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Albert Einstein and the History and Philosophy of Science

by Jeroen van Dongen

Michel Janssen; Christoph Lehner (Editors). *The Cambridge Companion to Einstein*. xvi + 562 pp., bibl., index. Cambridge: Cambridge University Press, 2014.

Scholarship that addresses the science and life of Albert Einstein is experiencing a remarkable year in 2015. As in 2005, Einstein is honored by centenary celebrations, this time recognizing the hundredth birthday of the general theory of relativity (1905, Einstein's "miracle year," had produced a less general version of the theory, along with other key ideas, such as the light quantum). Furthermore, Einstein scholarship may celebrate the highly anticipated appearance of *The Cambridge Companion to Einstein*. Here, then, we have good reason to pause and consider what the *Companion* may teach us about what the last ten years have brought and where Einstein scholarship stands today.

The *Companion* proves to be a landmark publication. The editors, Michel Janssen and Christoph Lehner, rightly state in their preface that "physicist" might not be the right category for characterizing Einstein. Encompassing fourteen essays, this volume sets out to present Einstein as a scholar whose work and ideas crossed disciplinary boundaries, some of which were firmly established only during the second half of the twentieth century. Einstein's interests were wide ranging, including the foundations, epistemology, and methodology of physics as well as technology, Zionism, and pacifism. The lion's share of the *Companion*, however, is devoted to Einstein's physics and its relation to his philosophy of science. Ten chapters analyze Einstein's writings on the topics of general and special relativity, the quantum enigma, statistical mechanics, relativistic cosmology, and his attempts at unification theories. Three chapters focus on Einstein's thought in philosophy of science in general. A final chapter discusses Einstein's politics.

The chapters on statistical mechanics and Brownian motion by A. J. Kox and on the light quantum by Olivier Darrigol and Roger Stuewer are fine examples of conceptual history, based on a solid grasp of the physics involved. Kox neatly and convincingly shows that Einstein's work in statistical physics was guided "(1) by a strong belief and (2) by an important insight" (p. 103): his solid belief in atoms and his innovative uses of "fluctuation" methods to buttress his atomism. Indeed, whereas earlier scholars often shunned fluctuations—deviations from the mean in macroscopic quantities owing to the presumed microscopic nature of matter—Einstein explicitly used them to dramatic effect when he calculated the size of atoms,

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684

Avogadro's number, or the random motion of suspended particles ("Brownian motion"). These results, in turn, gave supporting evidence for the atomic hypothesis.

In his contribution on the light quantum, Darrigol sets out to dispel "three persistent myths" (p. 117) that all seem attributable to linear historiography: he wishes to counter notions that Planck, and not Einstein, first developed a full understanding of the physics of the energy quantum; that the initial opposition to Einstein's particle-like light quantum was due to blind conservatism; and, finally, that the Compton scattering of a light quantum off an electron convinced all critics of the validity of the light quantum hypothesis in one fell swoop. Stuewer also addresses the 1924 Compton experiment and earlier experiments that pried into the particle versus wave nature of light. Both articles offer fine overviews, yet they unjustly overlook the "Einstein-Rupp" experiments on light emission. On the basis of the Compton experiment, many—including of course Einstein—thought that light emission was instantaneous. In 1926 Einstein designed experiments to test this contention, to be conducted by Emil Rupp. During his exchanges with Rupp, Einstein reversed his expectations; and indeed Rupp confirmed a noninstantaneous picture of light emission in these wave-type experiments. Rupp, however, most likely fabricated his results—which probably contributed to the omission of his name and the Einstein-Rupp experiments both from the historiography of the quantum and from biographies of Einstein.¹ In any case, given that these experiments played a key role in reconfirming wave aspects when many expected particle behavior, Darrigol and Stuewer unfortunately end their discussions of these events too early.

The *Companion* further provides us with some excellent contributions to the historiography of the philosophy of science. Don Howard argues that early logical empiricism grew out of attempts by Moritz Schlick, prompted by Einstein, to defend relativity against the apriorism of (neo-)Kantians. In the end, however, according to Howard's analysis, Einstein would insist on Duhem-style holist positions when speaking of the relation between physics and geometry—which produced the familiar problems with the empiricists' notion that one could assign empirical content to theories one statement at a time. The contributions by Thomas Ryckman and Michael Friedman meanwhile make it clear that Einstein was quite attuned to other aspects of Kantian philosophy. To make the point, Ryckman in particular derives his argument not just from Einstein's explicitly philosophical pronouncements; he also seeks to link these up with Einstein's later, highly abstract work on a unified description of fundamental forces. At that time Einstein argued that, in order to organize and understand our experiences, we need to posit concepts and a notion of reality regarding the world. For the same reason, we aim for unification in our theories. All these Kantian moves would be prerequisites to conducting science. In this projection of our employment of reason onto the world, Ryckman's Einstein would, later in life—and fully absorbed for many years in his "unified field theories"—indeed identify the "truly valuable in Kant" (pp. 342, 349, 353, 357).²

The *Companion* is at its strongest where history of philosophy of science engages with conceptually focused history of science. In his own contribution, Michel Janssen discusses Einstein's road to the general theory of relativity and beyond. He argues that, even though the

¹ See Albert Einstein, "Vorschlag zu einem die Natur des elementaren Strahlungs-Emissionsprozesses betreffenden Experiment," *Die Naturwissenschaften*, 1926, 14:300–301; Einstein, "Über die Interferenzeigenschaften des durch Kanalstrahlen emittierten Lichtes," *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, 1926, pp. 334–340; Emil Rupp, "Über die Interferenzeigenschaften des Kanalstrahllichtes," *ibid.*, pp. 341–351; and Jeroen van Dongen, "Emil Rupp, Albert Einstein, and the Canal Ray Experiments on Wave-Particle Duality: Scientific Fraud and Theoretical Bias," *Historical Studies in the Physical and Biological Sciences*, 2007, 37(Suppl.):73–120.

² See also Thomas Ryckman, *The Reign of Relativity: Philosophy in Physics, 1915–1925* (Oxford: Oxford Univ. Press, 2005).

theory was the high point of Einstein's scientific achievement, it did not in the end fulfill all of his hopes, as it failed to obey the "Mach principle"—the notion that all gravitational fields should be attributed to material sources. It was in an effort to salvage this principle that Einstein introduced the notorious cosmological constant, which, in turn, sparked a debate that eventually germinated into the field of physical cosmology, as Christopher Smeenk's essay here shows.

Janssen's essay also discusses the study of Einstein's "Zurich notebook" that he conducted together with John Norton, Jürgen Renn, Tilman Sauer, and John Stachel.³ Its results have been singularly important and deserve special attention. Einstein kept the "notebook" while he was trying to find candidate relativistic field equations for gravity, and Janssen *et alia* have managed to produce a line-by-line reconstruction of its contents. Their most important contribution is a methodological analysis: as Einstein was closing in on the final field equations of gravity, he combined a set of typically "physical" principles and approaches with what was suggested as mathematically the most natural realization of, in particular, the principle of equivalence (i.e., the notion that, locally, no distinction can be made between the inertial effects of acceleration and the effects of gravity). The latter found its expression in the mathematics of tensors and Riemannian geometry, but initially this could not be squared with what Einstein demanded from physics. He abandoned Riemann's curvature tensor in 1913, only to return to it once he understood how to remold his faulty prototheory through a new comparison with the theory of electrodynamics.⁴

The entire process, including its emotional resolution after some four years of intense work, made a lasting impression on Einstein, as becomes clear when we consider his many later methodological pronouncements.⁵ This is exactly why the Zurich notebook research has proven so essential. Einstein largely spent the last decades of his career on attempts, as ambitious as they were fruitless, to formulate a field theory in which the fundamental forces and particles would be unified. Einstein would explicitly justify his unified field theory work by pointing to his own methodological and epistemological stances as derived from his recollections of the events leading up to the general theory of relativity.⁶ In Einstein's recollections of this work, which changed over time, the constitutive role of mathematics would gradually grow; all the while, his own work on unification came to rely more and more on mathematical creativity. At the same time, the principles and practice of unified field theory were closely linked with Einstein's critical stance toward quantum theory and with his gradual drift away from experiment. As he expressed the point in 1954 to his fellow quantum dissenter David Bohm:

³ Michel Janssen, John D. Norton, Jürgen Renn, Tilman Sauer, and John Stachel, *The Genesis of General Relativity*, Vol. 1: *Einstein's Zurich Notebook: Introduction and Source*, Vol. 2: *Einstein's Zurich Notebook: Commentary and Essays* (Dordrecht: Springer, 2007); and Renn and Matthias Schemmel, *The Genesis of General Relativity*, Vol. 3: *Gravitation in the Twilight of Classical Physics: Between Mechanics, Field Theory, and Astronomy*, Vol. 4: *Gravitation in the Twilight of Classical Physics: The Promise of Mathematics* (Dordrecht: Springer, 2007). All this is part of a larger project on the history of general relativity pursued by Renn's group at the Max Planck Institute. The project also comprises an extensive survey of the various rival theories.

⁴ Michel Janssen and Jürgen Renn, "Untying the Knot: How Einstein Found His Way Back to Field Equations Discarded in the Zurich Notebook," in *Einstein's Zurich Notebook: Commentary and Essays*, ed. Janssen *et al.*, pp. 839–925. John Norton, "Nature Is the Realisation of the Simplest Conceivable Mathematical Ideas: Einstein and the Canon of Mathematical Simplicity," *Studies in History and Philosophy of Modern Physics*, 2000, 31:135–170, emphasizes a more direct return to mathematics.

⁵ See Norton, "Nature Is the Realisation of the Simplest Conceivable Mathematical Ideas." The quotation in the title of Norton's article is taken from Albert Einstein, *On the Method of Theoretical Physics* (Oxford: Clarendon, 1933).

⁶ Jeroen van Dongen, *Einstein's Unification* (Cambridge: Cambridge Univ. Press, 2010).

I believe that these [ultimate] laws are logically simple and that the faith in this logical simplicity is our best guide, in the sense that it suffices to start from little empirical knowledge. The realization that in a half empirical way one could never have arrived at the gravitational equations for empty space had a particularly strong influence on me. In that case, only the viewpoint of logical simplicity can be of help.⁷

Arguably, the last ten years have shown that Einstein's unified field theory attempts are a substantial and inalienable part of his *oeuvre*. They need to be included in the discussion of many aspects of his science, whereas earlier scholarship tended to isolate and thereby unduly diminish their importance.⁸ In the *Companion*, Einstein's unified field theories are indeed included in many discussions, while a more systematic treatment is provided by Tilman Sauer. Sauer produces a rich overview along “conceptual, representational [i.e., mathematical], biographical and philosophical” lines (p. 281). Einstein's attempts, and his persistence in them, were increasingly seen as idiosyncratic by his contemporaries, and one rightly asks what may explain them. Instead of a more microhistorical argument of the sort outlined above, Sauer ultimately points to Enlightenment beliefs in the power of the human mind to understand all of nature; these might have inspired Einstein's political interventions as well. Even though such a connection is persuasive, how it might explain the particular nature of Einstein's course, so distinctively different during the years when he pursued his unified field theory from the concerns and pursuits of many of his generation, does need further exploration.

Christoph Lehner's excellent contribution again demonstrates that great insight can still be achieved by combining conceptual history with philosophical concerns. Lehner argues that, in fact, Einstein's methodological positions also informed his realist stance—an argument that makes the mutual coherence between Einstein's unified field theory, his quantum criticism, and his epistemology even stronger. In Lehner's analysis, Einstein distinguished between what was “physically real” and what was “phenomenally real,” with physics aiming to describe the former, not the latter. This was the lesson he felt he had learned when it turned out in gravitation theory that the invariant “metric tensor,” not the observer-dependent expression for the gravitational field, is the key concept. This realism, which Lehner terms “methodological realism,” would have inspired Einstein's rejection of the statistical, phenomenally adequate description provided by quantum theory: owing to its statistical nature, it is inherently dependent on a choice of observables and therefore not “invariant” and objective.

A different aspect of Einstein—his political beliefs—is discussed in the *Companion* by arguably the greatest expert on the subject, Robert Schulmann. He gives an insightful account of how Einstein's Zionist activism was awakened by the plight of East European immigrant Jews in Berlin.⁹ Even though Einstein signed a pacifist manifesto and met with the French pacifist Romain Rolland in Switzerland in 1915, during World War I he lived in a “self-absorbed” inner universe nearly exclusively filled with science. When he witnessed the position of refugee Jews, and particularly their treatment by their German co-religionists,

⁷ Albert Einstein to David Bohm, 24 Nov. 1954, *ibid.*, pp. 181–182.

⁸ See, e.g., Abraham Pais, “*Subtle Is the Lord . . .*”: *The Science and the Life of Albert Einstein* (Oxford: Oxford Univ. Press, 1982), Ch. 17.

⁹ The most complete recent publication on the subject of Einstein's political beliefs is David Rowe and Robert Schulmann, eds., *Einstein on Politics: His Private Thoughts and Public Stands on Nationalism, Zionism, War, Peace, and the Bomb* (Princeton, N.J.: Princeton Univ. Press, 2007). For the first authoritative book-length study of Einstein's Zionist activism see Ze'ev Rosenkranz, *Einstein before Israel: Zionist Icon or Iconoclast?* (Princeton, N.J.: Princeton Univ. Press, 2011).

Einstein finally engaged “the external world”—yet not until the announcement of the 1919 eclipse results. The confirmation of key predictions of relativity provided him with a global platform. Even so, the eclipse announcement, in Schulmann’s account, is the only moment when Einstein’s politics and his science came together. But this ignores the fact that Einstein’s science was perceived at the time as highly politically charged. In 1920 “anti-relativists” rallied in public protest against his work, and many such interactions between science and politics followed, such as his dismissal from the Berlin Academy in 1933, the creation of the anti-Semitic Deutsche Physik movement, and the many lectures on relativity that he delivered in (for instance) the former warring nations of World War I.¹⁰ In her recent monograph, Milena Wazeck has further shown convincingly how relativity functioned as a political force *within* science: it came to stand for a new highly specialized and abstract kind of scholarship that marginalized universalist gentleman amateur scientists and experimental academic traditionalists alike.¹¹ These marginalized figures then united in resentment and loud dissent, their rhetoric blending physical-philosophical discourse with antimodernist or reactionary sentiments. Only when we look at both his public persona and how it was entangled with his scientific track record can we understand how Einstein came to be perceived, and would mockingly self-identify, as “subversive and revolutionary” (p. 442).¹²

John Norton’s presentation in the *Companion* of Einstein’s route to the special theory of relativity moves us through familiar territory—the philosophies of Mach and Hume, the optical experiments on stellar aberration and Fizeau’s work, and the particular problems in electrodynamic theory that Einstein was preoccupied with. Norton does qualify the role of light signals and processes of clock synchronization, central to Peter Galison’s study of the technological concerns that passed through Einstein’s Berne patent office, as “decisive in the final moments” (p. 62); yet, at the same time, he finds their enduring link to Einstein “an artifact” that has been expanded too much due to “our own preoccupation with them.” They “need not appear at all in a spacetime formulation of special relativity” (p. 63).¹³ Norton’s emphasis on the electrodynamics of moving systems is entirely justified, yet I cannot go along with his near-dismissal of the relevance of the technology in the Berne patent office. The study of material culture has introduced a new and contextually rich ingredient to a list that has been pretty much fixed since at least the 1960s; if we wish to understand the relation between Einstein’s thoughts and the time and place where they were formulated, its value should not be dismissed.

Many articles in the *Companion* are little reflective of the cultural turn that much history

¹⁰ See, e.g., Alan D. Beyerchen, *Scientists under Hitler: Politics and the Physics Community in the Third Reich* (New Haven, Conn.: Yale Univ. Press, 1977); Hubert Goenner, “The Reaction to Relativity Theory, I: The Anti-Einstein Campaign in Germany in 1920,” *Science in Context*, 1993, 6:107–133; Thomas Levenson, *Einstein in Berlin* (New York: Bantam, 2003); David Rowe, “Einstein’s Allies and Enemies: Debating Relativity in Germany, 1916–1920,” in *Interactions: Physics, Mathematics, and Philosophy, 1860–1930*, ed. V. F. Hendricks et al. (Dordrecht: Springer, 2006), pp. 231–280; Jeroen van Dongen, “Reactionaries and Einstein’s Fame: German Scientists for the Preservation of Pure Science, Relativity, and the Bad Nauheim Conference,” *Physics in Perspective*, 2007, 9:212–230; and Alexandre Moatti, *Einstein: Un siècle contre lui* (Paris: Jacob, 2007).

¹¹ Milena Wazeck, *Einstein’s Opponents: The Public Controversy about the Theory of Relativity in the 1920s* (Cambridge: Cambridge Univ. Press, 2014).

¹² On Einstein as revolutionary see also David Rowe, “Einstein and Relativity: What Price Fame?” *Sci. Context*, 2012, 25:197–246; and Jeroen van Dongen, “Mistaken Identity and Mirror Images: Albert and Carl Einstein, Leiden and Berlin, Relativity and Revolution,” *Phys. Persp.*, 2012, 14:126–177.

¹³ Similarly critical is Alberto Martínez, “Material History and Imaginary Clocks: Poincaré, Einstein, and Galison on Simultaneity,” *Phys. Persp.*, 2004, 6:224–240. For Galison’s work see Peter Galison, *Einstein’s Clocks, Poincaré’s Maps: Empires of Time* (New York: Norton, 2003).

of science has taken lately. An obvious exception to this observation is the contribution by Daniel Kennefick, who discusses a notion of “theoreticians’ regress” in gravitational wave research in analogy to the famed “experimenters’ regress.”¹⁴ In another, likewise impressively integrative, approach, Jürgen Renn and Robert Rynasiewicz show how, in the events of 1905, Einstein’s resolution of a number of separate problems in statistical mechanics, thermodynamics, and electrodynamics hangs together. They focus on the “knowledge systems” of Einstein’s predecessors and how, when studied in combination, these produced certain “borderline problems” that Einstein tried to resolve by constructing some novel, all-encompassing atomic theory. In Renn and Rynasiewicz’s story, scarce primary sources are placed in a broad account of how Einstein would have deepened his understanding of these theories and of their limitations.¹⁵ He could not overcome these limitations until he had replaced his constructive approach with a focus on a limited number of principles, such as the relativity principle, which were then heuristically used as selective criteria for possible solutions. These were founded on a rearrangement and, foremost, a reinterpretation of key concepts in the old “system of knowledge.” Renn and Rynasiewicz’s narrative discusses conceptual issues in a broad framework. The *explanans* is offered by a focus on mental conditioning through long-term developments in knowledge. This is easily expanded to include more than just abstract theories. Indeed, their version of Einstein’s thinking in May 1905 does emphasize his connecting up the “local” technology of clock synchronization à la Galison with Norton’s “long term” studies in electrodynamics in the final push that revealed how simultaneity for relatively moving frames of reference prescribes a new kinematics—that is, how the special theory of relativity was formulated. Here, then, conceptual and contextual history go hand in hand in a most fruitful manner.

No single image of Einstein comes to the fore in the pages of this *Companion*, thanks in no small measure to the rich results attained by the conceptual and technical analyses of the past decade. More than we knew even ten years ago, the various strands of Einstein’s thought and biography hang closely together. A further fusion of perspectives on his physics, philosophy, politics, and cultural history is needed to address the many aspects that are still unknown or unclear. An integrated history and philosophy of science approach, as exemplified in *The Cambridge Companion to Einstein*, points to a fruitful future for Einstein scholarship, as its subject is well placed to give us a uniquely insightful perspective on the history and philosophy of twentieth-century science.

¹⁴ See also Daniel Kennefick, “Star Crushing: Theoretical Practice and the Theoreticians’ Regress,” *Social Studies of Science*, 2000, 30:5–40; and Kennefick, *Traveling at the Speed of Thought: Einstein and the Quest for Gravitational Waves* (Princeton, N.J.: Princeton Univ. Press, 2007).

¹⁵ See also Robert Rynasiewicz and Jürgen Renn, “The Turning Point for Einstein’s *Annus mirabilis*,” *Stud. Hist. Phil. Mod. Phys.*, 2006, 37:5–35; and Renn, *Auf den Schultern von Riesen und Zwergen: Einsteins unvollendete Revolution* (New York: Wiley, 2006).