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Introduction to the special issue Hermann Weyl and the philosophy of the 'New Physics'

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ABSTRACT

This Special Issue *Hermann Weyl and the Philosophy of the 'New Physics'* has two main objectives: first, to shed fresh light on the relevance of Weyl's work for modern physics and, second, to evaluate the importance of Weyl's work and ideas for contemporary philosophy of physics. Regarding the first objective, this Special Issue emphasizes aspects of Weyl's work (e.g. his work on spinors in n dimensions) whose importance has recently been emerging in research fields across both mathematical and experimental physics, as well as in the history and philosophy of physics. Regarding the second objective, this Special Issue addresses the relevance of Weyl's ideas regarding important open problems in the philosophy of physics, such as the problem of characterizing *scientific objectivity* and the problem of providing a satisfactory interpretation of fundamental symmetries in gauge theories and quantum mechanics. In this Introduction, we sketch the state of the art in Weyl studies and we summarize the content of the contributions to the present volume.

1. 100 years of Weyl's physics

One hundred years ago, in 1917, students of the ETH in Zurich could attend Hermann Weyl's lectures on his original presentation and novel interpretation of general relativity. The set of lectures given at the ETH constituted the bulk of his masterpiece *Raum-Zeit-Materie* published in 1918. This work was a source of inspiration and controversy in the period immediately following its publication, and it became later a fundamental contribution to the debates on unified field theory and the elaboration of gauge theory. However, it would not do justice to Weyl's *Raum-Zeit-Materie* to classify it as a mere technical discussion of relativity theory or as a novel interpretation of the formalism (Ehlers, 1988). The book contained an *Introduction* that merged mathematics, physics, and philosophy in an insightful and unexpected manner. Weyl tried to interpret, through the philosophy of his time, and in particularly Husserl's phenomenology (Feist, 2002, 2004a, 2004b; Kerszberg, 2007), key questions posed by Einstein's new physics: *what is a physical object? What is space? What is time? What is matter?* He tried to show how epistemology and physics go hand in hand in the new theory and how philosophy helps in clarifying the physical meaning of mathematical objects. He also addressed the problem of characterizing the different relevant operations in the formation of a scientific theory and in its systematic organization. In the present Special Issue we aim at emphasizing Weyl's approach in mixing scientific work with philosophical reflection, an approach that provides an important guideline for the interpretation and the reconstruction of his theoretical work.

This Special Issue contains contributions that explore a wide range of topics, from mathematical physics to philosophy, that Weyl's works touched and deepened throughout the years. It also considers the direct and indirect contributions that Weyl made to the history of modern physics and its debates, in order to offer an enriched picture of his legacy and work. The idea of this Special Issue arose in 2015 soon after the conference *Weyl and the Philosophy of the 'New Physics'* that we organized at the University Paris Diderot (10–11 December 2014) with the support of the ERC Grant *Philosophy of Canonical Quantum Gravity* (led by G. Catren) and the Evert Wilhelm Beth Foundation. By fostering interactions between historians and philosophers of science, we invited Weyl scholars to

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discuss both Weyl's contributions to physics and the philosophical underpinnings of his work. This Special Issue gathers some of the scholars that participated to this conference (like E. Scholz, N. Sieroka, and J. Bernard) and researchers, like I. Toader, addressing subjects not discussed in the conference.

Fundamental scientific concepts such as *gauge invariance* and *symmetry* – as well as philosophical concepts like *theoretical* or *symbolic construction* (see Tieszen, 2000; Toader, 2011) – are naturally linked to Weyl's name.[1] In what follows, we shall briefly recall the most relevant of Weyl's concepts that influenced the history of modern physics, and then highlight which philosophical aspects characterized Weyl's approach to the foundations of physics and which contributions still constitute a valuable legacy for the philosophy of physics. The scope of this Special Issue is indeed to uncover the philosophy of physics emerging in Weyl's work, by spelling out how his methods and models shaped modern physics. On a general note, the literature is now witnessing a revival of Weyl studies. Works by Afriat (2013), Chandrasekharan (1986), Coleman and Korté (2001), Friedman (1995), O'Raifeartaigh and Straumann (2000), Ryckman (2003; 2005), Scholz (2001; 2004; 2005), Sigurdsson (1991; 2001), Straumann (2001), Yang (1986), among others, emphasized Weyl's impact on the history of relativity and of gauge theories, chiefly represented by his seminal 1929 paper *Elektron und Gravitation*, which introduced the notion of tetrad (*vierbein*) in general relativity and the fundamental concept of gauge invariance (*Eichinvarianz*). Weyl's group theoretic approach to quantum mechanics deserves attention both in the history of physics and mathematics (Scholz, 2006), as well as in the philosophy of science and of philosophy of physics (Bueno, 2001; French, 2000; Howard, 1997; Muller & Saunders, 2008). Recent works by Eckes (2011) focuses on Weyl's historically important contributions to mathematics and the epistemological underpinnings of Weyl's work (Eckes, in press). Recent attempts at reconstructing Weyl's writings on the problem of space (Bernard, 2015) emphasize the role played by Weyl's reflection on the Pythagorean nature of the metric as a fundamental step influencing both the history of physics and mathematics from the 1920s onward. In the wake of Scholz (2004), Ryckman (2005), and Mancosu and Ryckman (2002), Bernard also emphasized the relevance of Husserl's philosophy for Weyl's analysis of the problem of space (see also Toader, 2013, 2014;).[2] Furthermore, Bernard (2015) has shown how Weyl's position with respect to phenomenology changed throughout the years.[3]

Regarding the importance of Weyl's example for contemporary philosophy of science, it is worth stressing that Weyl – far from restricting his engagements with philosophy to epistemological reflections – was not afraid to engage with highly ambitious, wide and systematic properly philosophical programs like Husserl's and Fichte's. In the last two decades, philosophical interpretations of Weyl's work have tried to inscribe Weyl's work into two major traditions. The first one endorses a transcendental reading (e.g. Bernard, 2015; Ryckman, 2005), whereas the second one emphasizes a reading of Weyl's work that is sympathetic with structural realism (French, 2000). However, it is immediately clear that Weyl's philosophy of physics and metaphysics escape any reduction to current philosophical positions. Even when one wants to connect his position to the philosophers of his time, one has to recognize the fact that Weyl himself changed his views from one decade to another. Therefore, the analysis of his texts cannot afford not to recognize both the historical development of his work and the different philosophical influences on his reflections throughout his career. This is evident in the case of Husserl's phenomenology, which captures Weyl's attention from 1912 onward and that is so important for his philosophical discussion of infinitesimal geometry in *Raum-Zeit-Materie* (1918). However, as Bernard underlines, the situation again changes in 1923–1924, when Weyl no longer endorses Husserl's phenomenology (see Bernard's contribution to this Special Issue). One can trace a new trend in Weyl's philosophical interests emerging in the mid-1920s, and focused on philosophers like Fichte, Cassirer, and Leibniz (see Röller, 2002; Sieroka, 2007, 2009, 2010, 2012 this volume and; Scholz, 2012). These philosophers captured Weyl's attention and prompted him to analyze the foundations of physics from a new perspective, leading to the publication of his masterpiece *Philosophie der Mathematik und Naturwissenschaft* (1927), a book in which we can also recognize Weyl's particular style of mixing scientific theories and philosophical reflections. Starting his new life in Princeton in 1933, Weyl found new stimuli for his reflections on topology and algebra by interacting with James Waddell Alexander and Oswald Veblen, thereby enriching his notion of *symbolic construction*. The relevance of topology for Weyl grows in the 1940s and culminates in his 1955 argument for the dimensionality of the world (see Weyl, 2013, pp. 203ff.). In a paper entitled *Why is the world four-dimensional?,* presented in Washington D.C. a few months before his death, Weyl gave a very intriguing account of the methodology by means of which we could explain the world dimensionality without appealing to any anthropic principle. Another example is provided by the content of manuscripts dated in between 1944 and 1948 where Weyl developed his thoughts on a link between symbolic construction and the role of topology in constructing scientific theories and explanatory models,[4] as well as on the nature of the Pythagorean metric of the world. Some of these aspects have been discussed in the present Special Issue (see Scholz, Sieroka this volume), but others still remain unexplored and are relevant for the development of our understanding of Weyl's contribution to modern physics.

This volume covers a number of issues that have been partially discussed or even neglected in the literature. It is a matter of fact that the central concepts in Weyl's *corpus* – like the concept of *symbolic construction* – require interpretational strategies developed both at the scientific and philosophical levels. Even if Weyl's view of symbolic construction has already been the object of an extensive literature, the philosophical path that led him to this particular conception of the method of natural science and mathematics is far from being clear. By showing the impact of Leibniz's philosophy on Weyl's characterization of symbolic construction, Sieroka's contribution sheds new light on the genesis of this notion. The importance of Leibniz and Weyl's view of symbolic construction for the debates on the identity of indiscernibles has been partially recalled by Scholz (2012). Sieroka's contribution in this Special Issue spells out other aspects that Weyl borrowed from Leibniz, including his reading of the *principle of continuity* and his

[1] For a recent collection on Weyl's writings on symmetry, including unpublished material discussed by Scholz (this volume), see Weyl (2017).

[2] One of the first studies on Weyl's problem of space is Scheibe (1957). For its development, see Scheibe (1988).

[3] Julien Bernard and Carlos Lobo organized a wonderful conference entitled "Weyl and the Problem of Space" in Konstanz (27–29 May 2015) and are now editing a volume on this topic.

[4] Part of these manuscripts and papers have been recently published in Weyl (2013). Others are stored at the ETH archives in Zurich. For an example, see Scholz (this volume).

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