup>22</sup> Heidegger, M., *Die Frage nach der Technik*, in *Vorträge und Aufsätze*, Neske, Pfullingen 1954, pp. 5-27; Giannetto, E. R. A., *Un fisico delle origini. Heidegger, la Natura e la scienza*, Donzelli, Roma 2010.

<sup>23</sup> Giannetto, E. R. A., op. cit..

<sup>24</sup> Jammer, M., *Concepts of Mass in Classical and Modern Physics*, Harvard University Press, Cambridge, Mass. 1961, third edition, Dover, New York 1993.

<sup>25</sup> Kuhn, T., *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago 1962; Bachelard, G., *Essai sur la connaissance approchée*, Vrin, Paris 1927; Bachelard, G., *Le nouvel esprit scientifique*, Alcan, Paris 1934; Bachelard, G., *La formation de l’esprit scientifique. Contribution à une psychanalyse de la connaissance objective*, Vrin, Paris 1938.

<sup>26</sup> Giannetto, E. R. A., *Saggi di storie del pensiero scientifico*, Sestante for Bergamo University Press, Bergamo 2005.

If the Ionic and the first Greek philosophers, like the atomists, try to reconsider matter as a generating force, the then dominant philosophy of Plato (428-348 BC), will represent matter as *chora* (formless space in which ideas are impressed as generating forms), while regarding matter as the root of all evil and imperfection, and the body as a prison for the soul. *Eros* must be sublimated and addressed to ideas. Not long thereafter, Aristotle (384-322 BC) will come to think of matter as *hylè* – as mere potential being, a passive power subordinate to form, itself viewed as the generating force.

The original revolution of primitive Christianity, which is based on overturning hierarchies (*Mt.* 20.16: “the last shall be first”), eliminates dualism and rehabilitates matter: *Logos* becomes (is) flesh, body, matter (*John* 1.14), Spirit descends into matter, the Earth is like Heaven, woman is like man. But this original Christian physics and cosmology will remain almost silent, for century after century: the Christianization of the West indeed turns out to be a Hellenization (Platonization and then Aristotelization) of Christianity.

However, whereas Christian Aristotelianism would reach its culmination in St. Thomas (1225-1274), the Franciscan revolution initiated by Francis (1181-1226) – with its abolition of hierarchies, exemplified by the brotherhood and sisterhood of all creation in the “Canticle of Creatures” – has been subtly restoring the original Christian meaning of Nature-Matter as creation.

For John Duns Scotus (1265-1308), created matter acquires an effective being and is considered as a good<sup>27</sup>. The Eucharist celebrated in the Christian Mass (from the Hebrew *matza*, unleavened bread) becomes the fundamental incarnate “mass” that characterizes physical reality. The notion of *quantitas materiae*, as a property distinct from geometric quantities, was introduced by Egidio Romano, a disciple of St. Thomas, precisely to explain transubstantiation: it was necessary to distinguish matter from geometric dimensions to understand the possibility that the body of Christ was really present in the size of the Eucharistic bread<sup>28</sup>.

Nicholas of Autrecourt (1299-1369), a Franciscan, was the first to develop a Christian physical atomism. Nicholas of Cusa (1401-1464), was the first to consider the Earth as a material star with the outer part of fire, when viewed relativistically from the outside as part of the sky of other material bodies, above other material celestial bodies: matter returned to inhabit the sky. Nicolaus Copernicus (1473-1543) really placed the Earth above the Sun (almost at the center of the universe), in a celestial sphere higher than even Mercury and Venus. Giordano Bruno (1548-1600) resumed atomism to give physical consistency to the system of the Copernican universe, and decreed the non-subordination of matter to

<sup>27</sup> Duns Scotus, J., *De rerum principio*, in *Opera Omnia*, ed. by Wadding, L., Lyons 1639, and then reprinted by Olms, Hildesheim 1968, *qu.* 7 art. 1 n.3; Jonas, H., *Philosophical Essays. From Ancient Creed to Technological Man*, The University of Chicago Press, Chicago 1974.

<sup>28</sup> Jammer, M., *Concepts of mass in Classical and Modern Physics*, Harvard University Press, Cambridge (Mass.) 1961; *Storia del concetto di massa nella fisica classica e moderna*, It. trans. by M. Plassa, I. Prinetti, Feltrinelli, Milano 1974, pp. 50-54; Jammer, M., *Concepts of Mass in Contemporary Physics and Philosophy*, Princeton University Press, Princeton 2000.



form (forms understood to be irregular forms of matter), and matter as a living generating force, as impetus motive energy<sup>29</sup>.

Galileo followed Bruno in this respect, but René Descartes (1596-1650) disempowered matter by reducing it to a mere *res extensa* without weight, considering matter as inert and passive, introducing the principle of inertia, according to the theology of the absolute sovereignty of God to whom force-power alone is attributed, and to whom Nature as inert and passive matter is subjected like a machine that blindly obeys the “laws of Nature” imposed by God<sup>30</sup>.

Descartes’ perspective nullifies, while formally maintaining, the introduction of *quantitas materiae*, reducing it to a geometric quantity. Newton binds matter to gravitation, but the weight-force that animates it is of divine origin and gravitational mass is nothing more than the inertial mass that qualifies matter as inert and passive.

#### 4. Matter in modern science according to Bachelard

The epistemologization of mechanical technique, carried out by Galileo and Newton, had removed it from functional purposes and practical interests by converting it into a theoretical science, but Francis Bacon (1561-1626), followed in some way by Descartes, inversely brought about a technicization of science, leading to a mechanistic conception of Nature. Nature was now considered and treated as a machine, as inert and passive matter – a mass resistant to changes produced by the force deployed in human techno-mechanical work, as in the Neolithic view of matter which resists the force of agricultural technical work.

Bachelard places the mechanistic conception of Nature under the rubric of *metatechnique* or *metatechnology*, in the sense already explained. Modern physics and modern science, in the works of Gilbert, Galileo and Harriot are characterized first of all as experimental, non-discursive practices, irreducible to philosophy as a theoretical-discursive discipline<sup>31</sup>. Modern physics does not simply study phenomena given to experience and understood through philosophical phenomenology. By means of its technical-experimental practices, it indeed produces phenomena.

Yet such practice – which Bachelard labels *phenomenotechnique* – plays both a deconstructive and constructive role, in his view. To explain the historical condition of possibility of indeterminism and quantum physics, Bachelard brings determinism back to its “phenomenotechnical” roots.

With Bachelard we learn that theoretical *determinism* – which distinguishes the mechanistic conception of Nature (consciously at least from Laplace onwards) – is

<sup>29</sup> Giannetto, E. R. A., *La relatività del moto e del tempo in Giordano Bruno*, in *Physis* XXXVIII (2001) 305-336.

<sup>30</sup> Giannetto, E. R. A., *Un fisico delle origini. Heidegger, la Natura e la scienza*, Donzelli, Roma 2010.

<sup>31</sup> Giannetto, E., *Some remarks on Galileo and atomism in Galilaeana* XIV (2017), pp. 21-38.

essentially technical<sup>32</sup>; that is, it expresses the human technical dominion over phenomena experimentally produced in a laboratory: a practically absolute control of the temporal evolution of produced phenomena, univocally determined.

This technical dominion is transposed into the mathematical domain of the theorem of existence and univocity of the solutions for differential equations of motion, in which Newton's second law of the proportionality between forces and accelerations is expressed. This technical dominion over phenomena artificially produced within the laboratory is considered as extensible (in an undue and illusory extrapolation) to all natural phenomena, in the possibility of an absolute human technical dominion over all Nature: it is this *metatechnique* that translates into a materialistic, mechanistic and deterministic, technical and mathematical metaphysics, in which theory is transformed and reduced to the mere expression or project of a technical dominion over Nature.

Bachelard, however, does not put forward this deconstructive function of *phenomeno-technique* as an indistinct and *a priori* critique of all modern science on the basis of its presumed essential technical presupposition, as does Heidegger<sup>33</sup>. Rather, he shows some historically determined effects of modern science – effects which will be overcome through a negative dialectic (“la philosophie du non”) of the history of science that will lead to the formation of the quantum conception of Nature, free from this metatechnical presupposition.

Indeed, although Heidegger recognizes the revelatory function of technique (considered non-technically), he remains a prisoner of the characterization of science as a metatechnical theory to be deconstructed, because he does not realize that technique's revelatory function of *physis* is fulfilled only through its defunctionalization (with respect to technical purposes) operated by science. Heidegger does not realize that pure technique, aimed at technical-instrumental purposes, is not revelatory but rather a violent constitution of a human dominion, and that science is essentially technical only when it is transformed into a mechanistic metatechnique for which *physis* is reduced into a mechanical-tool, functional and subordinated to violent human technical dominion.

On the other hand, the constructive-revelatory function of *phenomenotechnique*, for Bachelard, can be well understood in relation to the question of conceptions of matter. The matter which Bachelard talks about is only the theoretical elaboration of something that emerges from experimental practices and mathematical practices<sup>34</sup>: it is not understandable from a history of science articulated as a history of ideas or mere concepts. Bachelard's matter cannot be framed within a history of the idea of matter, nor within a history of the philosophical conceptions of matter. It is also necessary to take into account the history of experimental and technical practices and mathematical practices on which modern and contemporary physics is based.

<sup>32</sup> Bachelard, G., *L'activité rationaliste de la physique contemporaine*, P.U.F., Paris 1951, pp. 243-256.

<sup>33</sup> Heidegger, M., *Die Zeit des Weltbildes*, in *Holzwege*, Klostermann, Frankfurt am Main 1950.

<sup>34</sup> Alunni, C., *Spectres de Bachelard et l'école surrationaliste*, Hermann, Paris 2019.

Bachelard clarifies a whole series of conclusions to be drawn from contemporary physics. The “philosophy” proposed by Bachelard is not a purely contemplative theoretical-discursive practice, but is the elaboration of modern physics’ theoretical-discursive practice based on technical-experimental and mathematical practices. As a modern theoretical physicist, Bachelard is more an “experimental philosopher” than a philosopher in the traditional sense.

As mentioned above, matter had first of all been quantified by Newton (*quantitas materiae*) as a constant quantity, also called mass, linked to the inertia that a body presents when its state of rest or uniform rectilinear motion changes. However, special relativity, would later show that the measurement of the quantity of matter varies with motion and is therefore also relative to the state of motion of the reference system that determines our point of observation: matter thus ceases to be quantifiable in a unique and absolute way, and its inertiality itself is relative and not absolute<sup>35</sup>. The different reference systems can only agree on the value (equal for all) of the mass of a body at rest, i.e. with respect to a reference system at rest which cannot generally be identified or which would be, in any event, just a particular case. The term “mass” in Newtonian physics therefore has a different meaning from the term “mass” in special relativity.

Special relativity also establishes an essential relationship ( $E = m c^2$ ) connecting mass and energy in an equivalence which is confirmed by the creation-annihilation of particles from the energy field<sup>36</sup>. Matter, as mass, must therefore be rethought in terms of energy; it is a form of energy, a “condensation” of energy: if we still talk about “materialism”, we must always mean energetism<sup>37</sup>. Bachelard’s rational materialism<sup>38</sup> is therefore very different from any traditional philosophical materialism. Matter is no longer inert and passive, but is instead active energy, capacity for transformation and generation.

Thus, the mechanistic conception of Nature – based on its identification with inert and passive matter, which had characterized much of modern science and which had provided a scientific basis for a whole metaphysical philosophical tradition – breaks down. Henceforth, Bachelard claims, static ontology is replaced by dynamology<sup>39</sup>. Matter is no longer a permanent substance over time and simply placed in space<sup>40</sup>; it is now understood as an energetic activity that unfolds in space-time *events*.

<sup>35</sup> Bachelard, G., *La philosophie du non*, op. cit., pp. 21-40.

<sup>36</sup> Blackett, P.M.S., Occhialini, G.P.S., *Some photographs of the tracks of penetrating radiation*, in *Proceedings of the Royal Society of London. Series A*, 134 (1933), pp. 699-727; Kemplerer, O., *On the annihilation radiation of the positron*, in *Mathematical Proceedings of the Cambridge Philosophical Society*, 30, 3 (1934), pp. 347-354; Deutsch, M., *Gamma-Rays from Cu<sup>64</sup>, Annihilation of Swift Positrons, and Experiments on Orbital-Electron Capture*, in *Physical Review* 72 (1947), pp. 729-730.

<sup>37</sup> Bachelard, G., *L’activité rationaliste de la physique contemporaine*, op. cit., pp. 157-178.

<sup>38</sup> Bachelard, G., *Le matérialisme rationnel*, P.U.F., Paris 1953.

<sup>39</sup> Bachelard, G., *L’activité rationaliste de la physique contemporaine*, op. cit., pp. 162 e 176.

<sup>40</sup> Bachelard, G., *La philosophie du non*, op. cit. ; G. Bachelard, *Le matérialisme rationnel*, op. cit.

Since energy is not only linked to a single body, but to the interaction between several bodies and therefore to the force field that connects them, the mass of a body generally depends on its interaction with the rest of the universe. It is no longer an individual property, but a relational and collective property: the matter that “identifies” a body, which constitutes it in its “individuality”, is its specific energetic relationship with other bodies, with the rest of the universe.

However, this is not the whole story. The relativistic *phenomenotechnique* which, in nuclear transformations of bodies into energy, reveals Nature not as a set of material objects but as “energy”, does not reveal Nature as a “fund” (*Bestand* for Heidegger)<sup>41</sup> of available energy resources for human mechanical-technical work, but as a transforming-creative power in itself. Relativistic physics by no means functions in the service of the technical dominion over Nature as a “fund” of resources. Rather, it reveals Nature phenomenotechnically – through a technique cleared of its functional purposes – as creative energy itself, as an “objective transcendental” or “noumenon” as defined in Kant’s *Opus Postumum*. It is this Kantian heritage that is preserved in Bachelard, but was instead lost in Heidegger’s hermeneutical phenomenology.

With the theory of general relativity, the matter of a body ceases to be associated with a scalar mathematical quantity identifiable by a single number, as in Newtonian physics, or with a four-vector such as momentum-energy in special relativity, but it must be represented by a tensor, the “energy-matter tensor”, which also includes the energy of the gravitational field, incorporated in this same energy-matter, which in turn actively determines the structure of space-time as gravitational and therefore the space-time distribution of the bodies in the cosmos<sup>42</sup>.

## 5. The quantum-relativistic creation of matter and *phenomenotechnique*

In quantum physics, matter no longer has the property that most of all characterized it in the history of philosophical thought, at least from Descartes onwards, and in classical physics: spatial localization<sup>43</sup>. Bachelard correctly interprets Heisenberg’s uncertainty principle in all its radicality, while limiting the possibility of geometrization which had been re-established by a misunderstanding of Bohr’s principle of complementarity. The concept of a particle’s “spatial localizability” (the possibility of determining its spatial position) *breaks down*, as does the reducibility of matter to a “point” according to the Cartesian mode (namely, a “material point” understood as a body with “spatial extension” or something that has a geometric shape)<sup>44</sup>.

<sup>41</sup> Heidegger, M., *Wissenschaft und Besinnung*, in *Vorträge und Aufsätze*, Neske, Pfullingen 1954.

<sup>42</sup> Bachelard, G., *La valeur inductive de la relativité*, Vrin, Paris 1929.

<sup>43</sup> Bachelard, G., *L’Expérience de l’espace dans la physique contemporaine*, op. cit., pp. 20-41.

<sup>44</sup> *Ibid.*

According to Adolphe Buhl's mathematical perspective<sup>45</sup>, which Bachelard follows<sup>46</sup>, the possibility of defining the tangent at a point on a curve breaks down; the concept of spatial trajectory or a continuous geometric line in which the material point would drag, equally breaks down.

The process of “de-materialization” and “de-realization” of matter as substance<sup>47</sup> is outlined by Bachelard in the consideration of the wave/particle duality, as implied in Niels Bohr's complementarity principle, or of the “probability waves” associated with “particles” in Max Born's probabilistic interpretation of the Schrodinger equation: matter as the energy of relativity now becomes a quantum wave, whose existence has a connotation of activity that propagates temporally and discontinuously, and of the active potentiality of phenomena rather than of permanent spatial substance or the substantial reality of things<sup>48</sup>.

Even more important, however, is the fact that the uncertainty principle in quantum-relativistic physics implies processes of creation and annihilation of matter, of particles, experimentally proven<sup>49</sup>: processes in which a sort of ontological relativity of the being and non-being of a corpuscle is manifested, or, as in contemporary quantum-relativistic cosmology, through which the origin of the universe itself is understood in terms of indeterminacy-creation<sup>50</sup>.

Here, the whole radicality of Bachelard's phenomenotechnical perspective is outlined: not only can phenomena, not initially given in experience, be produced; not only can the “absence of matter” be produced, as in the vacuum (previously inexistent in our terrestrial experience) created in the seventeenth-century; but also, through experimental activity, Nature itself can be created as matter. Nature is not given to human experience, but is created by the human subject through experimental action: philosophical realism is completely inadequate for the understand-

<sup>45</sup> Buhl, A., *Sur quelques analogies corpuscolaires et ondulatoires*, in *Bulletin des Sciences mathématiques*, second series, vol. LVIII n. 24 (November 1934), pp. 333-368.

<sup>46</sup> Bachelard, G., *La philosophie du non*, op. cit., pp. 89-99.

<sup>47</sup> Bachelard, G., *Lumière et substance*, in *Revue de métaphysique et de Morale*, v. 41, n. 3 (1934), pp. 343-366.

<sup>48</sup> Bachelard, G., *L'activité rationaliste de la physique contemporaine*, op. cit., pp. 101-156 e 179-241; Bachelard, G., *L'Expérience de l'espace dans la physique contemporaine*, op. cit.; Bachelard, G., *La philosophie du non*, op. cit.

<sup>49</sup> Lamb, W. E., Retherford, R. C., *Fine Structure of the Hydrogen Atom by a Microwave Method*, in *Physical Review* 72 (1947), p. 241; Casimir, H. B. G., Polder, D., *The Influence of Retardation on the London-van der Waals Forces*, in *Physical Review*. 73 (4) (15 February 1948), pp. 360-372; Casimir, H. B. G., *On the attraction between two perfectly conducting plates*, in *Proc. Kon. Ned. Akad. Wet.* 51 (1948), pp. 793-795; Lähteenmäki, P., Paraoanu, G. S., Hassel, J., Hakonen, P. J., *Dynamical Casimir effect in a Josephson metamaterial*, in *Proceedings of the National Academy of USA*, vol. 110 no. 11 (2013), pp. 4234-4238.

<sup>50</sup> Tryon, E. P., *Is the Universe a Vacuum Fluctuation?*, in *Nature* 246, n. 5433 (December 14, 1973), pp. 396-397; Barrow, J., *The Book of Universes*, The Bodley Head, London 2011; Giannetto, E. R. A., *Il crollo del concetto di spazio-tempo negli sviluppi della fisica quantistica: l'impossibilità di una ricostruzione razionale nomologica del mondo*, in *Aspetti epistemologici dello spazio e del tempo*, Boniolo, G. (ed.), Borla, Roma 1987, pp. 169-224; Giannetto, E. R. A., *On the Quantum Geometry and Quantum Potential of the Universe*, in *Quantum Matter* III, n.3 (2014), pp.276-278.

ing of reality, but Bachelard also overcomes the risk of philosophical idealism and the idealistic interpretation of quantum physics. Bachelard wrote about a mode of creation from nothing<sup>51</sup>.

Here, the problem of a possible subjectivistic and idealistic declination of phenomenology arises, but Bachelard (not unlike *Heidegger vis-à-vis* technology) does not fall into this drift<sup>52</sup>. As in Marx, this is not intellectual activity, nor is it thought that produces reality. Rather, even if understood as thought that transforms itself into action, it is *material activity*, experimental action (de-functionalized technique) that produces the reality<sup>53</sup>. Contrary to Marx, however, anthropocentrism is avoided: this is an action in which the human subject denies or excludes itself as such, leaving room for technical tools transformed into instruments of scientific measurement to perform the productive role.

The indeterminacy principle also places limits on the interpretability of energy in technical terms that assume a fund of energy resources (Heidegger's *Bestand*) available to humanity, because energy is never exactly determinable-controllable. The process of creation of matter thus shows itself as an objective process: the experimental acts, in which quantum indeterminacy is manifested, are acts that restore the "things themselves" to the human subject beyond their relative subjective determinations. However, what are "things themselves", or "things in themselves"? Nature, matter, and the universe are "indeterminable creation".

Quantum indeterminacy, considered from a Bachelardian perspective, thus brings us back to the enchantment or mystery of the original experience of Nature and Matter, to its full positive reconsideration. From a historical point of view, this positive reconsideration – which runs against the devaluation of matter in Platonic-Aristotelian dominant Greek thought – can be traced back to the Christian perspective. Here we encounter a new quantum-relativistic philosophy of matter as "created" in its contingency. There is no longer a rational principle of matter-energy "conservation" which could prevent the unpredictable creation of matter in the attestation of a law of Nature. This is a creation, which, however it is interpreted, derives from the Christian perspective of creation<sup>54</sup>.

A parallel with some developments in twentieth-century Italian philosophy can perhaps clarify the overcoming of any idealism (including mathematical idealism) in Bachelard's perspective. It should be emphasized that any "gnoseology of creation" is excluded in Bachelard – such as we find in Giovanni Gentile's "actualism" where a difference is stressed between "thinking, living thought" (namely, the act

<sup>51</sup> Bachelard, G., *Physique et Métaphysique*, in *Septimana Spinozana. Acta Conventus Oecumenici in memoriam Benedicti De Spinoza Diei Natalis Trecentesimo Hagae Comitibus Habiti*, Nijhoff, La Haye 1933, pp.74-84.

<sup>52</sup> Bachelard, G., *Le Rationalisme appliqué*, P.U.F., Paris 1949; Bachelard, G., *Le Matérialisme rationnel*, P.U.F., Paris 1953.

<sup>53</sup> Engels, F., *Ludwig Feuerbach und der Ausgang der klassischen deutschen Philosophie. Mit Anhang: Karl Marx über Feuerbach v. J. 1845*, Detz, Stuttgart 1888, 1946.

<sup>54</sup> Giannetto, E. R. A., *Hans Blumenberg, il significato storico del principio d'inerzia e la creatio continua*, in Blumenberg, H., *Autoconservazione e inerzia. Sulla costituzione della razionalità moderna*, Medusa, Milano 2016, Giannetto, E.R.A., Doni, M. (eds.), pp. 5-30.

of thinking) and “thought (that was) thought”. Following Spinoza, in Bachelard thought becomes an attribute of Nature<sup>55</sup>, and the difference lies between *Natura construens* and *Natura constructa*. In Bachelard’s work, we arrive at the end not only of ontology, but also of gnoseology itself and the logic of the philosophy of knowing as found in Guido Calogero’s critique of Gentile<sup>56</sup>. Bachelard wrote about an onto-genetic epistemology which overcomes every rationalism through its venture into a surrationalism<sup>57</sup>.

Thus, it can be understood that the “philosophie du non” as a “negative philosophy”, developed by Bachelard, starting from the physics of the twentieth century and from the elaboration of *phenomenotechnique*, has brought about a deconstruction of Western metaphysics perhaps deeper than that which constituted the outcome of Heideggerian phenomenology and hermeneutics. It has constituted the basis for an overcoming of the spirit-matter metaphysical dualism through a quantum-relativistic philosophy of matter.

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<sup>55</sup> Bachelard, G., *Physique et Métaphysique*, in *Septimana Spinozana. Acta Conventus Oecumenici in memoriam Benedicti De Spinoza Diei Natalis Trecentesimo Hagae Comitibus Habiti*, Nijhoff, La Haye 1933, pp.74-84.

<sup>56</sup> Calogero, G., *La conclusione della filosofia del conoscere*, Sansoni, Firenze 1938, 1960; Calogero, G. (1942-1943), *Logica, gnoseologia, ontologia*, in *Lezioni di Filosofia I-II-III: Logica-Etica-Eстетica*, Einaudi, Torino 1948-1946-1947, second edition 1960.

<sup>57</sup> Bachelard, G., *L’activité rationaliste de la physique contemporaine*, P.U.F., Paris 1951, pp. 55-72. See also: Castellana, M., *Il surrazionalismo di Gaston Bachelard*, Glauk, Napoli 1974; *Il surrazionale: come la materia diventa progetto*, in AA.VV., *Bachelard e le “provocazioni” della materia*, Il Melangolo, Genova 2012, pp.169-177.

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