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Philipp Frank and the Relationship Between Physics and Philosophy in the Belle Époque

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Abstract:
Philipp Frank (1884-1966) was an Austrian theoretical physicist and philosopher and a founding member of the Vienna Circle. Although much of his recognition as a proponent of logical positivism emerged in the 1920s, Frank's deep interest in and engagement with philosophy, particularly the philosophy of science, was evident from the early years of his professional career. Under the mentorship of Ludwig Boltzmann at the University of Vienna and significantly influenced by Ernst Mach, Frank exemplified key traits among Austrian physicists of the early 20th century: a commitment to antidogmatism, a pluralistic approach, and an emphasis on dialogue amidst the growing specialization and fragmentation of knowledge. This article aims to explore both the personality and his ideas through an examination of Frank's articles and reviews from his formative years in 1907 up until the end of the so-called Belle Époque in 1914.

Keywords: Historical epistemology; Indeterminism; Philipp Frank; Pluralism; Worldviews

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Remarks About the Life and Work of a Physicist-Philosopher Educated at the Time of the Belle Époque

Born in 1884 in Vienna, then part of the Austro-Hungarian Empire (now Austria), Philipp Frank was a distinguished theoretical physicist, philosopher, intellectual, and a founding member

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of the Vienna Circle (Holton 2006; 1993; Stadler 1993; 2015; Stöltzner, 2003; Romizi 2012; 2013; Holton *et al.* 1968). He earned his doctorate in theoretical physics from the University of Vienna, where he conducted research under the supervision of Ludwig Boltzmann. His doctoral thesis, titled *Über die Kriterien für die Stabilität der Bewegung eines materiellen Punktes in der Ebene und ihren Zusammenhang mit dem Prinzip der kleinsten Wirkung* (1906, *On the Criteria for the Stability of the Motion of a Material Point in the Plane and Its Connection with the Principle of Least Action*), marked him as one of Boltzmann's last students (Holton, 2006; 1993). Despite his rigorous training in theoretical physics, Frank possessed a profound interest in philosophy, particularly what is now referred to as philosophy of science. For Stadler (1993), the core principles of logical or scientific empiricism, as they evolved in Vienna and Berlin during the 1920s and early 1930s, emerged from the collaborative efforts of philosophers with a deep interest in science and scientists with a strong philosophical inclination. These thinkers observed that while the claims of the physical sciences could be objectively tested through experiment and observation, metaphysical assertions lacked such empirical scrutiny. The Vienna Circle broadly contended that the issues raised by metaphysics did not constitute genuine problems. In their view, metaphysical questions could not even be properly formulated within a rigorous conceptual and linguistic framework; they were considered pseudo-problems devoid of meaningful content (Stadler 1993, 1). Nonetheless, the Vienna Circle was not a homogeneous entity; there were nuances and differing views among its members, particularly concerning the role of metaphysics. For a more detailed exploration of these differences, see Romizi (2013) and Gruber (1991). According to Holton (2006), Frank began participating in meetings of young intellectuals in 1907 – a group that would later become known as the Vienna Circle – primarily motivated by Boltzmann's influence.

Philipp Frank's extensive publication[3] record in theoretical physics includes a variety of works that address physical questions intertwined with philosophical themes. This article will focus specifically on his contributions from his doctoral work up to the end of the Belle Époque (1914). Key publications from this period include: *Kausalgesetz und Erfahrung* (1907); *Mechanismus oder Vitalismus* (1907); *Die Einheit des physikalischen Weltbildes* (1909) – a review of Planck's article of the same title; *Die Theorie der Physik bei den modernen Physikern* (1909) – a review of Abel Rey's[4] book, originally published in French as *La Théorie de la Physique chez les Physiciens Contemporains*; *Der Phänomenalismus. Eine naturwissenschaftliche Weltanschauung* (1913) – a review of Hans Kleinpeter's book; *Letzte Gedanken* (1913) (*Dernières Pensées*) – a review of Henri Poincaré's book. Before delving into these reviews, it is useful to provide an overview of Frank's professional career to better contextualize his contributions as a philosopher of science.

After completing his doctoral studies, Philipp Frank remained in Vienna until 1912. At that time, he was appointed to the chair of theoretical physics at the German University of Prague, a position previously held by the founder of General Relativity, on the recommendation of Albert Einstein (Holton 1993; 2006; Stöltzner 2003). Frank continued his tenure in Prague until 1938, when he emigrated to the United States as a visiting professor to lecture on physical and philosophical topics. Shortly after his departure for North America,

[3] For a comprehensive overview of Philipp Frank's bibliographical contributions, refer to *The Law of Causality and Its Limits* (1998), edited by Robert Cohen. The book includes a nearly complete bibliography of Frank's works. However, it is worth noting that this list omits Frank's reviews, which he published frequently, particularly during the early stages of his career. This omission will be addressed in subsequent discussions.

[4] Abel Rey was a French philosopher who made significant contributions to various fields of knowledge, including the philosophy of mind, epistemology, and the history of science. He also demonstrated a deep understanding of scientific matters. For more information on Abel Rey, cf. Chimisso 2002.

the *Anschluss* of Austria by Nazi Germany occurred. As a result, Frank, who was of Jewish descent and held Austrian citizenship, found himself stateless and unemployed (Holton 1993; 2006; Holton *et al*. 1968).

Facing financial difficulties and lacking a visa to secure permanent residency in the United States, Philipp Frank got a position at Harvard University in September 1939 (Holton 1993; 2006). Among his initial courses at Harvard was one titled *Contemporary Physics and Its Philosophy. A Philosophical Interpretation*. Frank also taught subjects such as radioactivity, thermodynamics, and philosophy of science (Holton 2006). Throughout his life, Frank remained an active organizer and advocate for events fostering interdisciplinary dialogue between science and philosophy. His former students and colleagues characterized him as charismatic, friendly, and deeply committed to promoting collective dialogue.

Holton (2006), one of Frank's last students, recounts that in 1964, when Frank was in his 80s and bedridden, he refused to eat, seemingly foreseeing his fate. Despite his condition, he humorously reassured his friend not to worry, asserting that death is merely a natural phenomenon (Holton 2006, 307). Philipp Frank passed away in the United States on July 21, 1966, at the age of 82. An incident that reflects Frank's character is described by Holton as follows: at Frank's wake, a stranger appeared who identified himself as the gardener at Harvard University. When asked about his connection to the deceased, the gardener explained that he had frequently encountered Frank on the campus. Frank, regardless of his high status as a professor, would always greet him respectfully by raising his hat. This simple yet profound gesture of respect deeply touched the gardener, who, upon learning of Frank's death, felt compelled to pay his final respects (Holton 2006, 307-308).

These anecdotes are significant not only for illustrating Frank's personality but also for understanding his approach to physics and philosophy. As will be highlighted in the subsequent sections, one of Frank's most prominent epistemological attitudes was his advocacy for dialogue and the establishment of collaborative spaces for debate that fostered interaction among various fields of knowledge. He also championed an antidogmatic perspective. These attitudes, which were evident in his earliest writings, are central to both his contributions to physics and his philosophical outlook.

The Philosophical Attitude of a Young Physicist

One of Frank's early published works, *Kausalgesetz und Erfahrung* (*The Law of Causality and Experience*), delves into a topic that would continue to engage him throughout his career: the relationship between the principle of causality and the evolution of physical theories. Published in 1907, this work evaluates the contributions of two other scholars who, despite arriving at different conclusions, employ similar reasoning to reach their results: Henri Poincaré's *La Science et l'Hypothèse* (*Science and Hypothesis*) and *La Valeur de la Science* (*The Value of Science*), and Hans Driesch's *Naturbegriffe und Naturteile* (*Natural Concepts and Valuable Concepts about Nature*). The central issue addressed is whether fundamental principles of physics, such as the conservation of energy, inertia, and causality, are products of convention, a matter of habitual usage as Poincaré suggests, or whether they are a priori principles as argued by Driesch. At the outset of his text, Frank articulates his stance: "The thesis that we shall try to prove states that the law of causality, the foundation of every theoretical science, can be neither confirmed nor disproved by experience; not, however, because it is a truth known a priori, but because it is a purely conventional definition." (Frank 1941, 18).

By the laws of causality, we refer to the principle that "*if state A of the universe is followed by state B over time, then whenever A occurs, B will follow*" (Frank 1941, 18). Frank argues that this definition of causality is problematic because it presupposes knowledge of the entire universe's state, which is not feasible, nor can we guarantee that state A will recur. Nonetheless, Frank asserts that the law of causality employed in scientific practice is not precisely this universal form but rather: "[...] in a finite region of space, the state A is once followed by the state B and another time by the state C, we can make the region sufficiently large by adding to it its environment so that the state C becomes as close to the state B as we please." (Frank 1941, 19).

The ability to mathematically approximate something – whether large or small as needed – is a key feature of differential and integral calculus. This capability is frequently used in physics to establish causal relationships between phenomena, often based on criteria of convenience or alignment with a particular law or theory. In relation to this, Frank continues: "From our standpoint it is easy to answer that the nature which the human mind rationalizes by means of theoretical science is not at all the nature which we know through our senses. The law of causality and with it all of theoretical science have as their object not empirical nature but the fictitious nature of which we spoke above." (Frank 1941, 24).

According to Frank, providing unequivocal answers to fundamental questions of science – whether theoretical or experimental – is inherently impossible. This impossibility does not arise from a limitation of human intellect but rather from the inherently dynamic nature of knowledge production, where changes in conceptions, definitions, concepts, laws, and theories are integral to the progression of scientific understanding. Additionally, Frank highlights what he terms the fictitious[5] nature of natural science. Echoing the views of his former supervisor, Frank argued that scientific theories are not reflections of any inherent essence but are constructions of the human intellect. This perspective aligns with Frank's understanding of conventionalism, which is also influenced by his second intellectual mentor, Ernst Mach. Mach emphasized the historical and habitual aspects involved in the development and consolidation of scientific theories (Mach 1906; Videira 2009; Miguel and Videira 2008).

Based on a lecture delivered in December 1907 at the Philosophical Society of the University of Vienna (*Philosophischen Gesellschaft an der Universität zu Wien*), Frank published the article *Mechanismus oder Vitalismus? Versuch einer präzisen Formulierung der Fragestellung* (1908a, *Mechanism or Vitalism? An Attempt at a Precise Formulation of the Question*) the following year. In this article, Frank demonstrates not only a profound understanding of philosophical knowledge but also an engagement with the contemporary debates within this field, particularly those that intersect with physics. As the title suggests, in *Mechanismus oder Vitalismus?*, Frank examines the controversy – one he believes is inadequately framed – between the two philosophical perspectives of mechanism and vitalism. He begins his discussion with the following statement:

> The philosophical society has always been the place where representatives of the most diverse fields of knowledge came together to discuss borderline issues of their sciences. As a result, misunderstandings that inevitably arose from the separate operation of the individual disciplines were often destroyed or at least attempted to be destroyed with varying degrees of success. One such borderline issue between the fields of physics, chemistry, biology and philosophy should also concern us today, the question of whether or not the phenomena of animal and plant life, growth, reproduction etc. can be explained according to the laws that prevail in inanimate nature, a question that is usually summarized in the catchphrase: "Mechanism or vitalism?". (Frank 1908a, 393, authors' translation)

From this quotation, it is evident that Frank highly valued forums such as the Philosophical Society, as he believed that collective spaces and debates were crucial for addressing and potentially resolving many of the problems that inevitably arise within the

[5] For more on the use of fictional models in science, cf. Morrison 2014; Cartwright 1983.

scientific domain. Frank also highlighted how the separation or fragmentation between fields of knowledge, which became increasingly pronounced at the turn of the 19th century (Cassirer 1956; 1979; 2011; Chevalley 1994; Coen 2007; Gingras 2001; Hiebert 2000; Janik and Toulmin 1991; Kojevnikov 2020; Romizi 2011; Schnädelbach 2001; Videira 2011), contributed to misunderstandings and unfounded acceptance of certain theories. One such issue, as Frank pointed out, was the uncritical reception of specific philosophical positions such as mechanism and vitalism. The common query in this debate, "Can the phenomena of life be explained physically and chemically or not?" (Frank 1908a, 393), was often used but lacked clarity regarding what "physical-chemical explanations" actually entailed. Frank criticized this notion, suggesting that it was used arbitrarily and conveniently, and traced its origins to inadequately physics textbooks. He cautioned against the risks of formulating biological concepts, laws, and theses based on a problematic and interpretatively flawed understanding of physics. Moreover, Frank warned against the misconception that physics, as a discipline, was free from contradictions or had an unassailable foundation that could be applied unquestioningly to other areas. He emphasized the danger of such a view and pointed out that even physicists sometimes uncritically adopted biological theses[6], which he considered a hazardous practice (Frank 1908a, 394).

In Frank's view, the uncritical acceptance of certain concepts, reliance on poorly written textbooks, and the mistaken belief that physics should serve as a model for all other fields were central issues in the mechanism versus vitalism debate. According to Frank, disciplines such as biology, physics, and philosophy should be considered on equal footing, each capable of generating its own theories. This perspective does not preclude dialogue and exchange between different areas of knowledge; rather, it underscores the importance of maintaining rigorous and critical standards within each discipline. While strictly at the level of reason (the first level), science may initially seem unfeasible (Frank 1909, 394). Despite Mach's significant influence on Frank, the latter's willingness to critically engage with Mach's work highlights the open and debate-friendly atmosphere prevalent among natural scientists and philosophers in early 20th-century Vienna. This environment, characterized by robust and respectful discussion, was a hallmark of the intellectual community in the Austrian capital during that period.

Based on the publication of his article on vitalism, Frank discusses the thinking of Driesch, a defender of this concept. Frank compares the ideas of the German biologist (and his vitalist peers) with those defended by mechanists. Although it is not the focus of this article to reproduce the mechanism-vitalism clash, by presenting Driesch's ideas, Frank allows us to better understand his conception of realism and, especially, his position in relation to another important clash of the time, namely materialism vs. idealism:

> Driesch's starting point is the well-known idealistic basic statement, which says in its most concise form: "The world is my representation [*Vorstellung*]. There is nothing real but my sensations [*Empfindungen*]. The reflective understanding [*Verstand*] will soon draw the further conclusion that, in the most immediate sense, what is real is no longer the impressions I had a second ago, but that what is immediately real for me consists only in the content of consciousness that I have right now. If one wishes, one can now immediately begin to argue whether this real is the only real or not; what is certain is that we can distinguish this reality in the narrowest sense from everything else that can be called real. We call it, with Driesch, the real of the first level or the directly real. The whole reality of the first level is of course immensely meager and devoid of

[6] Although Frank does not provide specific examples, he mentions this in the context of discussing the adoption of the term "physicochemical explanations" in biology, as a way to account for any form of relationship between living organisms (Frank 1909, 394).

> content, but the reflective understanding [*Verstand*] can form [*bilden*] and understand [*verstehen*] this concept. (Frank 1908a, 395, authors' translation)

After outlining Driesch's conception of reality, Frank questioned its sustainability. He pointed out that the "concept of reality in the first stage is not that of everyday life," explaining that, in practical terms, he might assert, for instance, that people he knows but do not see at the moment exist just as much as those he can see (Frank 1908a, 395). While Frank did not entirely dismiss Driesch's view, he framed it as one among various alternative conceptions of realism. He proposed what he termed "second-level real" or "practically real," which he described as "[...] sensations that I do not currently have but which I can, if I choose, transform into first-level realities. [...] This awareness of the ability to convert a sensation into something directly real extends the concept of reality beyond total space" (Frank 1908a, 396).

In his exploration of the relationship between memory, the concept of a thing, and sensations, Frank sought to avoid hierarchizing idealism and materialism. He argued that "only properties are real in the sense of the first stage; but the thing is also real in the sense of the second stage, because part of the definition of the second stage is that it arises from the first by the addition of the concept of thing" (Frank 1908a, 396). By this, Frank emphasized that adopting an idealist or materialist conception is not mutually exclusive. Instead, both perspectives can coexist and engage in dialogue. This dialogical relationship is evident in the development of science itself. While strictly at the level of reason (the first level), science may initially seem unfeasible, at the level of things (the second level), it is possible to construct a purely descriptive science, such as zoology, anatomy, and experimental physics (Frank 1908a). Through reason, we generate concepts and, using these concepts, identify regularities in natural phenomena. In other words, it is a challenge to discuss a concept without a corresponding thing, or a thing without a concept, no matter how circular the reasoning might appear.

However, even these regularities are not permanently established; they are inherently provisional and subject to change. According to Frank, these changes reflect the very heterogeneity of nature, as the same concept might be approached differently depending on its context of application. In establishing regularities, whether chemical or physical, we may employ concepts that are not immediately evident, such as electric charge (Frank 1908a, 399). Thus, if physics does not always appear to be a domain of absolute uniformity, it is because it relies on the creation of concepts that facilitate the establishment of such regularities. Concepts like electric charge, while not immediately given, are fundamental to understanding phenomena such as electrification processes, and are therefore as real as the phenomena they help to describe.

Frank introduced the concept of a third level of reality, or third stage, which functions as a bridge between quantitative and qualitative aspects. He termed this integrative element "rational natural science." According to Frank, natural science serves as the mechanism that connects both purely descriptive elements and those derived from reason. Consequently, natural science does not entail choosing between idealism and materialism, or between vitalism and mechanism. Instead, it allows for the exploration of different, and sometimes seemingly contradictory, conceptions. In the scientific domain, transitioning between these viewpoints may be necessary. Each conception holds validity and possesses its own advantages and disadvantages. The scientific field should not be one where certain theories are outright rejected without consideration. Rather, it should be a space where every conception is given fair consideration and debate, acknowledging that while one perspective may ultimately prove insufficient, each holds potential value in principle:

> There is a widespread fear that any concession made to the vitalist view is a concession to anti-scientific currents. I, on the other hand, believe that any approach to

> dogmatism of any kind weakens the position of science, but that unprejudiced thinking and research is the ground on which science stands unconquerable. It is not wise to ignore the vitalist theories and leave their development to the enemy; these positions could one day become important; it is therefore important for science to take possession of them today so as not to offer the enemy any opportunity to take shelter. (Frank 1908a, 409, authors' translation)

The Production of Reviews as a Means for Philosophical Debate

Between 1909 and 1914, Frank published numerous reviews that, despite their brevity, reflect his concerns and positions over the years. Noteworthy among these published reviews are: *Die Einheit des physikalischen Weltbildes* (1908b); *Die Theorie der Physik bei den modernen Physikern* (1909); *Der Phänomenalismus* (1913a); and *Letzte Gedanken* (1913b). As previously mentioned, Frank's academic bibliography excludes all reviews he wrote (Frank, 1908b; 1909; 1913a; 1913b; Planck, 1944; Kleinpeter, 1913). At first glance, this decision appears reasonable, given that full articles are now typically valued more highly than reviews. However, this was not necessarily the case in the early 20th century. The journal *Die Naturwissenschaften* frequently featured prominent figures of the time, including Max Planck, Arnold Sommerfeld, Albert Einstein, Franz Exner, Hans Hahn, and Moritz Schlick, among others. Frank also contributed a series of articles to this journal. Notably, *Die Naturwissenschaften* promoted an interdisciplinary and non-specialized approach and was divided between original works and reviews of books and articles (Stöltzner 2003). Despite this division, reviews were not considered less important. In addition to being pedagogical, reviews served as a means of disseminating contemporary research across various fields, functioning as an informal forum for debate. Through these reviews, scientists could critically engage with the intellectual output of their peers.

Another significant aspect lost by omitting the reviews from Frank's bibliography is the weakening of his interest in philosophy. With the formation of the Vienna Circle, the rise of logical positivism, and the organization of the journal *Erkenntnis*[7], the Austrian physicist-philosopher produced a substantial corpus of philosophical work. However, his philosophical interest did not begin with the Vienna Circle (or the Ernst Mach Society[8]); it was present from the very start of his academic career. The reviews, therefore, provide valuable insights into this enduring interest in philosophy.

In the early stages of his professional career, a significant portion of Frank's published articles were dedicated to physics. This focus can be explained by the need to establish his reputation and secure employment. However, his reviews concentrated on central philosophical issues, such as the realism of physical theories, the relationship between subject and object, and the role of the absolute in knowledge. Examining these reviews, one might wonder that their publication was part of a strategy Frank adopted to gain recognition not only as an intellectual but also as a natural scientist. His approach as a reviewer indicates an awareness of the importance of philosophy for his professional trajectory within Austrian academia. The deliberate omission of the reviews from the organized bibliography not only leaves a gap in Frank's intellectual production but also inaccurately shifts the "awakening"

[7] The journal *Erkenntnis*, founded in 1930 and with Frank as one of its editors and organizers, was one of the results of the Vienna Circle. The journal covered a range of topics, such as epistemology, philosophy of physics, mathematics, logic, language, etc. (Stadler 1993).

[8] The Ernst Mach Society (Verein Ernst Mach) was the group that gave rise to the Vienna Circle. Its members included Moritz Schlick, Rudolf Carnap, Otto Neurath and Philipp Frank himself. In addition to debates on physics, philosophy, history, etc., the Ernst Mach Society also had a school for adults and functioned as a civic movement, advocating broad educational reform in Austria (Stadler 1993).

of his philosophical interest to later years, specifically to the 1920s. This period was indeed crucial for the organization and formalization of the Vienna Circle, but the omission suggests a mistaken understanding of the timeline of Frank's philosophical engagement.

In *Die Einheit des Physikalischen Weltbildes* (1908b), Frank analyzed how Planck explained the removal of anthropomorphism in physics and critiqued Mach, whom Planck held responsible for reintroducing subjective elements into the field. To support this point, Frank used a quote from Planck:

> When we are in a position finally to answer them, we shall also be in a position to consider the broader question, much discussed to-day [*sic*], as to what is the fundamental meaning of the so-called physical universe to us. Is it merely a practical, though fundamentally arbitrary, creation of our imagination, or are we forced to the opposite conception that it reflects real natural phenomena independent of us? (Planck 1960, 2)[9]

This inquiry emerged within a context in which Planck was reconstructing the process by which the unification of physics occurred. We can also observe Planck's concern with the realism and objectivity of physical concepts – whether they exist independently of us or are constructs of our minds, a strategy by which we interpret nature. Regarding these questions, Frank asserts that if science critiques the dogmatization of concepts such as God, freedom, and immortality, science cannot avoid discussions on the reality of atoms and electrons. This does not imply that we should not believe in the existence of the "objects" designated by these concepts, but rather that we should not confuse them with essences (cf. Frank 1909, 47).

When we compare Planck's attitude with Frank's, a notable difference emerges: while Planck stressed the need of unification of all physical theories, Frank was more open to the coexistence of multiple theories (pluralism), without necessarily advocating for the reduction of all theories to a single conception. Faced with the choice posed by Planck – between a mental image and the objectivity of nature – Frank argued that the very formulation of this dilemma was inadequate, as the two concepts are not mutually exclusive. According to Frank, when Mach referred to mental images, he was not denying the objectivity of nature; rather, Mach was suggesting that the correlations made and the forms assigned by humans to the laws of nature are arbitrary. Frank defended the use of mental images, asserting that, if Planck's notion were strictly adopted in physics, there would be numerous examples of mechanical models which, like Maxwell's, do not "agree with reality" but are nonetheless significant in a creative sense as they facilitate the construction of theories[10]. Another important point made by Frank is that we are unable to believe in something without being convinced of its reality, and this belief does not contradict the provisional nature of scientific theories (Frank 1909). This perspective underscores a strong correlation between the development of physical theories and our worldviews. In essence, Frank seems to be asserting that the free thinking and creativity necessary for developing theories cannot be exercised without the influence of worldviews.

[9] The quote used is the translation made by R. Jones and D. H. Williams, present in the book *A Survey of Physical Theory* (1960). However, the translation does not reproduce exactly what Planck says in the original. There are some changes and omissions of terms that were dear to the German physicist. In free translation directly from the original, this quote is: "What does what we call the physical view of the world [*physikalische Weltbild*] really mean to us? Is it just a convenient but essentially arbitrary creation of our spirit [*Geist*], or are we led to the opposite view, that it reflects real natural processes that are completely independent of us?"

[10] On the Maxwellian conception of models, see Puig and Videira 2017.

In *Die Theorie der Physik bei den Modernen Physikern* (1909), Frank discussed Abel Rey's analysis of the notion of objectivity in physics and the impact of conceptual changes on theoretical physics. For several decades, Newtonian mechanicism was essential for understanding any theory, but by the mid-1880s, this approach began to face significant challenges. Rey noted that the primary and most severe criticisms of mechanistic physics came from mathematics and mathematical physics. Consequently, the notion of objectivity underwent a transformation: whereas a mechanical and visualizable theory (*anschauliche*) was once synonymous with comprehensibility, these conditions eventually became insufficient. There emerged a growing demand for the mathematization[11] of physics, which would ensure the objectivity and intelligibility of theories. Despite this shift, a substantial portion of the physics community, both theoretical and experimental, remained loyal to the prevailing tradition, continuing to incorporate elements traditionally associated with mechanism into the core of their theories.

After addressing the main topics of Rey's book, Frank emphasized the need for collective work in frontier areas. By "collective work," he referred not to collaboration within different branches of the same discipline (such as electromagnetism, radiation, and thermodynamics within physics), but rather to interdisciplinary collaboration across different fields of knowledge. He cited figures like Descartes, Leibniz, and Kant, who made significant contributions beyond their primary areas of expertise, as exemplars of this approach (Frank 1909, 45).

By emphasizing how physics and philosophy can form a powerful alliance when they work together, Frank underscored the value of interdisciplinary collaboration. During the early 20th century, when this review was published, there was a pronounced specialization and fragmentation within academic disciplines – an evolving process that had been consolidating since the early 19th century. Until the end of the 18th century, physics and philosophy were considered closely intertwined, but a significant divide emerged between them in the subsequent decades (Videira 2011). Frank's argument highlights another crucial aspect of his perspective: the importance of dialogue. His advocacy for collaboration[12] between physics and philosophy and his recognition of how influential figures like Abel Rey, Descartes, Leibniz, and Kant made contributions across disciplinary boundaries illustrate his strong commitment to interdisciplinary discourse. This emphasis on collaborative work and dialogue was evident from the beginning of Frank's career. In his review, written during a politically and socially tumultuous period in Austria[13] Frank's central message is the significance of collective and cooperative effort in addressing complex problems.

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[11] The French-Canadian historian Yves Gingras (2001) provides an insightful analysis of how the process of mathematization transformed physics. According to Gingras, this transformation began with Newton's publication of *Philosophiae Naturalis Principia Mathematica*, in which the physical content is extensively geometrized. Gingras notes that Newton's formulations were initially met with resistance from both the physics and philosophy communities of the time. Prominent figures such as Gottfried Leibniz and George Berkeley criticized Newton's ideas, arguing that while they were mathematically correct, they were philosophically false. Despite the initial poor reception of the *Principia*, Gingras discusses how the scenario evolved over time. He explains how Newtonian physics eventually facilitated the rise of mathematical physics, leading to the perception of a mathematized theory as synonymous with explanation, comprehensibility, and objectivity (Gingras 2001).

[12] On this point, we would like to thank the referee for highlighting that this sentiment was widespread at the time. It is well known that Frank was also influenced by the ideas of the French physicist and historian of science Pierre Duhem, a figure frequently referenced in his writings (Frank 1941). For more details on Duhem's work and thinking, see Duhem 2014.

[13] The late 19th and early 20th centuries were a turbulent period for the former Austro-Hungarian Empire. Following a series of liberal reforms aimed at industrializing the country – similar to developments in neighboring Germany – there was a significant migration to Vienna. Many of the

In *Der Phänomenalismus* (1913a), Frank revisited the themes of realism, universalism, and the objectivity of physical theories, but approached them from a different point of view, influenced heavily by positivism – a view prevalent in the Austria *millieu* in natural sciences and significantly shaped by Mach. According to this perspective, the goal of science is to construct knowledge devoid of any subjectivity, relying solely on what can be verified through observation. This approach seeks to eliminate all elements governed by "our" will, including the realm of representations (*Vorstellungen*) and thought (*Gedanken*) (Frank 1913a, 46-47).

In the Austrian context of that era, the concept of representation (*Vorstellung*) was heavily influenced by Mach. For Mach, the objective of constructing a worldview (*Weltbild*[14]) was: "[...] to simplify and systematize experience in such a way that we could deal with it more easily" (Janik and Toulmin 1991, 151). Further elaborating on this influence, Janik and Toulmin (1991) note that, for Mach, descriptions formulated through mathematics aimed to simplify and organize natural phenomena in an economical manner. Consequently, it was less meaningful to discuss theories as true or false, and more pertinent to assess them as more or less adequate descriptions (Puig and Videira 2017).

Mach's notion of representation was central to addressing these issues, though it is important to note that his views did not constitute a universal consensus within Austria. With this in mind, let us return to Frank:

> Science now consists of building a system in this world of thought with the help of which we can control the world of sensations as simply and reliably as possible, i.e.

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poorer populations from rural areas flocked to the capital in search of work. This influx contributed to a growing number of unemployed, which in turn led to increased poverty, urban violence, housing inflation, and other socio-economic issues. In addition, these reforms also sparked political turmoil: the empire, largely dominated by a conservative, nationalist, and religious (and increasingly anti-Semitic) right wing, attributed the crisis to the liberal policies previously implemented. On the other side, the left wing – composed of social democrats and socialists – was primarily organized in support of the separation of church and state. This ideological divide contributed to further instability within the Austro-Hungarian Empire during this period. For more information on the political and social crisis that plagued the Austro-Hungarian Empire at the beginning of the 20th century, cf. Jungnickel and McCormmach 1986; Janik and Toulmin 1991; Coen 2007.

[14] According to Mittelstraß, "Weltbild refers to an intuitive model of the world that objectifies knowledge. In contrast to terms like *Lifeworld* (*Lebenswelt*) or *Weltanschauung* (worldview), *Weltbild* signifies the intuitive synthesis of the findings of a specific science (scientification) and is framed in relation to knowledge that has expanded into a broader worldview, such as a scientific-physical (causal-mechanistic), biological, sociological, or historical perspective. Different worldviews (*Weltbilder*) often compete in terms of content (diversity of worldviews) and can only be fully understood in their limited validity through philosophical reflection on the constitution of the worldview (*Weltbild*)" (Mittelstraß 1996, 654, authors's translation). However, Zoehrer identifies at least three definitions of *Weltbild* "In a broader sense, the term Weltbild refers to a unified conception of the 'world', which seeks to define the entire world from a comprehensive perspective. Worldviews can encompass transcendental images, images of humanity, and images of nature, offering broad explanatory models for the origin, structure, and development of the cosmos, the emergence and evolution of life, the role of human beings in the world and society, and the trajectory of human history" (Zoehrer 2016, 5, authors's translation). The second possible definition of *Weltbild* can be understood "[...] in a narrower scientific sense, where a worldview refers to an image of nature shaped by the subject matter, criteria, and principles of the natural sciences" (Zoehrer 2016, 5, authors's translation). Finally, the third definition is "[...] specific to astrophysics [and] understands the 'universe', i.e., the totality of all 'things' in the macroscopic realm, through empirical and theoretical methods. However, unlike earlier cosmologies – such as those from Greek antiquity or the Christian Middle Ages – this view does not attribute a normative quality to the cosmos (Gr. κόσμος, meaning order of the world)" (Zoehrer 2016, 6, authors' translation).

> predict future sensations from past ones. A great deal of arbitrariness is possible in the construction of such a system; every system of thought with the help of which we can correctly predict is "true". So there is no absolute truth, only relative truths that are more or less useful. (Frank 1913, 47, authors's translation)

There is a notable convergence between Mach's conception and the idea highlighted by Frank, as discussed in Hans Kleinpeter's book *Der Phänomenalismus. Eine naturwissenschaftliche Weltanschauung* (1913). Both perspectives reject the notion of absolute truth and instead advocate for science to construct systems that organize sensory data in the simplest and most coherent manner possible (cf. Frank 1913, 47). Since the existence of an absolute truth cannot be assured, Frank, in contrast to Planck's emphasis on unity, underscored the historical nature of physical concepts. Frank achieved this by characterizing scientific representations as "relative truths." This approach aligns with Mach's arguments presented in his influential work *The Science of Mechanics. A Critical and Historical Description of Its Development* (1897) (*Die Mechanik in ihrer Entwickelung Historisch-Kritisch Dargestellt*). Mach's work aimed to demonstrate through historical analysis that concepts once deemed absolute – such as time and space – were in fact contingent upon specific historical and conventional factors, including the considerable influence of theology on Newtonian thought (Mach 1897; Janik and Toulmin 1991). In essence, the formulation, establishment, and interpretation of physical concepts were influenced by factors beyond the scope of science itself. Recognizing this aspect is not only enlightening, as it allows for an understanding of the historicity of knowledge, but it also helps prevent the dogmatization of physical and philosophical concepts and systems.

Although brief, Frank's review of *Letzte Gedanken* (1913b) (*Dernières Pensées*) presents Poincaré's work as both a lucid exposition of the French mathematician's conception of conventionalism and a valuable corrective to the excessive verbiage surrounding the subject, which often raises more doubts and pseudo-problems than genuine contributions (Frank 1913b, 54). As discussed in his review of Planck's article (1908b), Frank interprets Poincaré's conventionalism as the view that the way we organize our experiences and develop our interpretations is merely a matter of convention, and therefore can be represented in various ways. In this framework, a representation does not hold intrinsic value in terms of being true or false, but rather can be evaluated based on its adequacy – whether it is more or less suitable for a given context or purpose (Frank 1908b, 46). Once again, Frank demonstrates his appreciation for conventionalism as articulated by Poincaré, particularly valuing Poincaré's integration of historical analysis into the examination of scientific theories. Moreover, another crucial aspect of Poincaré's philosophy that Frank highlights is his commitment to: "[...] establish, soberly and without prejudice, what science and morality have to do with each other. It is infinitely comforting to find a presentation that simply considers things as they are, in a field where traditionally there is more impulse than clarity." (Frank 19013, 55, authors' translation).

However, Frank does not provide further details about the relationship between science and morality, his mere acknowledgment of this relationship underscores the significance he placed on the discussion of their interconnections. In the Vienna of the early 20th century, just before the outbreak of the First World War, advocating for an honest discourse on the relationship between science and morality – an issue that can also be interpreted as the interplay between science and worldviews (cf. Videira and Videira 2001, 163-173; Videira 2013) – is notably significant. This emphasis on dialogue and the exchange of ideas highlights Frank's commitment to intellectual engagement and debate at a time marked by social fragmentation and overt violence.[15]

[15] See note 13.

Conclusions

From the preceding discussion, several key ideas emerge that are fundamental to understanding Frank's personality as well as his physical-philosophical attitude. Foremost among these is his advocacy for candid and open dialogue within academic settings. While this might appear to be a straightforward or self-evident principle, its significance cannot be understated, especially when considered within the context of the development of Austrian physics in the early 20th century.

Amid the social, political, and economic challenges that beset the Habsburg Empire, and considering the structural[16] and organizational issues at the Institute of Physics at the University of Vienna, a notable tradition emerged within the Viennese physics community. According to Stöltzner (2003), this tradition, referred to as "Viennese Indeterminism" or "Vienna Indeterminism[17]", represented a tendency or openness within the Austrian physics community towards incorporating indeterministic concepts into physical theories. This characteristic is evident in Frank, as well as in his mentors, such as Boltzmann and Mach. However, it is important to note that indeterminism is not the sole or even the principal characteristic of this tradition, as Stöltzner (2003) may suggest. Other elements of the Austrian cultural tradition played a more significant role, as will be discussed further.

As we have observed, Frank's philosophical inclination was not a phenomenon that emerged or solidified only in the 1920s with the establishment of the Vienna Circle. Instead, it was an interest that had been present since his student years. Frank himself attests to this ongoing interest in an interview (1962) with Thomas Kuhn:

> All the physicists in Vienna were interested in the philosophy of science. Hence, if there was anything connected with philosophy of science [such as the status of statistical laws] it would be widely discussed. Admittedly, Franz Exner was not well known for his interest or publications in philosophy of science, but in this matter he did clearly lead the way. Exner was an experimental physicist who usually left philosophical matters to Mach and Boltzmann who was the theoretical physicist. [But after Boltzmann's death, Exner took it upon himself not to let Boltzmann's concern with statistical laws die.] (In Blackmore 2001, 62)

We can observe that the philosophical *millieu* in Vienna was not merely a particular interest on figures like Boltzmann, Mach, and Exner, but rather a fundamental aspect of academic training in physics, especially theoretical physics. But how was this training structured? Unlike the German model, which was often rigid and unidirectional – characterized by formal academic rules for discussion or disagreement with professors and a prescribed physical-philosophical agenda heavily influenced by (neo)Kantianism (Stöltzner 2003; Jungnickel and McCormmach 1986) – the situation in Vienna was notably different.

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[16] For more information on the Institute of Physics at the University of Vienna, see Jungnickel and McCormmach 1986.

[17] According to Stöltzner (2003), a prevalent conception among Viennese physicists was that indeterminism not only held mathematical and/or probabilistic significance but could also serve as a stable foundation for formulating scientific theories. Importantly, indeterminism was not a direct opposition to determinism. Instead, determinism and indeterminism were seen as complementary concepts. In the same way, acausality was considered just as valid for constructing scientific theories as causality (Stöltzner 2003; Wegener 2010), with causality holding aprioristic value primarily due to historically acquired habits (Videira 2011; 2012; Blackmore 1995a; 1995b). In this regard, long before the development of quantum mechanics, probabilistic ideas were already well accepted among Austrian physicists, who contemplated the possibility that what we consider causal may simply be a higher frequency of interactions that, at a microscopic level, are acausal (Stöltzner 2003).

In Vienna, (neo)Kantianism did not exert the same influence it had in Germany and was not well received by physicists like Boltzmann (1905; 2004). Instead, one of the core elements of physics education in Vienna was an anti-dogmatic stance and a pluralistic attitude. Although individual physicists had their personal preferences – such as Frank's early alignment with logical positivism – this did not entail an automatic rejection or opposition to other schools of thought. This openness is evident in Frank's article on mechanicism and vitalism. Despite his clear preference for mechanism, Frank defended the right of vitalists to advocate for their theses and emphasized the importance of discussing these ideas, with appropriate respect and rigor, within the academic sphere.

Frank's antidogmatic and pluralistic attitude is evident in his article *Kausalgesetz und Erfahrung*. His critique of Kantianism – particularly Kant's notion of causality as an a priori condition for constructing knowledge – and his later criticisms of Planck on this issue, stem not from a strict preference for indeterminism but from the recognition that both causality and acausality are valid and not mutually exclusive conceptions. While physics often favors mechanistic determinism, this preference arises from a matter of familiarity and the adoption of inherited ideas, as highlighted in the discussion of Poincaré's conventionalism (Frank 1907).

Conventionalism, particularly how we inherit and naturalize certain ideas, is a central theme in the works of Mach (1897) and Boltzmann (1905; 2004), both of whom had a significant impact on Frank. This conception, which permeates all the articles and reviews discussed, is intrinsically linked to Frank's antidogmatic belief. By recognizing that concepts, systems, and notions we often regard as indispensable or even essential become so due to their familiarity – through prolonged and repeated use –, Frank aimed to introduce another crucial element into the physical-philosophical discourse of his time: the historicity of concepts. This perspective underscores the notion that our acceptance of certain ideas is not purely based on their intrinsic validity but is influenced by their historical and cultural evolution.

Causality, determinism, conservation of energy, and mass are concepts that are historically situated and therefore susceptible to influences from non-epistemic elements of their time. For instance, to fully understand Newton's mechanistic determinism, it is crucial to analyze its development within a period heavily shaped by Christian thought, as well as its evolution and consolidation over time. Physical concepts not only possess a history and are subject to prevailing worldviews, ethical, and moral values, but they also change over time (cf. Frank 1907, 444; 1913a, 54). What was once considered comprehensible or true, such as Newtonian physics – which was initially deemed "mathematically correct but philosophically false" – eventually came to be regarded as fundamental truths about nature throughout the 18th and 19th centuries (Gingras 2001). For Frank, the discourse on causality and acausality exemplifies this situation. The use of causal notions as conditions for physical theories is often more a matter of tradition and familiarity – grounded in the successful results they have produced over time – rather than an absolute necessity. This view opens the possibility for constructing equally robust physical theories from alternative perspectives.

Finally, an analysis of Frank's bibliographical production from his formative years up to the end of the Belle Époque reveals a young scientist and intellectual deeply concerned with the impact of disciplinary choices on academic dialogue. Despite the fragmentation between different areas of knowledge, Frank saw a positive and transformative potential within the natural sciences. While professional philosophy, or the philosophy of thought choices, might appear riddled with irreconcilable internal divisions, Frank believed that the natural sciences could serve as a bridge for dialogue and cross-disciplinary collaboration. For Frank, concepts such as materialism, idealism, causality, acausality, vitalism, and mechanism, though seemingly antagonistic within philosophy, should not be so within the natural sciences. In his view, the true potential of the natural sciences lay in their ability to foster an environment of engagement and cooperation, where the apparent boundaries – often enforced and desired by specialists – could be overcome.

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