his idea—an episode that sheds light on what science is, how it works, and where it can go wrong." Yet Chandra did not have to fight for recognition. The morning after the meeting, when Chandra saw Ralph Howard Fowler and told him what Eddington had said, Fowler said not to worry; Eddington was wrong. Leon Rosenfeld, Niels Bohr, Paul Dirac, and Wolfgang Pauli all agreed that Eddington's criticism had no substance. It was the empirically bound nature of astronomy and astrophysics of the 1930s, not the shortsightedness of the physics establishment, that impeded the acceptance of new theoretical ideas.

Miller is equally fanciful when he writes about the effects of the controversy on Chandra's personal life and accomplishments. According to the author, Chandra's life became tinged with tragedy and he never regained his confidence. Eddington had convinced Chandra that "success in the world of science was not simply a matter of the brilliance of one's ideas; even more important, it seemed, was playing the game and scheming along with every one else."

Anyone who knew Chandra personally or through his works would be astounded by Miller's assessment. Chandra has left behind an almost unparalleled legacy of theoretical and mathematical physics. For Chandra, his arguments with Eddington were based purely on science. Traumatic though they were, Chandra's relations with Eddington never faltered from great respect and affection. In the summer of 1935, just months after his unexpected rebuttal, Eddington took Chandra to the tennis finals at Wimbledon. They went to cricket matches and took bicycle trips together. In subsequent years, the two corresponded with each other. Eddington's letters were full of warmth, humor, and affection.

Although Miller is fully aware of all those events and writes about them in his book, he claims they were all façades Eddington created. He believes there were deep reasons for Chandra's brutal treatment, born out of racism, clash of cultures, and British colonialism. Such an attitude, notes Miller, "would be taboo today, but in those days the Raj still ruled India, and Englishmen still basked in the belief in their innate superiority."

Chandra never felt he was discriminated against in England. Both Eddington and Edward Arthur Milne, who also had science-related disagreements with Chandra, were responsible for Chandra's election to the Trinity and Royal Society fellowships. At the height of his dispute with Eddington, Chandra was the first Indian to give lectures on stellar structure at Cambridge University.

Miller's account of Chandrasekhar and Eddington, made into a story of a young, brilliant student from colonial India stifled and robbed of his discovery by an imperial egotist, gives a distorted view of history and how science works. Other reviews of Miller's book have taken up this work as evidence of the dark side of science, in which personal rivalry, clash of cultures, and deep-seated prejudices plague scientific minds. As human endeavor, science certainly has human pitfalls that should be brought to light. But *Empire of the Stars* does not do that in a credible way.

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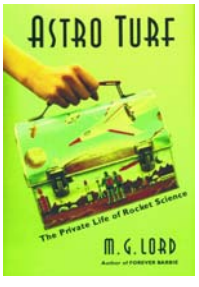
Astro Turf: The Private Life of Rocket Science

M. G. Lord
Walker, New York, 2005. $24.00 (259 pp.). ISBN 0-8027-1427-7



Rocket science is all about perfect physics in frictionless space, about amazing feats of precision in the glare of the public, who ask in awe, "How do they do that?"—not to mention the fantastic fireworks display to get things going. AstroTurf is the perfect engineering solution to having ever-green grass that needs no mowing, sun, or water. But perfection has its downsides, and so the new stadium fields in Houston are real grass. Maybe it was the longing from the fans for dirt on the uniforms and grass stains on the knees.

Astro Turf: The Private Life of Rocket Science takes us on an intriguing, well-written walk through the relatively short but spectacular history of the space program at the Jet Propulsion Laboratory in Pasadena, California. Mary Grace Lord, investigative reporter and cultural critic, also offers readers a much more personal look—complete with a little dirt and some grass stains—at those times as experienced by Lord, whose father, Charles Carroll Lord, was of one of those rocket scientists.

Lord recounts the roots of early space exploration and the personalities and politics that drove it. Going over ground that has been covered before by others, she recounts the contradictions of the dark beginnings and the brilliant successes of Wernher von Braun and his team. She traces the tortured paths of some early leaders of JPL in the McCarthy era—especially the path of Frank Molina, the JPL director on whom the FBI kept an exceptionally thick file on alleged anti-American activities. The history lesson is informative to the reader, and, more important, it informs Lord's search into the work world of her often distant father.

Charles's world was one of engineering precision, order, and discipline. Lord observes that at JPL the obsession for clear, logical thought, coupled with singular powers of concentration, was carried to nearly pathological extremes. Nevertheless, those qualities were so valued in scientists and engineers that, if they didn't have them naturally, they just might want to fake the behaviors for the good of their careers. These same behaviors often had an impact on the personal lives of those involved. Into the engineers' heady, technical world, Lord weaves her recollections of life growing up with her father, going places and doing things with him—and she ponders the things left undone and unsaid. The common thread of Lord's story is her discovering new insights about her father—from his making a perfectly knit scarf, just to show that he could, to his dismissive comments about Lord's ability to concentrate, to his struggles with his own low self-esteem as a second- or third-tier rocket scientist.

Rocket science, although precise and disciplined at the bench level, is fragile, ethereal, and political at the leadership level. Lord builds the story with consummate attention to detail and insight into the complex clashes of personalities of such leaders as Molina and von Braun. For example, the selling of rocket science to politicians and the public caught a wave of excitement with the introduction of Walt Disney to rocket science and the commercial and popular success of Disneyland. Disney raised von Braun to iconic status—every story needs a hero. The whole country was glued to the television set to see spaceflight portrayed in short films such as "Man in Space" and "Man and the Moon" created by the artful Disney cartoonists. Lord leaves us wondering just how much those fanciful previews influenced the decision to go to the moon.

Using more recent history, Lord sets

about dissecting JPL's personality and its belated acceptance of late-20th-century cultural norms. Women scientists and engineers, and later managers, broke into the intensely male culture at JPL and became role models for the women who followed them. The issues of homosexual lifestyle finally became publicly acknowledged in the 1990s with the debate over health benefits for JPL workers and their partners. Lord uses her knowledge of the lab and insights from her father's professional life to add depth and color to the ongoing evolution at JPL. This part of her story is unfinished and perhaps not completely circumspect. Her discussion of women in the JPL workforce and their successes and failures is largely anecdotal. The anecdotes are valuable, but there must be more to the picture. Likewise, the issues of ethnic diversity at JPL are in transition and continue to evolve. But then JPL is still a work in progress, and only time may allow us to look back at this epoch of change with greater clarity.

Astro Turf is an interesting read and filled with intriguing insights into the inner workings of JPL, the people who work there, and the history that contributes so richly to its unique character. Lord successfully accomplishes her mission in writing this story, which also serves as a memoir about her father. She comes to closure with a more complete understanding of his life, a life so inextricably woven into rocket science that to understand him she had to understand his work.

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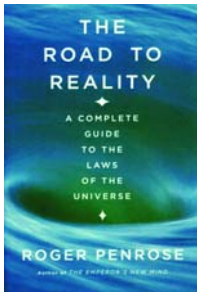
The Road to Reality: A Complete Guide to the Laws of the Universe

Roger Penrose
Alfred A. Knopf, New York, 2005.
$40.00 (1099 pp.).
ISBN 0-679-45443-8



Roger Penrose is very possibly the most creative and independent thinker working in theoretical physics today. It can be fairly said that he has contributed more to our understanding of general relativity than anyone since Albert Einstein. He is also the originator of several important and influential ideas that have been widely used. For example, he invented a simple model of quantum spacetime, called spin networks, that now underlies much work in quantum gravity. But he went on to develop his own approach to quantum gravity, called twistor theory. Although twistor theory has played a role in mathematics and, recently, in string theory, most physicists have not followed Penrose's explorations of the subject. And Penrose's views on quantum mechanics are decidedly original and heterodox: He believes that quantum mechanics is an approximation of a more complete theory in which the wavefunction will evolve nonlinearly as a result of gravitational effects.

In addition to writing *The Road to Reality: A Complete Guide to the Laws of the Universe*, Penrose, a distinguished professor emeritus in the mathematics department at the University of Oxford, is the author of two previous books that present his vision of the future of physical theory. Although those books have inspired a few physicists, most working theorists have rejected Penrose's vision in favor of a research program that aims to go beyond the standard model of particle physics without modifying any aspect of quantum theory. That dominant view has lasted for more than 30 years and has led from grand unified theories to supersymmetry, higher-dimensional theories, and string theory. Penrose's book appears at a moment when the dominant view faces a crisis following the discovery that any string theory compatible with the observed positive cosmological constant offers such a vast number of possible universes—at least 10^{500}—that it may never be able to make any falsifiable predictions. This has recently led great physicists like Leonard Susskind and Steven Weinberg to declare the dawning of an age of anthropic physics, in which a theory is to be believed even if it is untestable and there are to be no first-principles explanations for most properties of the elementary particles.

I mention the above crisis because it is the context in which Penrose's new book must be understood. Penrose's treatise is two books in one. The first is a pedagogical introduction to the main ideas of mathematics and physics sufficient, according to Penrose, to take lay readers from the integers to twistor spaces and Calabi–Yau manifolds. The second is a strongly argued critique of the dominant research approach, followed by a formi-