

BOOK REVIEWS

The downloaded PDF for any Review in this section contains all the Reviews in this section.

Craig F. Bohren, *Editor*

Pennsylvania State University, University Park, Pennsylvania 16802; mailing address: P.O. Box 887, Boalsburg, PA 16827; bohren@meteo.psu.edu

No Shadow of a Doubt: The 1919 Eclipse that Confirmed Einstein's Theory of Relativity. Daniel Kennefick. 403 pp. Princeton U. P., Princeton, NJ, 2019. Price: \$29.95 (hardcover). ISBN 978-0-691-18386-2. (Alexei Kojevnikov, Reviewer.)



Relativity meets popular culture, November 6, 1919 Painting by Quint Buchholz. Painting "Einstein meets Monroe" by Quint Buchholz (1986).

A heroic myth ingrained in popular memory describes the British astronomer Arthur Eddington leading an expedition to observe the total solar eclipse of May 1919. The photos he took on the African island of Principe definitively confirmed the fundamental prediction of Einstein's general theory of relativity that the Sun's massive body gravitationally deflects the light coming from distant stars. His colleagues who travelled to Sobral in Brazil were not as lucky with their photographs. Back in London, Eddington's announcement of his results in November 1919 provided the *experimentum crucis*, which convinced astronomers to accept Einstein's revolutionary theory of gravitation. The German theory proven correct by the British astronomer healed the wounds of WWI that had damaged international cooperation in science. Newspapers made Einstein a rock star both among the scientists and the general public.

Since the 1970s, various parts of this myth (except the very last sentence) were challenged by physicists, philosophers, and historians, who demanded corrections or at least important qualifiers. With the concept of *experimentum crucis* outdated, some argued that Eddington's observations were not sufficiently precise to be accepted as the definitive proof. Others added that Eddington was politically motivated and not impartial scientifically, too eager to pronounce Einstein correct. Daniel Kennefick's is the most detailed study of the eclipse expedition to date. His approach is critical of the critics: while not exactly restoring the original story in its entirety, Kennefick clears Eddington of some

unjust accusations. At the same time, the new details he supplies complicate questions regarding experimental confirmation even further.

Einstein first proposed the eclipse test in 1911. Astrographic telescopes sensitive just enough to measure the anticipated angles did exist, but astronomers' conservatism, the short duration of total eclipses, cloudy weather, logistics of transportation, and difficulties with making the equipment work reliably at unsuitable locations seriously complicated the execution. Chances existed for Argentinian, German, and American teams to discover the deflection during the 1912, 1914, and 1918 eclipses, respectively. WWI proved the main spoiler: Erwin Freundlich was especially unlucky that the outbreak of the war terminated his expedition from Germany to southern Russia in August 1914, and the British were especially lucky that the 1918 armistice was signed just in time to allow their travel to the sites of the 1919 eclipse.

Kennefick corrects the common misperception that Eddington headed the British team. The Astronomer Royal Frank Dyson was responsible for the overall logistics and much of the analysis of observational data, whereas Eddington, a mathematician par excellence, dealt more with theoretical interpretations. For Kennefick, this disproves allegations that Eddington's biases could have distorted the experimental results. A Quaker and religious pacifist, Eddington, narrowly escaped punishment for his refusal of military service during WWI. Just as for Einstein in Germany, Eddington's principled antiwar stance and scientific internationalism alienated him from colleagues in his home country and made him and Einstein natural allies, political as well as scientific. As the first receiver and chief promoter of general relativity in Britain, Eddington exerted some influence over the initially uncommitted Dyson and departed for the eclipse hoping to prove the theory he already believed in. I think it is undeniable that Eddington's political agenda of defending the then unpopular scientific internationalism played an important role in the 1919 expedition, at least heuristically and as a motivation.

The expedition's empirical results were complicated anyways. Kennefick explains many, often uncontrollable, circumstances that could have derailed the project and further difficulties and uncertainties that interfered with observations and data analysis. Eddington considered three alternative theoretical predictions: zero, $0.87''$, and $1.75''$. The first corresponded to classical gravitation and the ether theory of light; the second, dubbed "Newtonian," was predicted by Einstein from the equivalence principle in 1911, but could also follow from Newton's model of light as corpuscles; the third was the full deflection according to the completed 1915 general theory of relativity. Three different devices used by British teams provided three sets of data with the following averages for deflection: $0.93''$ (Sobral I), $1.61''$ (Principe), and $1.98''$ (Sobral II), neither of which was completely uncontroversial.

In Dyson's estimate, the Sobral II data, taken by Charles Davidson in Brazil, were empirically the most trustworthy, but produced with a smaller telescope intended as a backup. On Principe, cloudy weather allowed Eddington only two usable photographs with few stars, and he also skipped some initially planned control measurements. Though less reliable, his data were still used because they roughly agreed with the Sobral II set. The larger telescope in Brazil that took the Sobral I data temporarily lost focus, which blurred the star images and complicated subsequent analysis. The set was deemed the least reliable and dropped from consideration. The average between the two remaining sets was sufficiently close to the full value predicted by the general theory of relativity, which allowed the three authors of the published report to declare that the experiment favored the last of the three available theoretical predictions.

Kennefick defends Dyson's and Eddington's logic and decisions against later critics, though he occasionally resorts to the argument that only the experimenter knows best when to trust his equipment and when not. As a historian, I still see that a different astronomer, less committed to a particular theory or a hardboiled empiricist, would have likely drawn a more cautious conclusion from the same data, namely, that observations recorded a deflection effect, but not yet its precise numerical value. This would have already been a fundamental discovery, disproving the existing mainstream theory, but leaving still open the choice of alternatives. In practice, the professional astronomical community treated the result with caution: Dyson felt that additional observations were necessary, and room for legitimate skepticism remained. More eclipse expeditions followed but failed to fully satisfy the astronomers: the results were not always consistent, and precision did not greatly improve with time. Eventually, after the 1960s, radio astronomy came to help: it did not need a solar eclipse and could measure the deflection of rays any time, with stationary equipment at major observatories.

Wider audiences, scientific and general, perceived the 1919 result through media reports with much less uncertainty, as the definitive confirmation of general relativity. How exactly this happened, and why, is not completely clear. Kennefick's book does not delve much into the popular culture aspect of the story. One can surmise that Eddington's role as the chief interpreter for the Anglophone world and commentator on the suddenly famous relativity theory also assigned to him, in the eyes of the public, the main credit for the 1919 expedition, whereas Dyson's role gradually faded from memory. Eddington's advocacy of scientific internationalism was less successful: his colleagues welcomed the discovery as a triumph of British astronomy, and nationalists even mastered enough votes to deny Einstein the Royal Astronomical Society's gold medal.

Arguably, the 1919 eclipse mattered more as a symbol of the changing relationship between theory and experiment. 19th-century experimenters tended to treat theorists as their mathematical assistants, who helped calculate and interpret the data. After 1900, theoretical physics was emancipated and charged ahead, often leaving experimenters behind with the task of confirming theoretical calculations or, as in Eddington's case, choosing between selected predictions. Many experimenters complained about and resisted this role reversal. The 1919 event not only made Einstein's relativity publicly famous but also triggered public opposition to it on suspicions of rushed acceptance driven by media sensationalism and political agendas. The wide spread of anti-relativism was rooted in experimenters' resentment of the theoretical hubris, but in some situations and countries, the movement also became political, nationalistic, and media-driven.

Alexei B. Kojevnikov is an Associate Professor of History at the University of British Columbia, Vancouver, Canada. He works on the history of modern physics, nuclear history, and the history of Soviet science.

BOOKS RECEIVED

Mass Dimension One Fermion. Dharam Ahluwalia. 135 pp. Cambridge U. P., New York, 2019. Price: \$140 (hardcover) ISBN 978-1-107-09409-3.

Non-Inertial Frames and Dirac Observables in Relativity. Luca Lusanna. 338 pp. Cambridge U. P., New York, 2019. Price: \$155 (hardcover) ISBN 978-1-108-48082-6.

On the Life of Galileo: Viviani's Historical Account and Other Early Biographies. Stefano Gattie (ed.). 416 pp. Princeton U. P., Princeton, NJ, 2019. Price: \$49.95 (hardcover) ISBN 978-0-691-17489-1.

What Science Is and How It Really Works. James C. Zimring. 405 pp. Cambridge U. P., New York, 2019. Price: \$25.99 (paper) ISBN 978-1-108-70164-8.

AJP Index to Advertisers

AAPT Winter Meeting	Cover 2
AAPT Membership.	Page 769
AAPT ComPADRE	Page 771
APSIT	Page 772
AAPT Career Center.	TOC