C.R.AIPS 4

Proceedings of *the Académie Internationale de Philosophie des Sciences*

Comptes Rendus de l'Académie Internationale de Philosophie des Sciences

Tome IV

The Relevance of Judgment for Philosophy of Science

Éditeur
Jure Zovko

Does the neopositivist refutation of Kant's synthetic a priori judgments rule out the possibility of meaningful philosophical principles?

Giovanni Macchia and Gino Tarozzi

Dipartimento di Scienze Pure e Applicate, Università degli Studi di Urbino Carlo Bo, Via Sant'Andrea, 34, 61029 Urbino, Italy

Abstract. This paper examines the philosophical implications of the rejection of the *synthetic a priori* in the context of 20th-century scientific advancements, particularly General Relativity. It begins by tracing the historical development of the *synthetic a priori* as a cornerstone of Kantian epistemology, emphasizing its role in grounding the certainty and necessity of scientific principles. However, the emergence of non-Euclidean geometries and Einstein's redefinition of space and time undermined this foundation, prompting logical empiricists such as Carnap and Reichenbach to refute the *synthetic a priori* as incompatible with empirical science.

Building on these critiques, the paper explores the reconciliation of logical empiricism and realism through Evandro Agazzi's innovative concept of scientific objectivity. His approach reframes scientific objects as structured collections of properties defined by specific criteria of objectivity, offering a middle ground between the empiricist demand for verifiability and the realist commitment to an independent reality.

The discussion concludes by advocating for a refined philosophical framework that retains the meaningfulness of metaphysical principles while respecting the empirical constraints of scientific practice. Through this synthesis, the paper highlights the enduring interplay between philosophy and science in shaping our understanding of reality.

1 Introduction

For centuries, philosophers have sought certain and incontrovertible knowledge, either in a transcendent reality, as in the case of Plato's doctrine of ideas, or within the sensory world of experience, identifying essences capable of explaining natural phenomena.

Before Immanuel Kant, metaphysics, fortunately, was not as obscure as that of the philosophers who followed him. At times, its arguments displayed exemplary clarity, as seen in the works of equally renowned philosophers whose theses and conclusions, while absolutely clear, are ultimately untenable. The underlying issue lies in metaphysical philosophy's claim to establish certain and necessary statements about the properties of the real world—a claim that even the most advanced scientific theories cannot sustain without risking becoming a new form of metaphysics. This problem is

The Relevance of Judgment for Philosophy of Science, edited by Jure Zovko.
Comptes Rendus de l'Académie Internationale de Philosophie des Sciences 4 (2025).
G. Macchia and G. Tarozzi, The neopositivist refutation of Kant's synthetic a priori judgments, pp. 97–116.

particularly evident in the Galilean perspective and, most notably, in Kantian interpretations of classical mechanics.

Consider, for instance, the cases of Anselm of Aosta and Descartes. Both attempted to derive synthetic conclusions from analytical premises[1]: the former seeks to establish the existence of God from the definition of God as a perfect being, while the latter endeavors to demonstrate the existence of the self (the ego) from the certainty of doubt. Let us examine them more closely.

The most notable attempt to establish the certainty of God's existence was made by Anselm of Aosta in the 11th century. Anselm's argument begins with the definition of God as an infinitely perfect being. Since such perfection necessitates that this being possesses all essential properties, it must therefore possess the property of existence. Consequently, one is led to the conclusion that God necessarily exists. However, the premise is clearly analytic, as it rests on a definition, while the conclusion is synthetic, implying the existence of God in the real world. The inference from essence to existence seems to be a logical sleight of hand, deriving a synthetic conclusion from an analytic premise.

Descartes, on the other hand, was deeply troubled by the uncertainty surrounding knowledge. In various writings, he offered arguments about the unreliability of our perceptions and even vowed a pilgrimage to the Sanctuary of Loreto, asking the Virgin Mary to illuminate his mind and help him discover absolute certainty. His proof of such certainty, though not obscure, contains a logical flaw. He argues that he can doubt everything except one thing: the fact that he doubts. But in doubting, he reasons, he must think; and if he thinks, he must exist.

In 1730, David Hume introduced his famous distinction, known as "Hume's fork". According to this distinction, all human knowledge can be classified into two categories of propositions, which he termed "relations of ideas" and "matters of fact." The former, as in the case of mathematical principles, are universal and necessary but devoid of any empirical significance, while the latter possess empirical content but lack universality and necessity. More specifically, Hume argued that every statement that is certain, such as those in geometry, arithmetic, and algebra, falls under "relations of ideas." For instance, the proposition that the square of the hypotenuse is equal to the sum of the squares of the other two sides is a relation of ideas. Such facts represent *a priori* knowledge and can be known purely through reasoning. However, according to Hume, they are not significant in the sense that they do not convey any information about the

[1] As is well known, a synthetic proposition is one that conveys information beyond what is contained in the subject's definition, adding new knowledge. In contrast, an analytic proposition states only what is already implicit in the definition of the subject, offering no additional information.

actual world. "Matters of fact", on the other hand, encompass *a posteriori* knowledge and consist of synthetic propositions that provide information about the world. However, they are not certain, as they rely on sensory experience and the principle of cause and effect. Matters of fact represent contingent truths, such as the statement that Donald Trump is the President of the USA—a proposition that is neither universally nor necessarily true.

All propositions that could not be classified into one of these two categories were to be rejected as false. A famous passage is that of Hume, in *An Enquiry Concerning Human Understanding*, published in 1748:

> When we run over libraries, persuaded of these principles, what havoc must we make? If we take in our hand any volume; of divinity or school metaphysics, for instance; let us ask, *Does it contain any abstract reasoning concerning quantity or number?* No. *Does it contain any experimental reasoning concerning matter of fact and existence?* No. Commit it then to the flames: For it can contain nothing but sophistry and illusion. (Hume 2007, p. 144)

2 The Kantian synthetic a priori as a significant philosophical question

Kant attempted to overcome Hume's fork with the ingenious idea that the logical distinction between analytic and synthetic propositions does not necessarily correspond to the epistemological distinction between *a priori* and *a posteriori*, as Hume had thought (see Fig. 1, from Carnap 1966, p. 179).

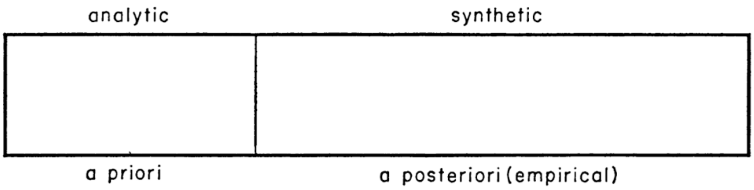

FIGURE 1. The boundary line between *a priori* and *a posteriori* coincides with the boundary line between analytic and synthetic.

It is true that all analytic knowledge is *a priori* and that all *a posteriori* knowledge is synthetic. However, there are instances in which certain synthetic forms of knowledge are *a priori*—meaning they are certain and necessary, yet not derived from experience. From this perspective, the logical distinction between analytic and synthetic no longer aligns with the epistemological distinction between *a priori* and *a posteriori* (see Fig. 2, from Carnap 1966, p. 179).

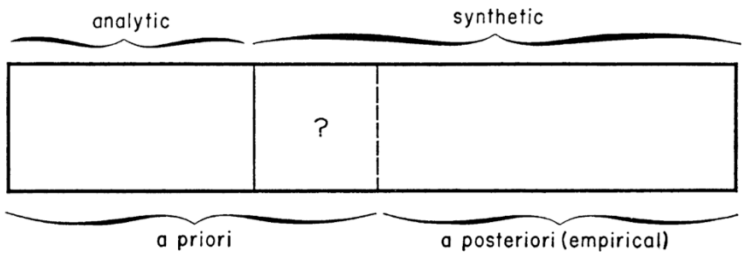

FIGURE 2. The boundary between *a priori* and *a posteriori* lies to the right of the boundary between analytic and synthetic, creating an intermediate zone where the synthetic overlaps with the *a priori*.

According to Kant, therefore, there exists a realm of knowledge that is both synthetic (insofar as it conveys information about the world) and *a priori* (because it can be known with certainty without requiring empirical justification). The existence of the synthetic *a priori* "is one of the great controversial questions in the history of the philosophy of science" (Carnap, 1966, p. 180).

Through this doctrine, Kant reestablished the non-contingent nature of classical physics, aligning himself with Galilean principles. These principles included the rejection of the Aristotelian essentialist conception, and posited that distinctions in nature explained the diversity of behaviors among natural objects, as well as affirmed the necessary character of the mathematical laws describing the world of phenomena. It was precisely the laws of classical physics that highlighted the existence of synthetic *a priori* judgments.

This passage from Reichenbach highlights the significance of Kant's approach to the synthetic *a priori* in the history of philosophy:

> If progress in the history of philosophy consists in the discovery of significant questions, Kant is to be assigned a high rank because of his question concerning the existence of a synthetic *a priori*. Like other philosophers, however, he claims merit not for the question but for his answer to it. He even formulates the question in a somewhat different way. He is so convinced of the existence of a synthetic *a priori* that he regards it as hardly necessary to ask whether there is one; therefore, he poses his question in the form: how is a synthetic *a priori* possible?
>
> The proof of its existence, he continues, is supplied by mathematics and mathematical physics. (Reichenbach 1951, p. 40)

For example, among the synthetic *a priori* judgments in mathematical physics are the conservation laws, such as the conservation of mass—the Newtonian concept of matter, considered indestructible. This idea had already been articulated by Lavoisier in 1789: "Nothing is created by human action or in natural operations. It is a fundamental truth that in all operations there is the same quantity of matter before and afterward and that the quality and quantity of the material principles are the same; there are only alterations and modifications" (de Lavoisier 1789, p. 107).

Another example of a synthetic *a priori* judgment in mathematical physics is the principle of causality. According to Kant, while we may often fail to identify the cause of a particular observed event, we do not assume that the event occurred without a cause. Instead, we maintain confidence that a cause exists and that it can be discovered through further investigation.

As with other aspects of Kant's philosophy, the existence of the synthetic *a priori* is supported by reference to scientific methodology and practice.

3 The impossibility of synthetic *a priori* in General Relativity

The crisis of the Kantian foundation of science, based on synthetic *a priori* judgments, emerged with the advent of modern physics—namely General Relativity and Quantum Mechanics—at the beginning of the twentieth century, which profoundly transformed the Kantian framework. General Relativity, in particular, continued—so to speak—the assault on Kantian confidence in the reliability of scientific conclusions. It further emphasized the fragility of "classical" science by exposing a fundamental inadequacy in the basic ontology of Newtonian physics, specifically its enumeration of fundamental entities. For instance, in the Newtonian paradigm, gravity is conceptualized as a force, with forces representing one of the foundational elements of its ontology. In contrast, General Relativity reconceptualizes gravity not as a force but as a manifestation of the curvature of spacetime. This redefinition constituted the primary philosophical revolution introduced by General Relativity with respect to space and the geometry used to describe it. In the decade following its formulation, such a redefinition implied a profound reevaluation of the nature of geometric knowledge.

In truth, General Relativity culminated a trend that had already begun in the 19th century, when it was discovered that geometries other than Euclidean geometry were consistent and logically possible. This development began with Carl Friedrich Gauss, who, as early as 1816, formulated a non-Euclidean geometry with negative curvature—a discovery later made independently around 1829 by the mathematicians János Bolyai and Nikolai Ivanovich Lobachevsky. Gauss, however, refrained from publishing his work to avoid "the yelling of the Boeotians", as he later remarked.

Notably, Gauss was the first to recognize that a measure of length might be inherent in physical yet "empty" space. In other words, he understood that both small and large triangles must contain exactly two right angles only if we are in a Euclidean space. Motivated by this insight, he devised and conducted an experiment to determine whether space was truly Euclidean on scales larger than those of everyday experience. As the director of the Göttingen Observatory, Gauss utilized an instrument of his own design to focus and reflect sunlight between three distant mountain peaks in the German principality of Hanover. His goal was to test the Euclidean hypothesis that the internal angles of the triangular formation of these peaks would sum to 180°. However, he realized that the confirmation he obtained of space's Euclidean nature was not decisive: a rigorous empirical test would require much greater distances, potentially on a stellar scale.

The important outcome of Gauss's efforts was the conceptual shift that geometry came to be seen as an empirical science akin to mechanics, unlike arithmetic, which Gauss assumed to be *a priori*. Consequently, the necessity and universality that Kant attributed to Euclidean axioms lost their philosophical grounding.

A few years later, Bernhard Riemann further enriched the field of non-Euclidean geometries with elliptic geometry, complementing hyperbolic geometry as the other traditional non-Euclidean system. Particularly noteworthy was the beginning of Riemann's famous lecture, delivered in Göttingen in 1854 and published in 1868. This text, recognized as one of the most important works in geometry, laid the foundation for what would come to be known as Riemannian geometry:

> It is known that geometry assumes, as things given, both the notion of space and the first principles of constructions in space. She gives definitions of them which are merely nominal, while the true determinations appear in the form of axioms. The relation of these assumptions remains consequently in darkness; we neither perceive whether and how far their connection is necessary, nor, *a priori*, whether it is possible. (in Jost 2016, p. 31)

Thus, with these foundational works, mathematicians began to recognize that these new geometries had to be taken seriously—even as physical possibilities for describing the geometry of actual space. The 18th-century notion that Euclid had uncovered the ultimate truth of geometry (and similarly that Newton had done the same in physics for mechanics, as Euclidean geometry was unquestioningly adopted as the foundation for 18th-century physics), a supposedly certain knowledge independent of experience, began to collapse. Geometry came to be understood as describing how our space actually *is*, rather than how it *ought to be*.

By the second half of the 19th century, however, these alternative geometries were regarded merely as unrealized possibilities: Nature, despite having many options, had apparently chosen Euclid's system. If the recognition of the mere logical possibility of geometries other than Euclid's was shocking, even more so was the realization—through General Relativity—that non-

Euclidean geometries were no longer merely unused possibilities in Nature, nor pure speculation, but actual physical realities. In the presence of strong gravitational fields, Nature itself selects non-Euclidean geometries: such geometries, characterized by variable curvature (depending on the distribution of matter and energy), represent our actual space, with Euclidean geometry holding only as an approximation.

This revolutionary perspective can even be associated with a specific date: November 6, 1919. On that occasion, the astronomer Arthur Eddington presented the results of his measurements of light deflection during the solar eclipse of May that year to the Royal Astronomical Society in London. The apparent displacement of the positions of stars, caused by the Sun's mass curving spacetime—and thus bending the trajectory of light—was considered the first experimental confirmation of General Relativity.

The discovery of non-Euclidean geometries had a ripple effect that extended far beyond the boundaries of mathematics and science. The immediate philosophical casualty of Einstein's theory, of course, was one of the most successful epistemologies: that of Kant. In Kant's account of human knowledge, geometry held a special role. The science of Euclidean geometry was paradigmatic of synthetic *a priori* truths—truths that were certain and necessary (neither derived from the senses nor deduced through logic) and known independently of any particular experience, yet genuinely descriptive and applicable to physical or empirical reality. Synthetic *a priori* truths were propositions about the world that could simultaneously be regarded as true even prior to any experience of it. Euclidean geometry was a repository of such truths. According to Kant, Euclid's postulates were synthetic *a priori* conditions, as they expressed the necessity and universality of the form of outer intuition.

General Relativity, however, demonstrated that the laws of geometry were neither truths nor *a priori*. Geometry did not necessarily have to be Euclidean, and its validity was something to be discovered empirically in the world.

4 The rejection of synthetic *a priori* judgments as the fundamental thesis of logical empiricism

The logical empiricism of the early 20th century—represented by Moritz Schlick, Hans Reichenbach, and Rudolf Carnap—openly acknowledged the influence of the theory of relativity in shaping the core of its philosophical perspective. This groundbreaking application of non-Euclidean geometry to physics—the first of its kind—has been regarded, since the emergence of logical empiricism (from which later developments in the philosophy of science have arisen, albeit often in a critical spirit), as a definitive refutation of the Kantian philosophy of geometry and, by implication, as a decisive rejection of the broader Kantian doctrine of the synthetic *a priori*.

In his 1951 book, Reichenbach wrote:

> I do not wish to be irreverent to the philosopher of the Enlightenment. We are able to raise this criticism because we have seen physics enter a stage in which the Kantian frame of knowledge does break down. The axioms of Euclidean geometry, the principles of causality and substance are no longer recognized by the physics of our day. We know that mathematics is analytic and that all applications of mathematics to physical reality, including physical geometry, are of an empirical validity and subject to correction by further experience; in other words, that there is no synthetic *a priori*. But it is only now, after the physics of Newton and the geometry of Euclid have been superseded, that such knowledge is ours. (Reichenbach 1951, p. 48)

Carnap's perspective was similarly critical of Kant and aligned with Moritz Schlick's identification of logical empiricism as the philosophy that rejects the existence of synthetic *a priori* judgments: "Indeed, as Schlick once remarked, empiricism can be defined as the point of view that maintains that there is no synthetic *a priori*. If the whole of empiricism is to be compressed into a nutshell, this is one way of doing it" (Carnap 1966, p. 180).

As is widely recognized, a central tenet of logical empiricism was the verification principle (or verificationism), which asserts that a statement is meaningful only if it is empirically verifiable—capable of being confirmed through sensory experience—or a tautology, true by virtue of its meaning or logical form. This principle is articulated by Alfred Ayer, one of the most prominent proponents of logical positivism, in the following formulation:

> The criterion which we use to test the genuineness of apparent statements of fact is the criterion of verifiability. We say that a sentence is factually significant to any given person, if, and only if, he knows how to verify the proposition which it purports to express—that is, if he knows what observations would lead him, under certain conditions, to accept the proposition as being true, or reject it as being false. If, on the other hand, the putative proposition is of such a character that the assumption of its truth, or falsehood, is consistent with any assumption whatsoever concerning the nature of his future experience, then, as far as he, is concerned, it is, if not a tautology, a mere pseudo-proposition. (Ayer 1951, p. 10)

The neo-positivists drew inspiration from the anti-metaphysical program initiated by Mach's critique of classical physics. This critique, which eliminated the concepts of absolute space and time, as well as the notion of undisturbed object trajectories, gave rise to two groundbreaking theories in 20th-century physics. However, the anti-metaphysical program of physics was eventually extended to philosophy. These anti-metaphysical conclusions evolved into an anti-philosophical stance following the rejection of the synthetic *a priori*, which the neo-positivists regarded as the only coherent attempt to construct a metaphysical framework.

This perspective led the verificationists to dismiss statements in metaphysics, theology, ethics, and aesthetics as devoid of truth value or factual content. While such statements were acknowledged as meaningful in their capacity to influence emotions or behavior, they were deemed meaningless in terms of conveying cognitive or empirical content. As a result, the central claims of traditional philosophy were rejected by logical empiricists as lacking cognitive content—they were seen as neither true nor false, as they typically corresponded to metaphysical propositions of existential import that are not empirically testable and offer no method for determining their truth.

In summary, logical empiricists arrived at the controversial conclusion that no philosophical principle possesses inherent meaning, thereby relegating meaning exclusively to scientific propositions. As Weinberg put it: "The ultimate and definitive doctrine of logical positivism is that the only proposition endowed with meaning are those of science" (Weinberg 1936, p. 105). Consequently, philosophical propositions were considered non-existent, as Neurath asserted: "All the representatives of the Circle are in agreement that 'philosophy' does not exist as a discipline, alongside of science, with propositions of its own: the body of scientific propositions exhausts the sum of all meaningful statements" (Neurath 1959, p. 282).

Even the thesis of realism was subjected to refutation: Carnap, followed by Ayer, sought to demonstrate the complete lack of meaning in both realism and its antithesis, idealism.

Ryckman recounts a particularly explicit statement made by Schlick—the éminence grise of the Vienna Circle and logical empiricism more broadly—in 1922, in Vienna, at the centenary meeting of the *German Society of Natural Scientists and Doctors*, on the topic of "The Theory of Relativity in Philosophy":

> Now along comes the general theory of relativity, and finds itself obliged to use non-Euclidean geometry in order to describe this same world. Through Einstein, therefore, what Riemann and Helmholtz claimed as a possibility has now become a reality, the Kantian position is untenable, and empiricist philosophy has gained one of its most brilliant triumphs. (in Ryckman 2005, p. 5)

According to Schlick, and later other logical empiricists, the collapse of the synthetic *a priori* in geometrical space signified a broader triumph of empiricism over metaphysical and idealist philosophies. For the logical empiricists, mathematical statements were reducible to logical statements, and purely mathematical truths were essentially logical truths—hence analytic, meaning they were true by virtue of the meanings of the terms they contained. This view reinforced the central thesis of logical empiricism: any meaningful statement is either analytic or a synthetic *a posteriori* statement, the latter being confirmable or refutable by experience.

Although General Relativity served as a significant stimulus for philosophical reflection, the question of whether it supports any specific philosophical interpretation remains contentious. Indeed, the cornerstone belief of logical empiricists—namely, as already mentioned, that this theory had definitively established the untenability of any "philosophy of the synthetic *a priori*"—should not be taken for granted,[2] particularly in light of significant neo-Kantian developments in Kantian thought by figures such as Ernst Cassirer, Hermann Weyl, and Arthur Stanley Eddington.

In the early 1920s, Schlick, responding to the growing neo-Kantian reaction to relativity, adopted the notion of convention as an alternative to the Kantian *a priori*. He suggested that "the 'constitutive principles' whereby experience is ordered and interpreted are more helpfully characterized as conventions than as elements of either a contingent or an apodictic *a priori* component of scientific cognition" (Howard 2014, p. 363). Einstein, who was in close and regular contact with Schlick at the time, had proposed a similar idea over the course of several years.

5 Einstein on Kant

It is beyond the scope of this discussion to provide a comprehensive account of Einstein's relationship with Kantian *a priori* principles. However, some of his reflections may be helpful in framing or contextualizing this relationship. In a letter to Max Born dated July 1918, Einstein wrote:

> I am reading Kant's *Prolegomena* here, among other things, and am beginning to comprehend the enormous suggestive power that emanated from the fellow and still does. Once you concede to him merely the existence of synthetic *a priori* judgments, you are trapped. I have to water down the '*a priori*' to 'conventional,' so as not to have to contradict him, but even then the details do not fit. Anyway it is very nice to read, even if it is not as good as his predecessor Hume's work. Hume also had a far sounder instinct (in Howard 2014, p. 363).

Essentially, Einstein reiterated the same point—that what Kant regarded as *a priori* should more appropriately be understood as conventional in nature—in numerous comments he made on the subject up until the mid-1920s.[3]

[2] See Ryckman (2024).
[3] See Howard (1994).

A famous and subtly critical remark about Kant is also found at the beginning of Einstein's renowned 1921 essay, "Geometry and experience".[4] In this work, Einstein delved more deeply into the philosophical issues underlying General Relativity, particularly his assertion that the axioms of geometry are "free creations of the human mind." He wondered:

> At this point a riddle presents itself that has troubled researchers throughout the ages. How is it possible that mathematics, being after all a product of human thought that is independent of experience, is so admirably appropriate to the objects of reality? Can human reason, then, without experience, through pure thought fathom the properties of real things? In my opinion, the answer to this question is, briefly, this: As far as the laws of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality. (Einstein 1921, p. 147)

Thus, in his response—arguably the most well-known passage of this paper—which is the most well-known passage of this paper, Einstein argued that Kantian synthetic *a priori* propositions cannot exist because mathematical propositions, including those of geometry, can be either synthetic (and thus "referring to reality") or *a priori* (and thus "certain"), but not both.

During a famous discussion with French luminaries at the *Collège de France* in April 1922, Einstein instead remained neutral in the choice between Kantian *a priori* principles and Poincaréan conventionalism, as Ryckman recounts, with some astonishment:

> It seems to me that the most important matter in Kant's philosophy is that one speaks of *a priori* concepts in the construction of science. But here there are two opposing viewpoints: the apriorism of Kant, in which certain concepts preexist in our mind, and the conventionalism of Poincaré. These two points of view agree on the point that science requires, for its construction, arbitrary concepts; with regard to whether these concepts are given *a priori* or are arbitrary conventions, I cannot say. (Ryckman 2014, p. 388)

Shortly thereafter, in 1924, in a review of Alfred C. Elsbach's text *Kant und Einstein*, Einstein provided a more comprehensive account of his negative assessment of the Kantian synthetic *a priori*, writing:

> Until some time ago, it could be regarded as possible that Kant's system of *a priori* concepts and norms really could withstand the test of time. This was defensible as long as the content of later science

[4] On this topic, and concerning the relationship between the problem of geometry in General Relativity and the philosophy of logical empiricism, see Friedman (2002; 2008) and Ryckman (2017, ch. 7).

> held to be confirmed* did not violate those norms. This case occurred indisputably only with the theory of relativity. However, if one does not want to assert that relativity theory goes against reason, one cannot retain the *a priori* concepts and norms of Kant's system.
>
> *[Footnote: To refute Kant's system it actually suffices to indicate a logically *conceivable* theory (corresponding to *conceivable* observational material) that conflicts with Kantian norms. Whether non-Euclidean geometries accomplished this remained controversial.]
>
> For starters, this does not exclude, at least, the retention of Kant's *way of posing the problem* [...]. I am even of the opinion that this standpoint cannot be strictly refuted by any scientific development. For, one will always be able to say that critical philosophers had hitherto erred in setting up the *a priori* elements and one will always be able to set up a system of *a priori* elements that does not conflict with a given physical system. I surely may briefly indicate why I do not find this standpoint natural. Let a physical theory consist of the parts (elements) A, B, C, D, which together form a logical whole that correctly connects the pertinent experiments (sensory experiences). Then the tendency is that less than all four elements, e.g., A, B, D, still say nothing about the experiences, *without* C; no more so A, B, C, without D. One is then free to regard three of these elements, e.g., A, B, C, as *a priori* and only D as empirically determined. What always remains unsatisfactory in this is the *arbitrariness of the choice* of elements to be designated as *a priori*, even disregarding that the theory could be replaced at some point by another theory that substitutes some of these elements (or all four of them) with others. One could be of the view, though, that through direct analysis of human reason, or thought, we would be in a position to recognize elements that would have to be present in *any* theory. But most researchers would probably agree that we lack a method for recognizing such elements, even if one were inclined to believe in their existence. Or should one imagine that the search for *a priori* elements was a kind of asymptotic process that advances along with the development of science? (in Norton 2017)

So Einstein, although skeptical and firmly confident in the ultimate authority of experience, recognized the relevance of the problem of identifying *a priori* elements—and therefore the significance of the Kantian approach to this issue—as Ryckman points out: "Notwithstanding well-known railings against Kant's unsustainable doctrine of synthetic *a priori* concepts and judgments, the later Einstein affirmed that while experience alone remained the ultimate arbiter of any theory, a 'belief in the comprehensibility of reality through something logically simple and unified' was a methodologically legitimate heuristic, whose general form Kant had thoroughly probed in the 'Transcendental Dialectic' of the *Critique of Pure Reason*" (Ryckman 2017, p. 344).

6 The dissolution of the synthetic *a priori* does not preclude the existence of meaningful philosophical principles

The fact that Kant's attempt was both highly significant and extraordinary is beyond question, as even Einstein's early reflections demonstrate. Moreover, the logical positivists themselves acknowledged that of all metaphysical doctrines, only one possessed meaning: the doctrine asserting the existence of synthetic *a priori* propositions. Although the transcendental constitution of objectivity in Kantian terms ultimately failed, this does not imply the invalidity of the "belief in the comprehensibility of reality through something logically simple and unified", as Einstein maintained. Nor does it mean that it is no longer possible to pursue a "good metaphysics"—that is, to formulate valid and meaningful philosophical principles.

In other words, the recognition that certainty and necessity cannot be combined does entail a return to Hume's view that grand philosophical questions are meaningless. The logical positivists sought to equate meaning with scientific validity. In concluding that—given their refutation of the synthetic *a priori* and their critique of metaphysics—only scientific propositions were meaningful, they inadvertently conflated their principle of verifiability with a principle of scientific demarcation, that is, of distinguishing science from non-science.

From Popper onwards, however, it has been understood that what is meaningful is not necessarily scientific. There exists a domain of statements that, while meaningful, are unfalsifiable and thus pseudo-scientific. The boundary between what is meaningful and meaningless, therefore, does not coincide with the distinction between scientific and pseudo-scientific.[5]

Philosophical propositions, while differing in status from scientific ones, can still have meaning, even if they are unfalsifiable and thus non-scientific. This perspective, however, repositions philosophy in a more modest role compared to Kantian philosophy: it no longer aims to establish certain and necessary knowledge that is impervious to empirical falsification. Instead, it aspires to provide regulative principles for describing the world of experience—principles that may be accepted or rejected within specific theoretical contexts, but which are not universally invalidated by the entire domain of experience.

More specifically, while scientific principles engage directly with experience and are subject to refutation, philosophical principles engage with the scientific theories through which we describe that experience, as their scope of application is defined precisely by those theories. Scientific theories, being rooted in empirical observations, are falsifiable when they conflict

[5] See Tarozzi (1988), particularly the diagram on p. 102.

with experience, whereas philosophical principles are falsifiable only within the bounds of a specific theoretical framework (e.g., determinism, which is applicable in classical physics but not in quantum mechanics). Consequently, experience directly determines the validity of scientific theories and indirectly influences the validity of philosophical principles, insofar as these principles are assessed in relation to theoretical contexts or in relation to specific principles within them, rather than in direct confrontation with experience itself.

Historically, the foundations of quantum mechanics have opened up new possibilities for rethinking and reformulating metaphysical principles and concepts. Just as classical physics in Kant's era provided the foundation for synthetic *a priori* propositions, grounded in the Euclidean metric of space and the causal laws governing matter conservation, quantum mechanics has introduced a radically different philosophical framework. By rejecting the synthetic *a priori* through Bohr's principle of complementarity[6], quantum mechanics has demonstrated the factual relevance of alternative philosophical principles, thereby reviving—under new forms—longstanding metaphysical controversies that had previously been dismissed as meaningless pseudo-problems.

Several examples can be identified of thoroughly meaningful philosophical issues that are applicable exclusively within specific scientific theories and that, particularly in quantum mechanics, present significant challenges. Such issues include realism[7], causality[8], determinism[9], holism[10], the mind-body relation[11] and the concept of nothingness[12].

In what follows, we will further examine one of these issues—realism—drawing once again on logical positivism and Evandro Agazzi's realist conception.

7 Was neopositivism truly antirealistic?

Neopositivists were generally not realists in the metaphysical sense but rather empiricists, frequently associated, as often reiterated, with an anti-metaphysical stance. Their philosophy was based on the idea that the meaning of propositions derives either from their empirical verifiability or their logical validity. Statements lacking empirical criteria for verification were considered pseudo-propositions, devoid of cognitive significance. This

[6] See Covoni et al. (2024).
[7] See Selleri & Tarozzi (1981), Tarozzi (1981), Auletta & Tarozzi (2004).
[8] See Tarozzi & Macchia (2021).
[9] See Tarozzi (1988b).
[10] See Calosi et al. (2011).
[11] See Calosi & Tarozzi (2013), Corti et al. (2023).
[12] See Afriat & Tarozzi (2006).

positioned them in opposition to metaphysical realism, which posits the independent existence of objects or structures in the world.

Although many neopositivists refrained from strong metaphysical commitments, some adopted a form of empirical or structural realism, maintaining that scientific theories provide a representation of the world—albeit limited to what can be observed or measured. For instance, realism regarding theoretical terms (such as "electrons") was not fully embraced, as such entities are not directly observable. Certain neopositivists leaned toward an instrumentalist approach, viewing scientific theories as tools for organizing and predicting sensory data rather than as literal descriptions of reality.

It is important to acknowledge differences among members of the Vienna Circle and other neopositivist thinkers. For example, Rudolf Carnap displayed openness to "methodological tolerance", deliberately abstaining from taking a stance on the ontological status of theoretical entities.

In summary, neopositivists were not strong or metaphysical realists, but their empiricism could align with a form of realism confined to observable and operationally definable aspects of science.

In addressing the question of whether neopositivism genuinely embraced a realist perspective on science, Evandro Agazzi provides an affirmative response:

> The epistemology of neo-positivism, despite having been profoundly influenced by Mach's thought, ended up accepting more or less explicitly a realistic view of science.
>
> ... the obsession with which neo-empiricism has tried to impose the most absolute fidelity to experience and the reducibility to it of the same theoretical components of the sciences can also be considered as an effort to ensure science a solid connection with reality (Agazzi 1985, p. 173).

In Agazzi's realist conception, the connection between knowledge and reality is ensured by the operational and interactive nature of the relationship established between the subject and reality, as articulated in his doctrine of "objectification." Within this philosophical framework, each science investigates objects solely through the lens of specific fundamental attributes, for which it has distinct criteria for their assignment. These criteria essentially consist of operations, which naturally include observation and measurement but are more broadly conceived as forms of interaction with the objects under investigation.

Observational or "protocol" propositions are those that affirm or deny a fundamental attribute of an object and are directly verifiable through the aforementioned operations. Each science subsequently introduces its own theoretical attributes, which are defined through relationships among these basic attributes. Theoretical propositions pertain to such attributes, and their assertability is established through rational inferences derived from protocol propositions and, where applicable, other theoretical propositions.

According to Agazzi, a scientific object is essentially a collection of predicates:

> ... a scientific object is a ‘thing’ conceived from a particular point of view, the general nature of the object being determined by means of the criteria of objectivity of the science in question. Thus the adoption of a given set of such criteria ‘*clips out*’ some particular object, while the adoption of a different set of criteria ‘clips out’ a different object, both from one and the same individual ‘thing.’ We can leave aside this metaphor of ‘clibbing out,’ and express the matter in a linguistic form. Thus we should say that an object of a given science contains only (and all) the aspects of a ‘thing’ which may be characterized by the basic predicates of that science. In this sense [...] *a scientific object is nothing other than a bunch of predicates.* (Agazzi 2014a, pp. 89–90).

Thus, according to Agazzi, a scientific object is defined by the criteria of objectivity specific to a particular science, which determine its general nature. These criteria isolate certain aspects of a ‘thing’ as relevant to that science, while different criteria may isolate other aspects. In essence, a scientific object can be understood as a structured collection of predicates that characterize the aspects of a ‘thing’ pertinent to the science in question. In this way, Agazzi proposed a reconciliation between logical empiricism and realism through his conception of scientific objectivity, replacing the notion of an entity with that of an object, understood as a structured set of properties.

8 Property realism and entity realism

The earlier conception of scientific objectivity significantly influenced the research of one of us (G.T.) on the foundations of quantum mechanics, originally conducted from a strictly logical empiricist perspective. This approach initially led G.T. to attempt, albeit unsuccessfully, to demonstrate the redundancy of the hypothesis asserting the validity of the physical reality principle of EPR in the derivation of their renowned paradox and Bell’s theorem. According to logical empiricists, philosophical principles are devoid of meaning unless they lead to empirically testable consequences; therefore, adopting or rejecting such a principle should yield the same conclusions. Contrary to expectations, however, these efforts revealed the opposite result: the EPR principle emerged as a necessary condition for deriving the paradox and proving the theorem.

This principle, as is well known, equated predictability with certainty through the mathematical laws of quantum mechanics themselves. This alignment constituted a robust form of scientific objectivity, serving as a sufficient condition for reality, as argued by Agazzi in his *Temi e problemi di filosofia della fisica*, where he asserted that "the position of correct realism, on the other hand, is the one that between objective and real sees a relationship of *inclusion*: everything that is objective is real, although not everything that is real is objective" (1969, p. 365). Now, since predictability pertains to the properties or attributes of an object, rather than to the object itself—or even to the existence of an object (as Kant had already pointed out before the neopositivists, since existence is not a property of an object)—an empirical radicalization of Agazzi's position has led to a form of property realism capable of satisfying the factual significance requirements of neopositivism.

A significant convergence and agreement between realism of properties and realism of objects, grounded in Agazzi's objectivism, had already been identified in G.T.'s original formulation: "[...] when we assert the reality of the predictable attributes or properties of an object, we maintain *implicitly* also the reality of the object itself, assuming once more a shape of independence from our perceptions" (Tarozzi 1980, p. 97).

This view was later confirmed by Agazzi himself, as reflected in the following excerpt:

> The comments that we want to propose about the issue of the realism of properties will shorten very much its distance from a form of entities realism, by dissolving the ambiguity inhering to the concept 'entity' itself. The first step will be the replacement of the term 'entity' by the term 'object' [...] in such a way that it consists in a 'structured set of properties', and from this follows the consequence that attributing 'reality' to properties amounts to attributing reality to the objects as well. (Agazzi 2014b, p. 23)

This nuanced perspective not only bridges the gap between property realism and entity realism, but also reaffirms the interdependence of empirical and theoretical considerations in defining scientific objectivity. By emphasizing the structured and relational nature of scientific objects, Agazzi's framework, as well as the modified proposal of G.T., offers a robust philosophical grounding for interpreting the predictive and explanatory power of scientific theories.

9 Conclusions

This paper has traced key moments in the complex trajectory of the *synthetic a priori*, from its Kantian origins—where it was firmly tied to the universality and necessity of scientific knowledge—to its eventual dissolution in the wake of General Relativity and logical empiricism. Despite the critique advanced by logical positivists, which led to a significant narrowing of what could be deemed cognitively meaningful, the subsequent dialogue with neo-Kantian thought and the philosophical interpretation of quantum mechanics demonstrate the enduring relevance of philosophical principles within scientific contexts. The dissolution of the synthetic *a priori* does not preclude the possibility of meaningful philosophical inquiry, but rather invites its reformulation in the light of evolving scientific paradigms. Indeed, Agazzi's conceptualization of scientific objectivity—as rooted in structured sets of properties—underscores that realism, far from being a purely metaphysical stance, can be productively connected to empirically testable theories. By accommodating both the empirical demands of logical empiricism and the ontological commitments of realism, property realism offers a pathway to re-envision philosophical principles not as sterile *a priori* commitments, but as regulative frameworks subject to theoretical assessment. This integrated approach reaffirms the ongoing and indispensable role of philosophical analysis in shaping how we conceive of—and engage with—scientific theories.

References

Afriat A., Tarozzi G. (2006), "Can Nothing Cause Nonlocal Quantum Jumps?", in *Quantum Mechanics. Are There Quantum Jumps?* ed. by A. Bassi et al., American Institute of Physics, Melville, New York, pp. 3–7.

Agazzi, E. (1969), *Temi e problemi di filosofia della fisica*, Manfredi, Milano.

Agazzi, E. (1985), "La questione del realismo scientifico", in C. Mangione (ed.), *Scienza e filosofia. Saggi in onore di Ludovico Geymonat*, Garzanti, Milano, pp. 171–192.

Agazzi, E. (2014a), *Scientific Objectivity and Its Contexts*, Heidelberg, Springer.

Agazzi, E. (2014b), "Realism of properties and realism of entities", in V. Fano (ed.), *Gino Tarozzi, Philosopher of Physics*, Franco Angeli, Milano, pp. 22–32.

Auletta G., Tarozzi G. (2004),"On the Reality of Quantum Waves", *Foundations of Physics*, 34–35, pp. 1675–1694.

Ayer, A. J. (1951), *Language, Truth and Logic*, V. Gollancz, London.

Calosi C., Fano V., Tarozzi G. (2011) "Quantum Ontology and Extensional Mereology", *Foundations of Physics*, 41, pp. 1740–1755.

Calosi C., Tarozzi G. (2013) "Is the Mind a Quantum Computer?", *Epistemologia*, XXXVI, pp. 194–206.

Carnap, R. (1966), *Philosophical Foundations of Physics: An Introduction to the Philosophy of Science*, Basic Books, New York & London.

Corti A., Fano V., Tarozzi, G. (2023), "A Logico-Epistemic Investigation of Frauchiger and Renner's Paradox", *International Journal of Theoretical Physics* 62:54.

Covoni, N., Macchia, G., Pietrini, D., Tarozzi, G. (2024), "Non-standard realistic models of quantum phenomena and new forms of complementarity", in H.-P. Grosshans (ed.), *Models and Representations in Science*, in *Proceedings of the Académie Internationale de Philosophie des Sciences* 3, pp. 39–54.

Covoni, N., Tarozzi, G. (2024), "Empiricism and Realism Reconciled in Agazzi's Conception of Scientific Objectivity", *Distinctio: Journal of Intersubjective Studies*, 3(1), pp. 47–55.

de Lavoisier, A.-L. (1789), *Traité élémentaire de chimie*, Cuchet, Paris.

Einstein, A. (1921), "Geometry and Experience", *CPAE* 7 (2002), English translation supplement, Doc. 52, pp. 208–222; also in P. Pesic (ed.), *Beyond Geometry. Classic Papers from Riemann to Einstein*, Dover Publ., Mineaola, New York, pp. 147–157.

Friedman, M. (2002), "Physics, Philosophy, and the Foundations of Geometry", *Diálogos* 37, pp. 121–42.

Friedman, M. (2008), "Space, Time, and Geometry: Einstein and Logical Empiricism", in P. Galison, G. Holton & S. Schweber (eds.), *Einstein for the 21st Century: His Legacy in Science, Art, and Modern Culture*, Princeton University Press, Princeton, NJ, pp. 205–216.

Howard, D. (2014), "Einstein and the Development of Twentieth-Century Philosophy of Science, in M. Janssen and C. Lehner (eds.), *The Cambridge Companion to Einstein*, Cambridge University Press, Cambridge, pp. 354–376.

Hume, D. (2007), *An Enquiry Concerning Human Understanding. And Other Writings*, ed. by S. Buckle, Cambridge, Cambridge University Press.

Jost, J. (2016), Bernhard Riemann. On the Hypotheses Which Lie at the Bases of Geometry. Birkhäuser.

Neurath, O. (1959), *Sociology and Physicalism*, in A. J. Ayer (ed.), *Logical Positivism*, The Free Press, Glencoe (Illinois), pp. 282–317.

Norton, J. (2017), “Einstein on Kant”, in J. Norton, *Einstein for Everyone*, Nullarbor Press, Pittsburgh (Pennsylvania).

Reichenbach, H. (1951), *The rise of scientific philosophy*, University of California Press, Berkeley.

Ryckman, T. (2014), “‘A Believing Rationalist’: Einstein and ‘the Truly Valuable’ in Kant”, in M. Janssen and C. Lehner (eds.), *The Cambridge Companion to Einstein*, Cambridge University Press, Cambridge, pp. 377–397.

Ryckman, T. (2017), *Einstein*, Routledge, London and New York.

Ryckman, T. (2024), “Early Philosophical Interpretations of General Relativity”, in E. Zalta (ed.), *Stanford Encyclopedia of Philosophy*, Edition Summer 2024.

Selleri F., Tarozzi, G. (1981),“Quantum Mechanics, Reality and Separability”, *Rivista Nuovo Cimento*, 4(2), pp. 1–54.

Tarozzi, G. (1980), “Realism as a meaningful philosophical hypothesis”, in *Atti della Accademia delle Scienze dell’Istituto di Bologna*, XIII, VII, pp. 89–98.

Tarozzi, G. (1981) “Realisme d’Einstein et mècanique quantique: un cas de contradiction entre une théorie physique et un hypothèse philosophique clairement définie”, *Revue de Synthèse* 101–102, pp. 125–158

Tarozzi, G. (1988a), “Science, Metaphysics and Meaningful Philosophical Principles”, *Epistemologia* 11, pp. 97–104.

Tarozzi, G. (1988b), “Probability and Determinism in Quantum Theory”, in *Probability in the Sciences*, ed. by E. Agazzi, Kluwer, Dordrecht, pp. 237–259.

Tarozzi, G., Macchia, G. (2021), “No-Thing and Causality in Realistic Non-Standard Interpretations of the Quantum Mechanical Wave Function: *Ex Nihilo Aliquid*?”, *Foundations of Science* 28, pp. 159–184.

Weinberg, J. (1936), *An Examination of Logical Positivism*, Kegan Paul and Co., London.