Mirror Matter, Pioneering Antimatter Physics

Author	Robert L. Forward and Joel Davis
Publisher	John Wiley and Sons, New York (1988)
Pages	262
Price	$18.95
Reviewer	George H. Miley

Robert Forward teamed with science writer Joel Davis to produce this fascinating scientific book for both lay audiences and those with technical backgrounds interested in a broad perspective of the field of antimatter physics and potential applications. Forward elected to use the terminology "mirror matter" for this book since antimatter is "the mirror image of ordinary matter" and this terminology avoids the negative connotation of "anti."

The authors review the interesting history of the discovery of the positron by Anderson in 1933 and go on to the detection of the antiproton by Segré, Chamberlain, Wiegand, and Ypsilantis at the University of California–Berkeley in 1955, followed by the subsequent mushrooming of big accelerator physics. A main theme of the book – that mirror matter is "not just the stuff of science fiction" but "really exists" – is vividly illustrated by the authors by, among other things, citing the growth of antiproton production from ~ 100 in 1955 to $\sim 10^{16}$ in 1990.

Other topics concerning mirror matter include storage techniques (traps), antiproton physics at major accelerator facilities, projected methods to make mirror matter, antimatter molecules, antihydrogen ice, concepts for antimatter rockets, potential applications, opening up the solar system, and on to the stars. The coverage includes a good mix of basic scientific concepts plus speculation. Indeed, to clearly separate out science fiction, a separate science fiction story, "Turn Left at the Moon," is woven throughout the book as distinct, separate chapters. It was intended to be motivational for the reader. However, my personal opinion is that this detracted from the strength of the book. Therefore, the reader has a choice – he can omit reading the science fiction chapters.

Persons in the fusion community may not be as directly interested in mirror matter as in the competition this may offer fusion as an ultimate power source. On an energy release per unit mass basis, mirror matter wins. However, the key issue is the large amount of energy required to create a mirror matter in the first place. Thus, unless a breakthrough occurs in the production of mirror matter, fusion "wins" the *net* energy race. The authors acknowledge that "there is simply no conceivable way it will be possible to produce and handle mirror matter more cheaply and safely than, say, gasoline or jet fuel." Thus, the authors rule out ground-based propulsion as an application but conclude that mirror matter can compete favorably with chemical propulsion because "the energy available . . . is so enormous . . ." Fusion is not listed in the index, but they do devote a page to "fusion rockets." They conclude that depending on the success of research on ground-based power plants, "we may someday have a fusion rocket engine." They stress, correctly, that, unfortunately, present concepts are unlikely to achieve the necessary thrust-to-weight ratio. But the conclusion is not completely negative, namely that "fusion rockets *can* get us to the stars – if they aren't too heavy."

It should be added that the book also briefly discusses a variety of the propulsion concepts, including the Orion concept (using controlled thermonuclear bombs), fission rockets, electric ion, the Buzzard ram-jet, and laser rockets. Regardless of how one views the relative to the roles of various concepts, this book is worth reading. Not only do the authors provide a fascinating view of the need for space travel (for survival of the human race), they also provide an interesting view of many aspects involved in exploring the solar system and the stars. Another aspect of interest is the discussion of potential nonspace applications of mirror matter, ranging from powering an undersea "village" ranging on to "mirror matter medicine" and educational uses. (Can fusion compete in these aspects also?)

Overall, this book may be heavy stuff for the average layman. However, those with a bent to technical subjects and/or science fiction should find it enjoyable and instructive. Fusion experts will find it enlightening.

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The Fourth State of Matter: An Introduction to the Physics of Plasma

Authors	Yaffa and Shalom Eliezer
Publisher	Adam Hilger, Bristol and Philadelphia (1989)
Pages	226
Price	$24.00
Reviewer	Thomas J. Dolan

This is a nonmathematical book that tries to acquaint ordinary people with the wonders of plasma physics. The book is similar in scope to Artsimovich's *Elementary Plasma Physics* and Boley's *Plasmas, Laboratory and Cosmic*, except that those books use mathematical equations. This book arose from a secretary's curiosity about the work of her plasma physicist husband. It is written in plain English to explain things to people who don't speak "physics." Some rhyming verse is inserted "to put big ideas and complicated issues into a compact, simplified and sometimes easy-to-remember form."

Chapter 1 provides a historical background of atomic theory, the periodic table, and nuclear theory. Chapter 2 describes the plasma state of matter and the features that make it unique. Several colorful illustrations are used to describe the phenomena in common terms, such as "a visit to an exotic nightclub" (ionization), "a joint ping-pong game" (collective interactions), "a one-mile run" (velocity distribution), and bowling (collisions). "The Solution to the Energy Problem" (Chap. 3) discusses fusion conditions, magnetic plasma confinement, tokamaks, and magnetic mirrors, followed by inertial confinement fusion experiments and reactors. I enjoyed the description of a future energy-poor world in the saga, "Soylent Green." Chapter 4 describes the cosmos on a level comparable to Hawking's book, *A Brief History of Time*. (Hawking's publisher warned him that each equation would halve the audience.) Chapter 5 presents the history of plasma physics. Chapter 6, "From the Visual to the Plasma Universe," describes the growth of man's knowledge of the universe, from astronomical observations (three millenia), to Newtonian dynamics (three centuries), to plasma physics (20th century). Then it tells about present and future applications of plasma physics, such as lasers and accelerators.

There are a few details I would change:

1. In Figs. 2.6 and 3.13, it is difficult to tell the directions of the spirals.

2. I believe that the energy equivalent should be 300 ℓ gasoline/1 ℓ water, not 500 000 ℓ gasoline/1 glass water.

3. By-products of fusion reactors (neutrons) *can* be used to produce nuclear weapons materials.

4. In my opinion, fusion reactors would not be as "clean" as implied.

5. A couple of the analogies seemed inappropriate: wind – magnetic field and compressional heating – people in a room.

The book is remarkably free from typographical errors.

As a nuclear fusion enthusiast, I would have enjoyed seeing brief discussions of other fusion concepts, e.g., stellarators, field-reversed configurations, muon-catalyzed fusion, and cold fusion. The index and glossary are well done. A bibliography would be useful.

The authors have avoided using anthropomorphisms. Their concessions to public ignorance, such as using "million million" instead of 10^{12} should help make this book widely accessible. "In our book we have tried to translate plasma science from the language of physics to the simple language of English. It is hoped that, in this way, this subject will be more comprehensible to the layman, the curious and intelligent individual, the student, the physicist's wife and any other curious reader . . . If, after having read this book, the reader becomes acquainted with plasma physics and realizes the importance of this subject for solving the energy problem, we think that a valuable message has been delivered." This book thus fills a role similar to the excellent TV video program *Fire from the Sun*. The authors attempt to bridge the gap between "Science" and "Literature" described in Snow's *Two Cultures and the Scientific Revolution*. I believe that they have succeeded.

Tom Dolan (PhD, nuclear engineering, University of Illinois, 1970) studied plasma physics in the USSR, taught at the University of Missouri-Rolla, and wrote the textbook Fusion Research *(Pergamon Press, 1982). He is currently involved with fusion reactor design, university programs, and arms control policy studies at the Idaho National Engineering Laboratory.*