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Book review

An Introduction to Black Holes, Information and the String Theory Revolution: The Holographic Universe.
Leonard Susskind and James Lindesay
2005 Singapore: World Scientific
183 pp
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The evaporation of a black hole formed by the collapse of matter is a nonunitary process involving loss of information. At least, this is how it appears in Hawking's semiclassical description, in which gravity is not quantized and the emergent radiation appears thermal.

Since unitarity is one of the pillars of quantum mechanics there has been an understandable reluctance to accept this as an ironclad conclusion. Conformal field theories in flat space are manifestly unitary, and the AdS/CFT correspondence therefore suggests that the information trapped in the depths of the hole must find some way to escape—a conclusion almost universally accepted today, at least among particle theorists. Just how it could escape remains a mystery, however, since nothing can escape without violating causality until the black hole has shrunk too far to hold much information.

Gerard 't Hooft and the senior author of this book, Leonard Susskind, have been vocal advocates of the view that the information paradox poses a real crisis for physics requiring significant paradigm shifts. They suggest that locality must be given up as an objective property of physical phenomena (even on large scales) and replaced by a new principle of 'black hole complementarity'.

Specifically, there are two very different ways to view the process of collapse and evaporation. To a free-falling observer, nothing unusual happens at the horizon and matter and information fall deep into the hole. To a stationary observer hovering just outside the hole it appears instead that the matter and information are deposited on the horizon (which he experiences as very hot because of his large acceleration), to be eventually re-emitted from there as Hawking radiation. According to 't Hooft and Susskind, these must be viewed as equally valid, 'complementary' descriptions of the same process. Black hole complementarity is essentially the statement (supported by operational arguments) that their simultaneous validity cannot lead to inconsistencies.

Students and nonspecialists will welcome this book, which provides an entry into this fascinating realm at a level that can be enjoyed by an enterprising undergraduate.

The first chapter introduces the Schwarzschild black hole and the various coordinate systems used for its description. In four brief chapters (29 pages) the authors then manage a clear presentation of the thermal properties of quantum fields in Rindler and Schwarzschild space that skirts the operator formalism of QFT. Two further chapters treat charged black holes and the stretched-horizon description of black hole electrodynamics.

Chapter 8, 'The Laws of Nature', explains how information is quantified, the quantum xerox principle and the entanglement entropy of black holes, with a detailed account of how this evolves as the hole evaporates. This sets the stage for a discussion of the black hole information puzzle and the complementarity principle in chapter 9.

The pace heats up in the second part of the book, which in 48 pages sketches a variety of topics: Bousso's entropy bound and holography, the AdS/CFT correspondence, a 13 page introduction to string theory and the ideas underlying the string-based derivations of the entropy–area relation for higher-dimensional black holes.

This well-planned, stimulating and sometimes provocative book can be enthusiastically recommended.

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