

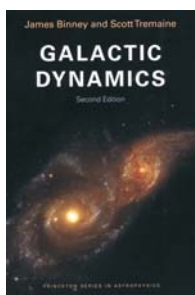
the concluding topic for the first edition—was similarly undeveloped.

Galactic Dynamics begins with an observational introduction that is broader in scope than its predecessor. As one who frequently teaches galactic dynamics to students who had somehow missed out on basic astrophysics, I find the new introduction very useful. It provides a comprehensive overview of essential stellar astrophysics, galaxies, star clusters, clusters and groups of galaxies, and the basic concepts of collisionless dynamics and cosmology.

In the 20 years since the first edition was published, astronomers have developed powerful new numerical orbit-based techniques for constructing stellar systems, each of which is tailor made to match the observational constraints on a system's structure and kinematics. We have learned much about massive black holes at the centers of galaxies and about how those black holes affect the dynamics of their host galaxy. The use of stellar kinematics as a mass detector has advanced greatly, both for central black holes and for application to more general problems in galaxies. The halos of dark matter that envelop galaxies are affected by adiabatic compression as stellar disks grow slowly in the halos' inner regions, and the halos in turn influence the behavior of the disks. Those and other topics appear in the chapters on potential theory, orbits, and the equilibrium of stellar systems.

Dynamicists have changed their perspectives concerning spiral structure in galaxies, and there is now more interest in how transient spiral structure and the central bars in galaxies can affect the stars of the disk by transporting angular momentum and inducing observable resonant effects. Nonetheless, the more classical theory of spiral waves remains interesting and is still thoroughly presented. The chapter on kinetic theory includes the dynamics of binary interaction, the statistical mechanics of gravitating systems, the gravothermal catastrophe, and the evolution of stellar systems as they are affected by those processes. Much of the chapter pertains more to the dynamics of star clusters than to galaxies, but the dynamics is nonetheless interesting and important because it is essential for understanding the star-cluster populations observed in galaxies.

In the current cold-dark-matter cosmology, galaxies are built from the merging of smaller entities. For that rea-



son, the encounters, merging, and destruction of galaxies are important topics in dynamics. Dynamical friction, tides, and high-speed encounters are all relevant, and the new edition contains an expanded discussion of those topics. It also includes new material on the evolution of binary black holes and additional information on

the evolution of tidal tails and streamers.

The book ends with an expanded and useful set of technical appendices. A new feature, the use of boxes, highlights special points of interest. Those boxes are not detailed in the table of contents; it would be helpful to list them in a future reprinting.

The second edition of *Galactic Dynamics* is a successful revision of its 1987 predecessor and will long be a reference for those working on galaxies. Astronomers teaching advanced courses in galactic dynamics will also use it widely, in part because it includes an expanded collection of interesting and demanding problems for teaching and consolidation of the wealth of material presented in the book.

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The Black Hole War

My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics

Leonard Susskind
Little, Brown and Co, New York,
2008. \$27.99 (470 pp.).
ISBN 978-0-316-01640-7

The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics is a highly informative and entertaining book about a fundamental debate in physics. Leonard Susskind, an innovative physicist and a father of string theory, gives a fast-moving, personal account of his clash with Stephen Hawking about whether black holes permanently remove information from the universe.

In 1974 Hawking discovered that black holes are not completely black but instead emit what is now called Hawking radiation. That means that black holes will lose mass and, presumably, eventually evaporate away. But what happens to the information that falls into the black holes?

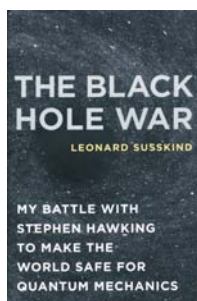
Not long after his seminal discovery, Hawking proposed that such information

is permanently lost from the universe when a black hole disappears. In his 1976 *Physical Review D* paper "Breakdown of Predictability in Gravitational Collapse," Hawking argued, "Because part of the information about the state of the system is lost down the hole, the final situation is represented by a density matrix rather than a pure quantum state." That is, after the black hole evaporates, one is confronted with an additional uncertainty beyond that demanded by the Heisenberg uncertainty principle.

Hawking's was a radical suggestion, since nowhere else in physics is there thought to be such a fundamental loss of information. Certainly, information can be lost in practice as it radiates away. If you put a match to a newspaper article, the information is essentially gone for good. But physicists had generally agreed that the unitary time evolution of quantum mechanics guarantees that in principle, no information would be irretrievably lost. Given enough effort and resources, you could reconstruct the newspaper article from the postcombustion ashes, smoke, and photons. Hawking argued that the situation was different in gravity, because gravitational collapse leads to singularities at which information can leave the universe.

For many years the information-loss question was considered by only a small number of physicists, mainly in the relativity community. Most of them sided with Hawking. Only a few were persuaded by my 1980 objection that Hawking's result depended on the semiclassical approximation of effectively treating the black hole itself classically rather than quantum mechanically.

Susskind heard of the issue at an Erhard Seminars Training conference in 1981—not 1983 as stated in the book, Susskind now tells me—that was also attended by Hawking. Unlike most of my relativist colleagues, Susskind became intensely upset by the idea that information might be lost. He and colleagues Thomas Banks and Michael Peskin soon came up with their own objection to Hawking's proposal. Theirs was the 66th paper to cite Hawking on the issue, but only the sixth to make an objection—the first four were by me and the fifth was by David Gross. As Susskind describes it in his book, "Although I knew that Stephen was wrong, I couldn't find the hole in his reasoning. Perhaps that was what irritated me the most."



The bulk of the book is Susskind's dramatic account of the "war" he entered to "make the world safe for quantum mechanics." Like some American accounts of World War II that start with 1941, Susskind's history does not describe the initial skirmishes. His account begins with 1981, but from then on he gives a good summary of the conflict. My own experience confirms Susskind's description: "It was not a war between angry enemies; indeed the main participants are all friends. But it was a fierce intellectual struggle of ideas between people who deeply respected each other but also profoundly disagreed."

Susskind provides a fascinating popularization of the physics involved, including quantum theory, gravity, string theory, the holographic principle, and Juan Maldacena's AdS/CFT (anti-de Sitter/conformal field theory) conjecture. He explains how those ideas convinced him and others that information is not really lost from the universe. Hawking held out for 28 years, but, as recounted in the book's epilogue, in 2004 he made a widely publicized statement in which he agreed that information is preserved.

Susskind argues that the black hole war has been won by those who fought to save the world for quantum mechanics. Although I have generally agreed with that position for more than 29 years, and I recognize that strong reasons have been developed to support it, I would caution that theorists do not yet fully understand how information gets out of a black hole or, alternatively, avoids falling into one. For example, though string theory calculations provide enormous support for Maldacena's idea, it still remains a conjecture that a gravitational theory of spacetime is equivalent to a nongravitational, information-preserving theory on the spacetime boundary. I personally think that information is not lost, but I do not think that my view has yet been proven beyond a shadow of a doubt.

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new books

acoustics

Acoustical Imaging. Vol. 29. I. Akiyama, ed. Proc. symp., Kanagawa, Japan, Apr. 2007. Springer, New York, 2008. \$299.00 (503 pp.). ISBN 978-1-4020-8822-3, CD-ROM

astronomy and astrophysics

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Atlas of the Messier Objects: Highlights of the Deep Sky. R. Stoyan, S. Binnewies, S. Friedrich (translated from German by K.-P. Schroeder). Cambridge U. Press, New York, 2008. \$70.00 (370 pp.). ISBN 978-0-521-89554-5

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