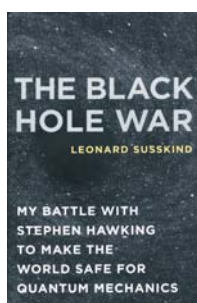


is permanently lost from the universe when a black hole disappears. In his 1976 *Physical Review D* paper "Breakdown of Predictability in Gravitational Collapse," Hawking argued, "Because part of the information about the state of the system is lost down the hole, the final situation is represented by 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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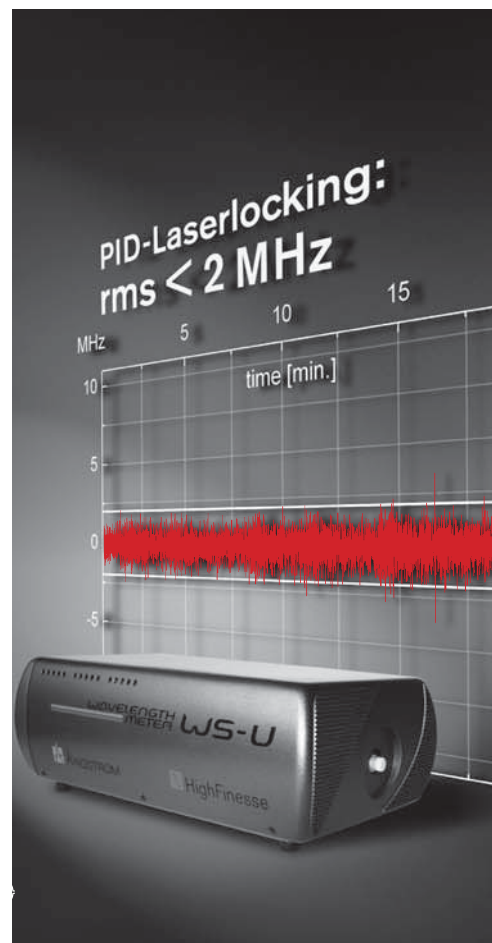
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