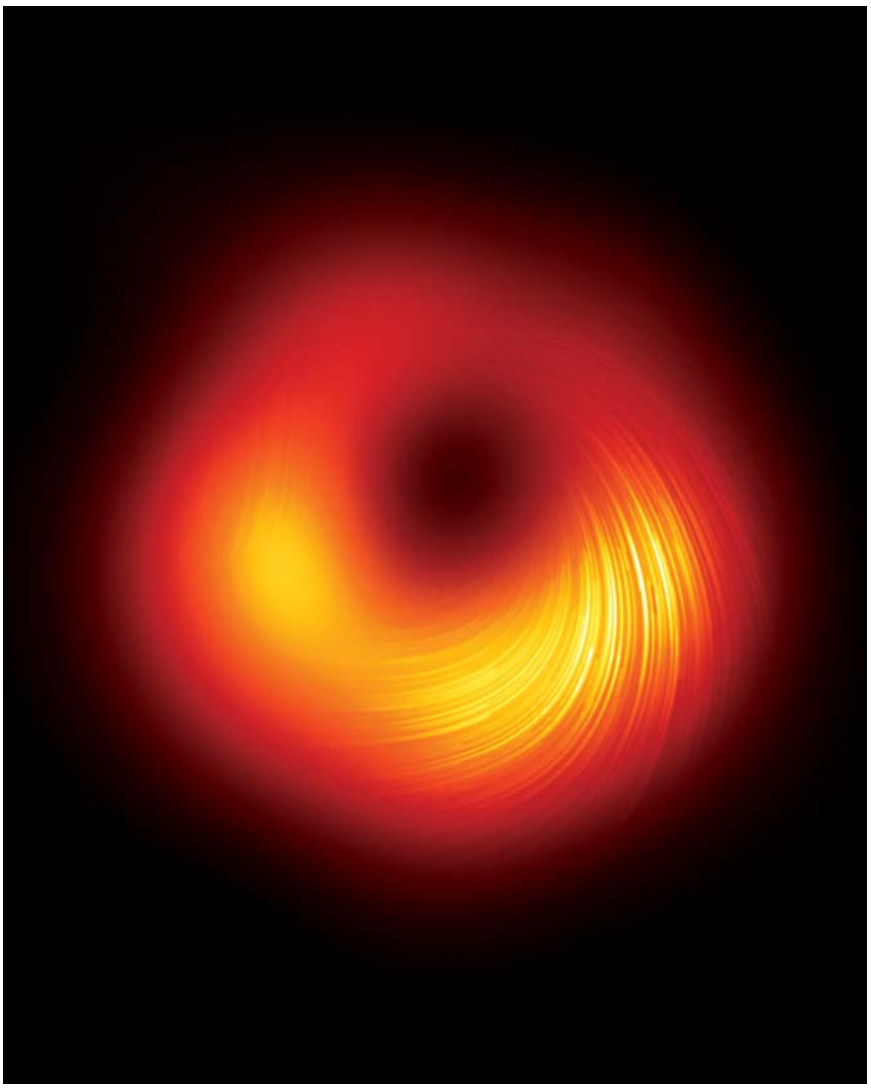
Rubin's story illustrates the resistance of the scientific community to altering an established paradigm—that light is the essential gauge of mass in the universe. Chapter by chapter, one senses the gathering force of theoretical and observational evidence for the existence of dark matter, until its impact on an array of astrophysical problems could no longer be dismissed. How does scientific transformation occur? To quote Ernest Hemingway: "Gradually and then suddenly."

Alan Hirshfeld
University of Massachusetts Dartmouth



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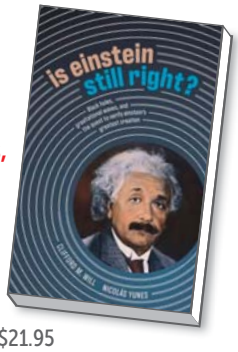
AN IMAGE of galaxy Messier 87's supermassive black hole in polarized light, which was released by the Event Horizon Telescope collaboration in March 2021.

Testing the theory of general relativity

Twice in the past four years, the Nobel Prize in Physics has been awarded for research into phenomena predicted by Einstein's theory of general relativity: in 2017 for the first direct detection of gravitational waves and in 2020 for theoretical and experimental work on black holes. The awards epitomize how general relativity has been empirically confirmed to an unprecedented extent in the past few years. We are a far cry from what historian of science Jean Eisenstaedt aptly called the "low water mark of general relativity": a period from the mid 1920s to the mid 1950s when the theory was considered little more than a mathematical curiosity.



Is Einstein Still Right?
Black Holes, Gravitational Waves, and the Quest to Verify Einstein's Greatest Creation
Clifford M. Will and Nicolás Yunes
Oxford U. Press, 2020. $21.95

Is Einstein Still Right? Black Holes, Gravitational Waves, and the Quest to Verify Einstein's Greatest Creation outlines the recent history of precision tests of general relativity and describes the current state of those experiments. Each chapter is devoted to either a physical effect or astronomical object that has been used to test the theory, including gravitational redshift, gravitational effects on light, geodetic precession and frame dragging in gyroscopes, pulsars, black holes, and gravitational waves. The final chapter describes gravitational-wave observatories that are currently being planned—both on Earth and in space—and are expected to be crucial to the future development of multimessenger astronomy.

Theoretical physicists Clifford Will and Nicolás Yunes are the ideal authors for a book about verifying Einstein's theory of general relativity. Will has long been the world's leading expert in experimental confirmations of the theory and has dedicated his 50-year career to the topic. Yunes, part of a younger generation, is internationally renowned in the experimental testing of general relativity with gravitational waves.

The present volume is a sequel to Will's

1986 book *Was Einstein Right? Putting General Relativity to the Test*. In that tome, Will coined the term "renaissance of general relativity" to describe how attempts to verify the theory beginning in the late 1950s gradually brought it into science's mainstream. The precision of such experiments has increased in the intervening years, as has their popular appeal: The first image of the supermassive black hole at the center of galaxy Messier 87 made the front page of many world newspapers when it was released on 10 April 2019. *Is Einstein Still Right?* is thus intended to chronicle developments in the field that have occurred since Will's first book was published.

The two authors have not only the broad spectrum of knowledge and personal experience necessary to master the subject, but also the writing skills needed to provide a fresh and witty narrative that is comprehensible to a wide audience. Without employing a single mathematical formula, Will and Yunes succeed in building a simple and highly intuitive picture of the abstruse theory's physical effects, all of which challenge common sense views of space and time. Particularly useful are the figures, which offer easy-to-grasp visual representations of experiments and effects. Many are bidimensional analogies of four-dimensional spacetime phenomena. Although the authors continuously remind readers that those analogies are imperfect, anyone unfamiliar with the theory will find them extremely helpful.

Since I am a historian of science, I cannot refrain from commenting on the book's use of history, which is important to the narrative. The historical passages are generally well written and fair, although they—perhaps inevitably—lack sophistication and, at times, accuracy. For example, the authors perpetuate the myth that Einstein gave four lectures to the Prussian Academy of Sciences on progressive developments of his theory during the crucial weeks of November 1915. In reality, those four lectures were actually four articles Einstein published in the academy's house journal that month. He did present one of the four papers in a formal lecture to academy members, but the other three appeared solely in print.

Will and Yunes consulted the historical literature and provide a useful list of their sources. However, they occasionally focus too heavily on anecdotes—for example, how a discussion between three naked scientists in a California pool eventually led to the *Gravity Probe B* experiment—rather than stressing the epistemic and socio-institutional elements of the theory's resurgence, which I believe are far more interesting. The authors acknowledge the help of several scientists who commented on parts of the book. Given the role history plays in it, one wonders whether consulting a few professional historians of science might have helped them avoid some inaccuracies.

Besides those minor reservations on the historical aspects of the book, I strongly recommend it to all those interested in general relativity. Although nonspecialist readers may find it challenging, they will surely be rewarded by its compelling descriptions and fascinating narrative.

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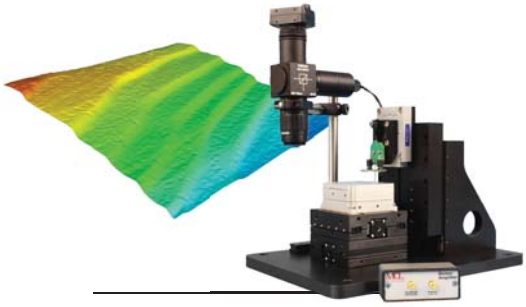
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