differential equations and other concepts that are typically explained or aided by pictures could not draw.

There are more connections with art and aesthetics worth mentioning. Poincaré's thinking was especially close to a surrealist's. Psychologist Édouard Toulouse wrote that Poincaré's thought "was spontaneous, little conscious, more like dreaming than rational, seeming most suited to works of pure imagination." It is well documented that Poincaré's *Science and Hypothesis* inspired Pablo Picasso and Marcel Duchamp, two of the most influential 20th-century artists.

The aesthetics connection is with elegant writing. Poincaré's obituary in *Nature* said that "passion for scientific truth did not suffice for him, he loved literary beauty. . . . He knew that the French language is itself a country, and, against every perilous invasion, this soldier of sound speech stood firmly at the frontier." Coming from an English publication, that was high praise indeed.

Philosophy of Physics
Space and Time

Tim Maudlin
Princeton U. Press, 2012. $29.95
(183 pp.). ISBN 978-0-691-14309-5

An understanding of the nature of space and time is central to both philosophy and physics. Tim Maudlin, a professor of philosophy at New York University, is well qualified to review theories of space and time from both perspectives, and he is successful in doing so in this concise and highly engaging book.

In *Philosophy of Physics: Space and Time*, Maudlin begins with a discussion of Isaac Newton's view of absolute space and time, including an interesting analysis of the Leibniz–Clarke correspondence, wherein Gottfried Leibniz attacked the notion of absolute space and Samuel Clarke defended it. Maudlin then explains the changes to the Newtonian view of space and time needed to incorporate Galilean relativity's demand that absolute velocities have no meaning. Then he presents special relativity from a fully geometrical point of view. Maudlin concludes with a discussion of general relativity, but the presentation is extremely cursory and the choice of topics within general relativity is quite desultory. It is therefore hard to see how a reader who is not already deeply familiar with general relativity will be able to follow the discussion in a serious and meaningful way.

The main strength of the book is its presentation of special relativity, which is done without ever introducing a Lorentz transformation. Maudlin explains very clearly why commonly made statements like "time slows down for moving observers" are utterly nonsensical. His discussion of the twin paradox is excellent, and it corrects many of the wrong and confusing statements that have been made previously by a number of distinguished people. There also are several worked examples that concretely illustrate how calculations can be done in special relativity by direct use of the spacetime interval rather than via Lorentz transformations.

However, there is one significant flaw in Maudlin's presentation. In chapter 4, the first of the two chapters dedicated to special relativity, he introduces a "clock hypothesis," and constructs global inertial coordinates using the idealized clocks he thereby introduces. The fact that the coordinate speed of light is one light-minute per minute is then a tautology. But in chapter 5, Maudlin tries to explain that there is, in fact, a nontautological meaning to the statement that the speed of light is "constant in all frames." To do so, he introduces the notion of (approximately) rigid rods as *physical systems* and then asserts that such rods would undergo a *physical* Lorentz contraction. By introducing the notion of physical Lorentz contraction, Maudlin edges backwards toward exactly the same type of confusing presentation of special relativity that he rightly criticizes in chapter 4. There is no justification for treating clocks and rods asymmetrically, so if it is appropriate to say that physical rods undergo a physical Lorentz contraction, then it must be equally appropriate to say that physical clocks undergo a "physical time dilation." And that concession leads one back toward the usual discussions of the twin paradox that Maudlin demolishes in chapter 4.

It would be much better if Maudlin consistently stuck to the view that all of the structure of space and time in special relativity is described by the topological and differential properties of events together with the spacetime metric. Only that structure enters the laws of physics governing the dynamical behavior of matter and fields in spacetime, so the dynamical behavior of physical systems directly reflects the properties of the spacetime metric. The physical manifestations of the spacetime metric may then be nicely elucidated by stating how idealized clocks and rods would behave. (However, since rigidity cannot be maintained for general, noninertial motions, it is much more awkward to formulate a "rod hypothesis" than a "clock hypothesis," since one would have to use arbitrarily short rods in such a formulation.) Of course, both real clocks and real rods are governed by the laws of physics for the matter of which they are composed. But one can make real clocks and rods that closely approximate the idealizations if the motion considered is not too extreme, so it is fine to base a discussion on idealized clocks and rods.

My expectation is that a perceptive reader will feel highly enlightened by the clear explanations in chapter 4, which uses clocks as idealized objects, but will likely feel uneasy after reading chapter 5, in which rods are introduced only as physical objects. Despite the above criticism, I would highly recommend *Philosophy of Physics* to anyone who wants to get a deeper historical and philosophical perspective on the nature of space and time, as well as to any physics student who has been confused by the twin paradox.

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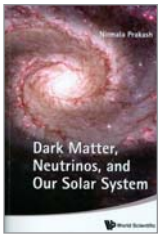
Dark Matter, Neutrinos, and Our Solar System

Nirmala Prakash
World Scientific, 2013. $77.00
(676 pp.). ISBN 978-981-4304-53-5

I appreciate the book *Dark Matter, Neutrinos, and Our Solar System*, by Nirmala Prakash. This work is quite unconventional in many aspects; actually, its style resembles a large edited scrapbook in which an amazing bunch of subjects have been recorded for further thought. The author´s preface actually states something like this; the result is quite eclectic in breadth and in its attempt to intermingle the many subjects.

The first chapter, which discusses the advent of dark matter, is supposed to motivate the rest of the book. That approach sounds promising, but I found the presentation to be sketchy. The



next two chapters, containing well-known information about stars and cosmology, seem unrelated to the book's central topics. To be clear, the presentation in those chapters is accurate, but given the presumed background of the intended audience, it could just as easily have been omitted. Chapter 4, devoted to black holes, is potentially more interesting and more pertinent to dark matter, but its tune is off. It contains some obvious shortcomings; for example, primordial black holes are not discussed as candidates for baryonic dark matter and are mentioned only briefly later in the text.

The core of *Dark Matter, Neutrinos, and Our Solar System* starts with chapter 5, a historical overview of particle physics. The technical content is at an intermediate level, in contrast to some difficult and less pertinent subjects, like Penrose diagrams presented in the earlier chapters. Nonetheless, the introduction in chapter 5 is undoubtedly useful, though perhaps it could have been expanded to better prepare the reader for what is to come.

Chapters 6, 7, and 8 represent the book at its best. In 280 pages they discuss the main issues behind the question of what dark matter actually is and, in particular, the role of neutrinos. Those chapters could be used for a graduate-level introduction to the subject and for physicists wishing to start their own studies. Chapter 8 deals with the timely and important issue of the supersymmetric particles known as WIMPs (weakly interacting massive particles)—including some discussion of how they might be detected. That chapter concludes the book's explorations of the main particle solutions to the dark matter puzzle.

To fully understand dark matter and neutrinos, the interested reader will need to seek additional material to supplement Prakash's presentation. I cannot refrain from imagining an alternative plan for chapters 1 to 5 that would boost the material presented in chapters 6 to 8. But these observations do not diminish the merits of the book. The ninth and final chapter is a discussion that, although fascinating, again seems off-topic, at least on first reading. It is hard to imagine how Saturn´s rings or Mars rovers relate to dark matter. In my opinion, this solar system fraction of the book would be more appropriate as a separate text.

I also could not help but notice how the author transmitted her passion for the general enterprise of science; many of its historical and human aspects were scattered throughout the book. In particular, her mathematical background shows intermittently, in a sort of *contrapunto* to the physical and phenomenological subjects. Many readers will appreciate that passion, as I did, in this exuberant book.

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Robert Oppenheimer
A Life Inside the Center

Ray Monk
Doubleday, 2012. $37.50 (825 pp.).
ISBN 978-0-385-50407-2

The cover of the May 1948 inaugural issue of PHYSICS TODAY featured a photo of J. Robert Oppenheimer's porkpie hat resting on a cyclotron. In *Robert Oppenheimer: A Life Inside the Center*, Ray Monk writes that this important physicist was "so famous that he did not actually need to be pictured in order to be represented." Despite that fame, Oppenheimer has remained enigmatic, even though about a dozen books since 2002