Aion Journal of Philosophy and Science 2, 2025

Imagination in the scientific process

Jean-Hugues Barthélémy

Abstract

This article aims to demonstrate that the theory of multi-modal scientific decentering, far from neglecting the question of scientific imagination, in fact provides a renewed framework through which to approach it. Initially introduced in *La Société de l'Invention* (2018) and further elaborated in its methodological sequel *La Philosophie du Paradoxe* (2024), the theory of multi-modal scientific decentering had, until now, not directly addressed the issue of scientific imagination. This omission stemmed from the fact that the theory arose in response to a more fundamental and global dual problem. For this reason, we first recall what is meant by "multi-modal scientific decentering". Only in a second step we address the specific nature of scientific imagination, understood precisely as shaped and constrained by the methodological decentering unique to each scientific discipline. Scientific imagination, inasmuch as it serves the aim of explaining phenomena, is neither merely reproductive nor freely productive (or creative) as is artistic imagination ; rather, it must invent what responds to a problem posed by the observed phenomena. Moreover, an exemplary instance of scientific progress — such as the transition from Newtonian to Einsteinian physics, which will be discussed here — was made possible through a form of productive imagination that operated not by addition but by subtraction : commonsense certainties, such as that of absolute simultaneity, became mere hypotheses, now deemed unnecessary.

***Keywords** : analogy, multi-modal decentering, scientific imagination, paradox, Simondon*

CONTACT: Jean-Hugues Barthélémy
e-mail : jh.barthelemy@gmail.com
University Marie & Louis Pasteur, laboratory « Logiques de l'Agir »

Résumé :
Cet article montre en quoi la théorie du décentrement scientifique pluri-modal, loin de négliger la question de l'imagination scientifique, permet de la revisiter. Cette théorie est née dans l'ouvrage *La Société de l'invention* (2018), puis a été précisée dans son complément méthodologique *La Philosophie du paradoxe* (2024). Si elle n'avait pas exploré, jusqu'ici, la question de l'imagination scientifique, c'est parce que cette théorie était née d'un double problème plus fondamental et plus global. C'est pourquoi est rappelé dans un premier temps ce qu'il faut entendre par le « décentrement scientifique pluri-modal ». Dans un second temps seulement, est soulevée la question de la spécificité de l'imagination scientifique, telle qu'elle est justement nourrie et contrainte par le décentrement méthodologique de chaque science. L'imagination scientifique, dans la mesure où elle est au service d'une recherche d'explication des phénomènes, n'est ni simplement reproductrice ni librement productrice (ou créatrice) comme l'est l'imagination artistique, mais elle doit créer ce qui répondra à un problème posé par les phénomènes observés. En outre, un progrès scientifique exemplaire, comme celui qui sera évoqué ici et qui a fait passer de la physique newtonienne à la physique einsteinienne, a pu mettre en œuvre une imagination productrice ne consistant pas à ajouter mais à retrancher : des évidences du bon sens comme celle de la simultanéité absolue y deviennent de simples hypothèses, désormais inutiles.

***Mots-clés** : analogie, décentrement multi-modal, imagination scientifique, paradoxe, Simondon*

Introduction

This article aims to demonstrate that the theory of multi-modal scientific decentering, far from neglecting the question of scientific imagination, in fact provides a renewed framework through which to approach it. Initially introduced in *La Société de l'Invention* (2018) and further elaborated in its methodological sequel *La Philosophie du Paradoxe* (2024)[1], the theory of multi-modal scientific decentering had, until now, not directly addressed the issue of scientific imagination. This omission stemmed from the fact that the theory arose in response to a more fundamental and global dual problem — one that necessitated the construction of a new general theoretical framework before turning to more specific questions such as that of imagination and its scientific modality.

[1] Jean-Hugues Barthélémy, *La Société de l'Invention : Pour une Architectonique Philosophique de l'Âge Écologique*, Paris : Éditions Matériologiques, 2018 ; *La Philosophie du Paradoxe : Prolégomènes à la Relativité Philosophique*, Paris : Éditions Matériologiques, 2024.

This broader and more fundamental dual problem can be articulated as follows :
- On the one hand, if philosophy has remained, to this day, the "battleground" that Kant believed could be confined to "speculative metaphysics" — from which he claimed to depart via the *Critique*, understood as a form of knowledge about knowledge —, then we must entertain the possibility that philosophy's true vocation, as a mode of self-knowledge, lies not in producing doctrines that claim strict forms of knowledge and thus perpetuate endless confrontation, but rather in inventing an auto-pluralizing approach. The fundamental aim, therefore, is to establish a new terrain for discussion rather than to propose yet another doctrine[2] ;
- On the other hand, the distinction that must also be revisited between science and philosophy entails, for philosophy, a form of humility — one that calls for attentive engagement with a discipline whose strength lies in its capacity to conceptualize scientific progress without subordinating the idea of objectivity to the value of "Truth" understood as a horizon : namely, the historical epistemology inaugurated by Gaston Bachelard[3]. At this juncture, the theory of multi-modal scientific decentering has established a dual critical dialogue with Kant and Popper, aiming to show that objectivity is less an ever-receding horizon — as it is often conceived — than a methodological quality that manifests in diverse modalities depending on the science in question, with the common thread being a surpassing of common sense ;

It is this second, properly epistemological problem that will serve here as the framework for turning now to the question of scientific imagination. For this reason, we will first recall what is meant by "multi-modal scientific decentering" — a notion that neither Kant nor Popper clearly conceptualized. Only in a second step will we address the specific nature of scientific imagination, understood precisely as shaped and constrained by the methodological decentering unique to each scientific discipline. Two essential points may be introduced here. First, scientific imagination — inasmuch as it serves the aim of explaining phenomena — is neither merely reproductive nor freely productive (or creative) as is artistic imagination ; rather, it must invent what responds to a problem posed by the observed phenomena. Second, an exemplary instance of scientific progress — such as the transition from Newtonian to Einsteinian physics, which will be discussed here — was made possible through a form of productive imagination that operated not by addition but by subtraction : commonsense certainties, such as that of absolute simultaneity, became mere hypothe ses, now deemed unnecessary. These two essential and interdependent points characterize scientific imagination as a very particular kind of productive imagination, one placed in the service of the ascetic rigor demanded by confrontation with

[2] See Barthélémy, *La Philosophie du Paradoxe, op. cit.*, § 32.

[3] On Bachelard, see Dominique Lecourt, *L'épistémologie historique de Gaston Bachelard*, Paris : Vrin, 1970 ; Vincent Bontems, *Bachelard*, Paris : Les Belles Lettres, 2010. On the relationship of filiation between the theory of multi-modal scientific decentering and Bachelardian historical epistemology, see Barthélémy, *La Philosophie du Paradoxe, op. cit.*, §§ 5 and 19.

the real, which it seeks to render intelligible. The first of these two points, as we shall see, defines the framework within which analogy may play a role in science — though only as a heuristic tool. The second point defines the framework in which the scientific truths progressively discovered since Galileo constitute, in their ever more pronounced surpassing of the evidences of common sense, a succession of paradoxes that increasingly unsettle common sense.

The theory of multi-modal scientific decentering was developed precisely in *La Philosophie du Paradoxe* as a dual rehabilitation of paradox — both in philosophy and in science — while also reaffirming its often-overlooked distinction from contradiction. At this level, the heterogeneity between philosophical "self-knowledge" and the actual knowledge constructed by science in no way prevents their shared transcendence of common sense from placing them both in affinity with paradox. As for analogy, the same work rehabilitated it as constitutive of philosophy — on the condition, however, that it be redefined as a translational operation involving three terms rather than four[4]. In the sciences, analogy is merely heuristic, and the task here will be to treat it as a modality of imagination that is both nourished and constrained by multi-modal methodological decentering.

1. The theory of multi-modal scientific decentering : a recapitulation

The theory of multi-modal scientific decentering, as it was first introduced in *La Société de l'Invention* and later refined in *La Philosophie du Paradoxe*, addresses a concern that ultimately lies beyond any strictly epistemological issue. For this reason, that deeper concern — which pertains to the very status of philosophy in its distinction from science — will not be discussed here, though it was briefly noted in the introduction. The epistemological concern, by contrast, is the renewal of the theory of knowledge through a dual critical dialogue with Kant and Popper.

The first of these two major figures is unable to account for either the extremely late emergence of genuinely scientific physics — born only in the seventeenth century — or for its revolutionary capacity to transition from Newtonian space and time (which Kantian criticism aims to philosophically ground) to the spacetime of Einsteinian relativity. In Kant's system, Newtonian physics is both merely human — since non-noumenal — and definitive as knowledge of phenomena. Space and time are at once absolute and marked by ideality, being nothing more than the "a priori forms of sensibility".

Popper, by contrast, is profoundly driven by the intention to account for the capacity of physical knowledge to progress. This is why he emphasizes, within his critical rationalism, the importance of the Einsteinian breakthrough. His other fundamental and original concern is to establish a "demarcation criterion" between, on one hand, the "empirical sciences" — which would be more accurately described as

[4] See Barthélémy, *La Philosophie du Paradoxe, op. cit.*, §§ 13 and 30.

experimental sciences, if instrumentally grounded — and, on the other, metaphysics, pseudo-sciences, as well as logic and mathematics[5]. Popper frequently recalls that it was, in fact, his youthful suspicion toward the scientific pretensions of psychoanalysis and Marxism that proved decisive for this project. Now, Chapter 4 of *La Philosophie du Paradoxe* has shown that, with regard to the issue of scientific progress, Popperian falsificationism grounds this progress less on the idea of an objective method than on that of a vague "critical spirit" traced back to the pre-Socratics — an impulse allegedly interrupted by Aristotelian "dogmatism"[6]. For this reason, Popper — curiously convinced that dogmatism is the true cradle of irrationalism — explicitly embraces a proximity between his critical rationalism and a new form of skepticism : on the one hand, scientific knowledge is said not to be discontinuous from that of common sense, which is thought capable of self-criticism ; on the other hand, this self-criticism is claimed to be the sole and genuine secret of scientific progress, which in turn is said to be the only thing distinguishing pre-critical myths from what Popper, at times, even dares to call the scientific "myth"[7].

The theory of multi-modal scientific decentering aims to be at once more coherent than Popperian falsificationism, more flexible, and less ambiguous in its capacity to distinguish itself from any form of skepticism :

- More coherent, because unlike Popper, it is not torn between, on the one hand, the idea that the progression from Newton to Einstein constitutes a relativization that renders Newtonian physics what Einstein called a "borderline case", and, on the other hand, the view — taken up and amplified by the relativist theses of Thomas Kuhn — that Newtonian physics is simply refuted rather than reinterpreted as an approximation[8]. The theory of multi-modal scientific decentering understands the specific methodological decentering of physics — its distinctive mode of methodological decentering — as based, from Galileo through Einstein and beyond, on a dual mathematical-experimental/instrumental mediation. Through this mediation, a methodological objectivity is produced, ensuring a rupture with the physics of mere common sense — exemplified by Aristotle —, of which the Galilean *Dialogue Con-*

[5] Popper himself at times contributed to the neglect of logic and mathematics within the second pole of his demarcation criterion, as well as to the blurring of the distinction between metaphysics and pseudo-sciences — such as astrology. This is why it must be continually emphasized that : a) the demarcation is not, in fact, between 'science and non-science', but rather between the 'empirical sciences' on the one hand, and on the other, any discipline that is at times scientific without speaking of the world, and at other times speaks of the world without being scientific ; b) his own discourse openly assumes a dual 'metaphysical and logical' character when it reveals that the deeper meaning of falsificationism derives from 'fallibilism'. On this point, see Barthélémy, *La Philosophie du Paradoxe, op. cit*., § 20, B).

[6] On this point, see Barthélémy, *La Philosophie du Paradoxe, op. cit*., § 19, A).

[7] On Popper's claim of a proximity between his critical rationalism and a new form of skepticism, see Popper, *Realism and the Aim of Science* (*Postscript to The Scientific Discovery*, Vol. 1), London : Hutchinson, 1983, Chapter 1, 2., I ; and Barthélémy, *La Philosophie du Paradoxe, op. cit*., § 20, A).

[8] For a renewed critique of Kuhn's discourse, see Barthélémy, *La Philosophie du Paradoxe*, *op. cit*., § 22.

cerning the Two Chief World Systems marks the final naïveté within the properly scientific domain[9] ;
- More flexible, because it does not require the exclusion from the scientific domain of a discipline such as psychoanalysis, which possesses its own distinctive mode of methodological decentering — one whose singularity and complexity account for its very late emergence and for the less assured nature of its progress. Moreover, here again, Popper reveals a lack of coherence when his texts are examined closely[10] ;
- Less ambiguous, finally, because it also embodies an anti-dogmatic rationalism which, in its double struggle against irrationalism and dogmatism, does not need to align itself with any new form of skepticism. This stems from the fact that objectivity, instead of being subordinated to the metaphysicians' value of Truth and conceived as a horizon — by definition, forever out of reach —, is here rethought as a methodological quality grounded in decentering. It is this decentering that allows the subject to reconstruct itself beyond the subject of common sense, as is paradigmatically the case in physics, where the knowing subject reconstructs itself through the dual mathematical-experimental/instrumental mediation[11]. It is this very methodological objectivity that enables progress — understood as, by nature, indefinite — and not, conversely, progress in knowledge that would ground objectivity if this one is conceived as a horizon that retreats the more one advances. That conception, characteristic of Popper's falsificationism, repeatedly and on principle refuses the break between the subject of common sense and the knowing subject.

2. Scientific imagination and the heuristic role of analogy

We may now turn to the question of scientific imagination — a topic which *La Philosophie du Paradoxe* had only touched upon in passing. Like any human subject, the knowing subject in science demonstrates a productive or creative imagination that is essential to his or her activity and its progress. Yet due precisely to the idea of a necessary progress in knowledge, scientific imagination, unlike artistic imagination, possesses a kind of freedom that remains under constraint. Scientific imagination can, of course, be subdivided into various types of mental operations, all of which involve what we commonly call "imagination". To propose an explanatory hypothesis is to engage the imagination. To invent a thought experiment is likewise to engage the imagination. But regardless of the differences between these types of mental operations, imagination functions in each case only insofar as it serves the pursuit of knowledge of the real. This is why scientific imagination — even though it is productive rather than merely reproductive — remains an imagination under control. It is inscribed within the broader framework of multi-modal methodologi-

[9] On Galileo's decisive role, see especially Stillman Drake, *Galileo Studies*, University of Michigan Press, 1970 ; and for an assessment, see Barthélémy, *La Philosophie du Paradoxe, op. cit*., p. 194-196.

[10] See Barthélémy, *La Philosophie du Paradoxe, op. cit*., p. 265-267.

[11] See Barthélémy, *La Philosophie du Paradoxe, op. cit*., § 15, A).

cal decentering discussed above. Since, as previously noted, each science possesses its own specific mode of methodological decentering, we shall focus here on that paradigmatic form of decentering : the mathematical-experimental/instrumental decentering of the knowing subject in physics — as the first natural science to become methodologically objective.

When the knowing subject in physics thinks the concepts of "mass" or "velocity", he or she generates these representations within a methodological framework governed by a dual necessity : that the concepts can be constructed in connection with mathematical formalism, and that the hypotheses in which these concepts acquire meaning can be tested through instrumented experiments — experiments that serve as an interface with the mathematical formalism. Here, a parenthesis is warranted : *La Philosophie du Paradoxe*, and indeed already *la Société de l'Invention*, began to develop the idea that if physics is the queen of the natural sciences, it is because its object lends itself to a mathematization that interfaces with laboratory instrumentation. And this mathematical-instrumental interface is grounded in the fact that mathematical operations constitute both a form of virtual technique and a formal language[12]. Returning from this parenthesis, it must be emphasized that in its progress — nourished by the extraordinary theoretical imagination of physicists —, physics subjects that decisive theoretical imagination to the equally decisive law of mathematical-experimental/instrumental reason. In so doing, it enables the knowing subjects to deepen their decentering and obliges them to continually redefine their objects.

Let us consider the example of the representation of the electron, as Michel Bitbol summarizes its "destabilizing transfigurations" :

> The name "electron," derived from the Greek word meaning "amber", was first used during the second half of the nineteenth century to denote a simple, indivisible, and measurable unit of electric charge. Taking advantage of new trajectory detection methods (such as Wilson's cloud chamber), the electron was, at the turn of the nineteenth and twentieth centuries, ascribed a "corpuscular" mass and localization, thus shifting from the category of quantity (elementary charge) to the category of substance (the thing bearing that elementary charge). Then, in the mid-twentieth century, following the quantum revolution, the electron changed status once more, becoming — under a somewhat misleading name — a quantized excitation mode of the "electronic field".[13]

[12] In conclusion, we will see that there is a connection between this fundamental techno-linguistic duality of mathematics and the contemporary ways of conceiving the genesis of the human from the primate — that is, anthropogenesis.

[13] Michel Bitbol, *Maintenant la Finitude : Peut-on penser l'Absolu ?*, Paris : Flammarion, 2019, p. 50 (our translation).

These "destabilizing transfigurations", which Bitbol also characterizes as the "irresistible drift in the meaning of a scientific term"[14], clearly emerge here as constituting, at once, a succession of discoveries that are only made possible by the ever more advanced mathematization and experimentation of theoretical imagination — an imagination that is itself subject to evolution[15]. Thus, the formidable theoretical imagination of the great scientists — creative rather than merely reproductive (as is the case with memory, which explains nothing) — is also not purely free, like that of the artist, who has nothing to explain. Rather, it is both inspired and constrained by methodological decentering, since it must account for phenomena in an increasingly legislative (or nomological), explanatory, and predictive manner in order to advance knowledge. This is why the theoretical imagination of the physicist must be, at least potentially, mathematizable and experimentable — criteria which define the mode of decentering specific to physics, insofar as its object is non-living and therefore uniquely suited to such methodological demands.

The subordination of specifically scientific productive imagination to the demands of the process of knowing reality — as these are embodied each time in a defined mode of methodological decentering — further explains why analogy can only play a heuristic role in science. On the one hand, an analogy in science is always imagined in relation to a problem to be solved, which defines the framework that constrains its development. On the other hand, this imagined analogy does not possess any demonstrative value in itself. It is well known that in physics, for example, a discovery often originates in the mental operation by which an analogy is imagined between two phenomena, themselves understood as relations — since any analogy is an identity between two relations, not a resemblance between two things[16]. Yet this imaginative and original intuition does not allow the physical analogy to play more than a heuristic role, and this is no longer a matter of debate. Chapter 2 of *La Philosophie du Paradoxe*, which is devoted to the question of analogy in science and philosophy, has suggested that if analogy thus possesses only heuristic value and not a constitutive one for scientific knowledge, it is because it is linked to the contingency of discovery in contrast to the content of knowledge that is discovered. The imagined analogy cannot become constitutive of scientific knowledge as demonstrated knowledge, and must be limited to playing a heuristic role, because it is an initial intuition that pertains to the contingency specific to what Hans Reichenbach called the "context of discovery," as opposed to the necessity that defines the "context of justification"[17].

---

[14] *Ibid*., p. 51 (our translation).

[15] Bitbol, on the following page of his text, appears, for his part, to set in opposition the mathematico-experimental/instrumental process of decentering and the notion of discovery. I have cited and discussed his remarks on pages 192–195 of *La Philosophie du Paradoxe*.

[16] See Barthélémy, *La Philosophie du Paradoxe, op. cit*., § 9, A).

[17] See *ibid*., § 9, B).

3. The Einsteinian paradigm of imaginative elimination of hypotheses and the role of paradoxes in science

Scientific imagination is not only characterized by its simultaneous creativity and constraint through the methodological decentering of which each science determines the mode appropriate to its object. Precisely because of this methodological decentering, which gives science the vocation of breaking with common sense in order to institute itself as capable of progress, it is driven to question the naïve presuppositions of common sense and to relativize even what common sense considers to be absolute certainties and unique truths. This is why the creative and conceptual imagination of science may paradoxically appear as eliminative rather than additive. And this paradox compounds the fact that, by surpassing the apparent certainties of common sense, science continuously discovers truths that are themselves increasingly paradoxical. Before returning to this second point — which was the main topic of Chapter 1 of *La Philosophie du Paradoxe* —, let us illustrate the first point with what may well serve here as a paradigm : the birth of the theory of special relativity.

Let us return, then, to the most decisive source of this theoretical revolution, whose full realization was enabled by Einstein. Shortly before writing the four articles of his “annus mirabilis” (1905), Einstein had read *Science and Hypothesis* (1902) by Henri Poincaré, in which the following four successive assertions could already be found :

1. There is no absolute space, and we can conceive only relative motion […]
2. There is no absolute time […]
3. Not only do we not have direct intuition of the equality of two durations, but we do not even possess that of the simultaneity of two events occurring in different places […]
4. Finally, our Euclidean geometry is itself but a kind of linguistic convention […][18]

In 1905 and 1906, Poincaré would also show that the transformations of the equations of the electromagnetic field — named “Lorentz transformations” by him — form a group, and he would introduce the idea of a “gravitational wave”, supposing that gravity propagates “at the speed of light”. He would even anticipate Hermann Minkowski by introducing time as a fourth imaginary coordinate, as well as the four-dimensional formulation that Minkowski would refine in 1908.

Nevertheless, in *Science and Hypothesis*, Poincaré provisionally accepted absolute time and Euclidean geometry, while Einstein boldly rejected such assumptions. What characterizes Einstein is precisely his willingness to question commonly accepted certainties. The theoretical difficulties of the time provided the opportunity : Hendrik Antoon Lorentz, for his part, had been forced to posit no fewer than eleven

[18] Henri Poincaré, *La Science et l’Hypothèse*, Paris : Flammarion, 1902, p. 111-112 (our translation).

hypotheses to account for the phenomena. Einstein's imaginative genius lies in his capacity to simplify the theory by abandoning presuppositions hitherto considered absolute and indisputable. This simplification is based on just two principles : the principle of relativity, which affirms the invariance of physical laws in all inertial reference frames, and the principle of the invariance of the speed of light (c). The former was known since Galileo, but it is now extended — beyond the mechanics of material bodies — to optics and electromagnetism. The invariance of c, although already accepted, becomes in Einstein's hands a foundational principle. As a result, the many hypotheses posited by Lorentz to explain the electromagnetism of moving bodies become unnecessary.

Let us now turn to the second point. The new theoretical framework enabled by Einstein — building in part on Poincaré — clashes directly with common sense. And it is precisely this that makes Einstein's intellectual gesture so daring. Indeed, the paradoxes inherent in the theory of relativity are in fact the culmination of an ever-deepening divergence between scientific truth and common sense. For common sense, it remains difficult to accept, for instance, that the Earth is in motion ; even its sphericity only became "obvious" thanks to the modern ability to observe our planet from space. As Bachelard noted, physical truths always arise in spite of, or even against, apparent evidence. The deepening of methodological decentering that defines Einsteinian relativity is thus not merely a surpassing of naïve common sense — but of common sense in its more developed, yet still fundamentally intuitive, forms. In general, no scientific conquest of truth occurs without the ability to recognize that certain apparent contradictions are merely subtle para-doxes — false contradictions, confused by the *doxa* with real ones[19]. This was already the case with the sphericity of the Earth : the scientific paradox is that the Earth is spherical, and yet no human being has their head "downward". The resolution of the paradox — that is, its constructive integration — lies in understanding that in the universe, there is no absolute "up" or "down" ; these directions are relative to a center of gravitational attraction.

Returning once more to Einstein : what follows from all this is that the profound divergence between Einsteinian physics and common sense extends first and foremost to what underpins the latter— namely, the perceptual evidence of a Euclidean space and a time understood, as Kant held, as the object of an "inner sense". In special relativity, space and time are no longer heterogeneous realities but one and the same : spacetime. Minkowski, who would deepen special relativity[20], established

[19] On this point, see Barthélémy, *La Philosophie du Paradoxe*, Chapter 1.

[20] The new interpretation of the theory of special relativity proposed by Minkowski in 1908 initially unsettled Einstein, but it later exerted a decisive influence on his work and even made general relativity possible. It should also be noted that in Minkowski's text, the shift to the revolutionary concept of space-time is not associated with a move away from perception ; on the contrary, Minkowski connects this concept to the fact that every place is perceived at a given moment, and conversely, every moment is observed in a particular place. However, this in no way invalidates our thesis concerning the connection between common-sense evidence and perceptual evidence — if it is true, for example, that the 'moment'

that this revolutionary theory implies a four-dimensional, non-Euclidean space. More radically still, Minkowski introduced the concept of “proper time” derived from the spacetime metric — a concept that would be preserved but redefined in general relativity. Every physical particle possesses its own proper time. There is no longer an absolute time that could define the simultaneity of two events ; the concept of proper time integrates both time and distance. Proper time is what separates two events on the same trajectory in spacetime. Its properties belong neither to classical distance nor to classical absolute time. Astronomy, when it expresses distances in “light-years”, illustrates how the concept of distance becomes integrated into proper time.

General relativity, in turn, introduces a new class of spacetimes that are not merely Minkowskian but Riemannian, named after Bernhard Riemann. As a new theory of gravitation, general relativity posits curved spacetimes, whereas Minkowskian spacetime was flat. Not only is it unnecessary to form an image of a curved four-dimensional spacetime, but it is likely impossible to do so correctly. This observation deepens the idea that the distancing from common sense is above all a distancing from the perceptual evidence that feeds it. For if it is impossible to form a proper image of four-dimensional spacetime curvature, it is because any figuration remains bound to perceptual constraints. The productive and conceptual imagination demonstrated by contemporary geometry and Einsteinian physics transcends all perceptually conditioned image.

4. Revisiting Simondon’s theory of the “cycle of images”

To conclude with three ideas for a future research program, I must first evoke the theory proposed in 1965–1966 by the French philosopher Gilbert Simondon in his lecture course *Imagination and Invention*[21]. Simondon sought to renew the theory of imagination by focusing on the question of images as they traverse the psychic development of both human and animal subjects, from pre-perceptual motricity to symbolism. This perspective is commendable for its emergentist approach, as is typical in Simondon’s work[22]. However, it lacks consideration of scientific and conceptual imagination in its capacity to transcend images. Hence, the research program on

at which every place is perceived, according to Minkowski, is not, strictly speaking, the duration as it is perceived by the internal sense. In our view, there is here a philosophical misunderstanding on Minkowski’s part when he grounds his revolutionary concept of space-time in the claim that 'the objects of our perception invariably involve both place and time combined' (*in* H. A. Lorentz *& al*., *The Principle of Relativity : A Collection of original Memoirs on the special and general Theory of Relativity*, Arnold Sommerfeld (dir.), Londres, Methuen, 1923, p. 76).

[21] Gilbert Simondon, *Imagination et Invention (1965-1966)*, Chatou : éditions de la Transparence, 2008.

[22] For an overview of Simondon’s work in general, see Barthélémy, *Simondon*, Paris : Les Belles Lettres, 2014. On the question of a general and emergentist ontology, following and going beyond the one proposed by Simondon in his major work *Individuation in the Light of Notions of Form and Information*, see Barthélémy, *La Société de l’Invention*, *op. cit*., chap. VI.

which I will conclude will suggest the necessity of going beyond both Kant—theorist of the "a priori schematism of transcendental imagination" — and Simondon.

Simondon's theory of the cycle of images examined what he called "pre-perceptual images", then "intra-perceptual images" followed by "memory-images" and finally "symbols", culminating in a treatment of invention as a "concretization" which marks the beginning of a "new cycle of relation to the real"[23]. This theory offered a genetic (i.e., developmental) perspective that renewed the problem of imagination by treating images as a cycle linking pre-perceptual motricity, perception, memory, and symbolization. Its final themes were art and technical invention. But for this very reason, Simondon did not address productive imagination in its scientific modality — nor, more broadly, did he develop a strict theory of knowledge. The theory of multi-modal scientific decentering, which engages in critical dialogue with both Kant and Popper, reopens the question of objectivity, central not only to Kantian epistemology but also to Popper's "problem of demarcation" — itself formulated with reference to Kant. Yet the fact that the theory of multi-modal decentering revisits objectivity does not prevent it from also incorporating imagination, specifically in its scientific modality. It will therefore be helpful to briefly recall the merits of Simondon's theory of the cycle of images as a renewed theory of imagination, before returning, in conclusion, to the issue of scientific imagination as that which transcends all image.

Simondon's *Imagination and Invention* follows his substantial *Course on Perception*[24], one of whose merits was to think perception in its relation to the two other great dimensions of the animal and human subject : action and emotion — three dimensions that are at once irreducible and mutually constitutive. In *Imagination and Invention*, the image is defined rather classically as "a concrete representation with sensory content constructed in the absence of sensory stimuli — or appearing in the absence of such stimuli"[25]. Yet this "absence of sensory stimuli" is rethought as a capacity for anticipation that far exceeds imagination conceived as a mere supra-perceptual faculty : here, the image is also infra-perceptual, embedded in basic motricity, and intra-perceptual — as it already was in the *Course on Perception* — before becoming supra-perceptual through memory-images that evolve into "symbols". This defines the "cycle of images". For Simondon, the symbol resolves tensions arising from the accumulation of memory-images through a formalization and also prepares for an externalization of universal value. Thus, the cycle culminates in the invention of a new relation to the real, with the invention of a reality that can exist independently of its producer.

Another merit of *Imagination and Invention* lies in its sketch of the "object-image" thesis — later developed by Bernard Stiegler in *Technics and Time*, drawing on

[23] Simondon, *Imagination et Invention, op. cit.*, p. 138.
[24] Simondon, *Cours sur la Perception (1964-1965)*, Chatou : éditions de la Transparence, 2006.
[25] Simondon, *Imagination et Invention, op. cit.*, p. 101.

André Leroi-Gourhan's paleoanthropological work *Gesture and Speech*. There, the artifact is seen as a "crutch of the mind" — or "prosthesis" in a new sense[26] :

> Circular causality, which proceeds from the mental to objective reality through cumulative social processes, also proceeds from objective reality to the mental. […] Nearly all objects produced by humans are to some extent object-images ; they bear latent meanings — not only cognitive, but also conative and affective-emotional ; object-images are almost organisms, or at least germs capable of being revived and developed within the subject.[27]

What Simondon calls the "image-object", embedded in object-images, enables these objects to retroactively nourish the human mind that produced them. In Stiegler, this insight is extended via the process of memory externalization through artifacts — first understood by Leroi-Gourhan in his study of the human becoming of the primate. Stiegler's thesis is that this externalization of memory through artifacts, from the earliest flint tools onward, is the condition for the development of true human psychic interiority[28].

Conclusion : three ideas for a research program

It will be especially fruitful to explore how Simondon in *Imagination and Invention*, and Stiegler in volume 3 of *Technics and Time*, rediscover — albeit in a "genetic" (Simondon) or "a-transcendental" (Stiegler) manner — the Kantian theme of that "hidden art in the depths of nature" that was, in the *Critique of Pure Reason*, the schematism of the imagination. Three ideas should be further developed to clarify the new contribution of the theory of multi-modal scientific decentering to the question of scientific imagination as transcending all image :

- First, though neither empiricists, Simondon and Stiegler have the merit of asserting — against Kant's transcendental and a priori perspective — that the image precedes the scheme. In Kant, the schematism of the imagination ensures that a priori concepts of the understanding can apply to the data of sensible intuition (perception) : each category of the understanding has its transcendental scheme, which provides meaning by unifying the various of intuition in a rule-governed way. Schematism pertains to the productive imagination as a priori and irreducible to reproductive imagination. This transcendental approach cannot account for the derivation of human faculties from the prehuman, whereas Darwinian insights reveal that the human subject originates in the primate ;

[26] Bernard Stiegler, *Technics and Time*, Vol. 1, 2 & 3, Stanford University Press, 1998, 2009 & 2010 (French edition : Paris : Galilée, 1994, 1996 & 2001).

[27] Simondon, *Imagination et Invention, op. cit.*, p. 13.

[28] See Stiegler, *Technics and Time*, Vol. 1, *op. cit.*

- Second, unlike Simondon, Stiegler revisits the anthropogenesis scenario formulated by Leroi-Gourhan in terms of "language-technics coordination" to explain the genesis of human mental faculties — including imagination. In Leroi-Gourhan, this coordination replaced and surpassed the "face-hand coordination" of the prehuman, who had not yet stood upright to enable the "liberation of the hand" and the "liberation of speech". For Stiegler, language is now subsumed under technics as a global phenomenon and as the "prosthetic condition" of properly human consciousness ;
- Third, unlike Simondon and Stiegler, the theory of multi-modal scientific decentering explicitly and rigorously confronts the difficult question of scientific imagination as transcending all image. This text marks the beginning of that treatment, which must be extended by connecting the problem of scientific imagination — and its specificities — with the issue of anthropogenesis as the genesis of human faculties. In *La Société de l'Invention*, neuroscientific data[29] were recalled to support a new hypothesis : technics is neither what encompasses language (as in Stiegler) nor merely coordinated with it (as in Leroi-Gourhan) ; rather, it is what existed separately in prehuman forms and progressively interpenetrated with vocal communication to generate, on the one hand, systems of interrelated objects, and on the other, grammaticalized languages. Mathematics, as the purest expression of this progressive interpenetration, are simultaneously entirely a language and entirely technical operations. They are also the site of the analogy of proportion : A is to B as C is to D — the paradigm of imaginative operation as it functions in science to transcend all image.

[29] For these neuroscientific data, see Barthélémy, *La Société de l'Invention, op. cit.*, § 9.

Bibliography :

Barthélémy, J.-H., 2014, *Simondon*, Paris : Les Belles Lettres.

Barthélémy, J.-H., 2018, *La Société de l'Invention : Pour une Architectonique Philosophique de l'Âge Écologique*, Paris : Éditions Matériologiques.

Barthélémy, J-H., 2024, *La Philosophie du Paradoxe : Prolégomènes à la Relativité Philosophique*, Paris : Éditions Matériologiques.

Bitbol, M., 2019, *Maintenant la Finitude : Peut-on penser l'Absolu ?*, Paris : Flammarion.

Bontems, V., 2010, *Bachelard*, Paris : Les Belles Lettres.

Drake, S., 1970, *Galileo Studies*, University of Michigan Press.

Lecourt, D., 1970, *L'épistémologie historique de Gaston Bachelard*, Paris : Vrin.

Lorentz, H. A. *& al*., 1923, *The Principle of Relativity : A Collection of original Memoirs on the special and general Theory of Relativity*, Arnold Sommerfeld (dir.), Londres : Methuen.

Poincaré, H., 1902, *La Science et l'Hypothèse*, Paris : Flammarion.

Popper, Karl, 1983, *Realism and the Aim of Science* (*Postscript to The Scientific Discovery*, Vol. 1), London : Hutchinson.

Simondon, G., 2006, *Cours sur la Perception (1964-1965)*, Chatou : éditions de la Transparence.

Simondon, G., 2008, *Imagination et Invention (1965-1966)*, Chatou : éditions de la Transparence.

Stiegler, B., 1998, 2009 & 2010, *Technics and Time*, Vol. 1, 2 & 3, Stanford University Press (French edition : 1994, 1996 & 2001, Paris : Galilée).