Weak Scale Supersymmetry

From Superfields to Scattering Events

Howard Baer and Xerxes Tata

Cambridge U. Press, New York, 2006. $80.00 (537 pp.). ISBN 0-521-85786-4

Theory and Phenomenology of Sparticles

An Account of Four-Dimensional *N* = 1 Supersymmetry in High Energy Physics

Manuel Drees, Rohini Godbole, and Probir Roy

World Scientific, Hackensack, NJ, 2005. $108.00, $64.00 paper (555 pp.). ISBN 981-02-3739-1, ISBN 981-256-531-0 paper

Modern Supersymmetry

Dynamics and Duality

John Terning

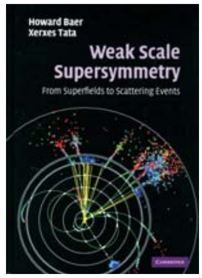
Oxford U. Press, New York, 2006. $99.50 (324 pp.). ISBN 0-19-856763-4

Supersymmetry is a remarkable possible symmetry of nature and a subfield with an odd history. It was proposed in the early 1970s around the same time as the development of the standard model (SM) and during the study of quantum field theories in other than four dimensions. The well-tested SM of particle physics is an extraordinary achievement of a century of physics. It tells us that the fundamental forms of matter are quarks and leptons and that they interact via electromagnetic, weak, and strong forces in a full, relativistic quantum field theory to form the world we see.

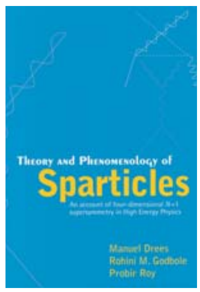
Yet the SM cannot answer a number of basic questions, including why the universe is made of matter and not antimatter. It also cannot provide a candidate particle for the dark matter of the universe, nor can it explain why the electroweak symmetry of the model is broken by Higgs physics to allow quarks and leptons to have mass, or why the weak force is so much stronger than the gravitational force.

The development of supersymmetry was unconventional. The theory was understood slowly and pursued because of its beauty, even though it did not seem relevant to nature. The four-dimensional version was written a few years after the SM was developed. About a decade later, researchers began to realize that the supersymmetric SM might be relevant to understanding our world. Supersymmetry is the only major theory not invented to resolve a puzzle or solve a problem.

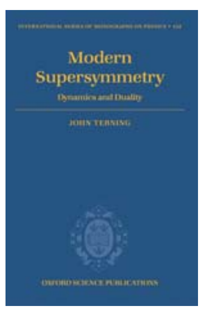
For a long time only a few books have described the theory, but they give little or no discussion of how to determine whether nature is supersymmetric and what that would imply. Steven Weinberg's powerful *The Quantum Theory of Fields: Vol. 3, Supersymmetry* (Cambridge U. Press, 2000) was limited in its discussion of ways to test whether nature was supersymmetric. At least three new books on the subject have been published: *Weak Scale Supersymmetry: From Superfields to Scattering Events* by Howard Baer and Xerxes Tata; *Theory and Phenomenology of Sparticles: An Account of Four-Dimensional* N = 1 *Supersymmetry in High Energy Physics* by Manuel Drees, Rohini Godbole, and Probir Roy; and *Modern Supersymmetry: Dynamics and Duality* by John Terning. Two more books have been scheduled for publication by now or later this winter: Pierre Binétruy's *Supersymmetry* (Oxford U. Press) and Michael Dine's *Supersymmetry and String Theory* (Cambridge U. Press), and both have extensive and welcome treatments of cosmology and what might be called string theory for particle theorists. The three books reviewed here are very good texts, each with its particular strengths. Although the books are suitable for those who want to begin working in the field, nonexperts can get substantial insights into the goals and motivation behind the theory by browsing through the texts.



One way to think of supersymmetry is that it associates to each SM particle—electron, top quark, photon, gluon, and so forth—a superpartner with a spin that differs by half a unit, yet all other quantum numbers stay the same. The names of the superpartners are pleasant: superpartners of fermions have an "s" in front of the fermion's name (for example, selectron and top squark), and superpartners of bosons that transmit forces have an "ino" suffix (such as photino and gluino). Because the superpartners have not yet been detected, the physical symmetry between the SM particles and superpartners must be broken. Other, more formal ways exist to view supersymmetry, such as imagining a world in "superspace" where each dimension has an associated quantum-fermionic dimension.



To establish that supersymmetry is a symmetry of nature, researchers will have to detect some of the superpartners experimentally. If supersymmetry can be established, it can provide explanations for some of the problems mentioned above, such as the matter asymmetry, dark matter, and electroweak symmetry breaking. However, solving those problems requires that the breaking of the supersymmetry does not separate particles and their superpartner sparticles by much more than a few times the mass of the heaviest quark. The now defunct Large Electron–Positron Collider at CERN could have found superpartners if researchers had been lucky, but it did not. The Tevatron collider at Fermilab in Illinois covers part of the reasonable mass range; the Large Hadron Collider, under construction at CERN, with an initial test run planned for 2008, is expected to cover the entire well-motivated mass range.



Baer and Tata's *Weak Scale Supersymmetry* is the most phenomenological text, closest to what will be needed to make detailed interpretations of the data. The book devotes more than 200 pages to sparticle production at colliders, sparticle decays, and the search for sparticles; it also includes a chapter on simulations of how superpartner events would look in detectors. Baer and Tata's book is a good introduction to practical supersymmetry theory and offers a helpful chapter on the superspace formalism and material on possible ways of breaking supersymmetry. Although other books that cover the field focus more on the two-component formalism, the authors use only the four-component spinor formalism, which is most practical for phenomenological calculations. The text has useful appendixes with formulas for production cross sections and sparticle and Higgs decay widths.

Theory and Phenomenology of Sparticles by Drees, Godbole, and Roy is also practical. About 300 pages cover the phenomenology of supersymmetry—from colliders to dark matter—with significant discussion of supersymmetry breaking and a 30-page chapter on supersymmetric Higgs bosons. The book begins with a good pedagogical treatment of the superspace formalism and ends with an extensive summary of Feynman rules. Both *Theory and Phenomenology of Sparticles* and *Weak Scale Supersymmetry* emphasize the minimal supersymmetric SM, an extension of the SM that gives every SM particle a superpartner but adds no new forces. If supersymmetry were not a broken symmetry, the MSSM would add no new parameters to the SM.

Terning's *Modern Supersymmetry* is quite different. The monograph begins with a good overview of Lagrangians and the MSSM. The book's main focus is on supersymmetric, relativistic quantum field theories, with good pedagogical treatments of nonperturbative results. It contains helpful discussions of the importance of holomorphy, exact solutions, Seiberg duality, and Witten–Seiberg theory, with considerable attention to formal ways of breaking supersymmetry. Baer and Tata and Drees, Godbole, and Roy offer nice introductory treatments of the important subject of nonrenormalization theorems via the Wess–Zumino model, while Terning presents a modern, general derivation in a strong chapter on the power of holomorphy.

If superpartners are indeed discovered at the Tevatron or Large Hadron Collider, these books will provide valuable help and tools in interpreting the data and in understanding the implications of the discoveries. The SM provides a description of how the world works; supersymmetry, so compelling to many particle physicists, could begin to teach us why the world is the way it is. Having good books on hand will make such insights easier to develop and more accessible.

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new books

astronomy and astrophysics

Astronomical Image and Data Analysis. 2nd ed. J.-L. Starck, F. Murtagh. *Astronomy and Astrophysics Library*. Springer, New York, 2006 [2002]. $119.00 (335 pp.). ISBN 3-540-33024-0

Astrophysical Concepts. 4th ed. M. Harwit. *Astronomy and Astrophysics Library*. Springer, New York, 2006 [1998]. $89.95 (714 pp.). ISBN 0-387-32943-9

Evolutionary Processes in Binary and Multiple Stars. P. Eggleton. *Cambridge Astrophysics Series 40*. Cambridge U. Press, New York, 2006. $120.00 (322 pp.). ISBN 0-521-85557-8

New Horizons in Astronomy: Frank N. Bash Symposium 2005. S. J. Kannappan et al., eds. *Astronomical Society of the Pacific Conference Series 352*. Proc. symp., Austin, TX, Oct. 2005. Astronomical Society of the Pacific, San Francisco, 2006. $77.00 (304 pp.). ISBN 1-58381-220-2

Physics of Active Galactic Nuclei at All Scales. D. Alloin, R. Johnson, P. Lira, eds. *Lecture Notes in Physics 693*. Springer, New York, 2006. $59.95 (233 pp.). ISBN 3-540-31207-2

atomic and molecular physics

Exploring the Quantum: Atoms, Cavities, and Photons. S. Haroche, J.-M. Raimond. *Oxford Graduate Texts*. Oxford U. Press, New York, 2006. $89.50 (605 pp.). ISBN 0-19-850914-6

Molecular Theory of Solutions. A. Ben-Naim. Oxford U. Press, New York, 2006. $124.50, $64.50 *paper* (380 pp.). ISBN 0-19-929969-2, ISBN 0-19-929970-6 *paper*