Jacob Bekenstein, Physicist, Dies at 68; Revolutionized the Study of Black Holes

By DENNIS OVERBYE

Jacob Bekenstein, a physicist who prevailed in an argument with Stephen Hawking that revolutionized the study of black holes, and indeed the nature of space-time itself, died on Sunday in Helsinki, Finland, where he was to give a physics lecture. He was 68.

The cause was a heart attack, said the Hebrew University of Jerusalem, where Dr. Bekenstein was the Michael Polak professor emeritus of theoretical physics.

Dr. Bekenstein's greatest achievement came in the early 1970s, when he was a graduate student at Princeton and got into a feud with Dr. Hawking, the celebrated physicist and expert on black holes.

Black holes are the prima donnas of Einstein's general theory of relativity, which predicts that space wraps itself completely around some object, causing it to disappear as a black hole. Dr. Bekenstein suggested in his Ph.D. thesis that the black hole's entropy, a measure of the disorder or wasted energy in a system, was proportional to the area of a black hole's event horizon, the spherical surface in space from which there is no return. According to accepted physical laws, including Dr. Hawking's own work, neither entropy nor the area of a black hole could ever decrease.

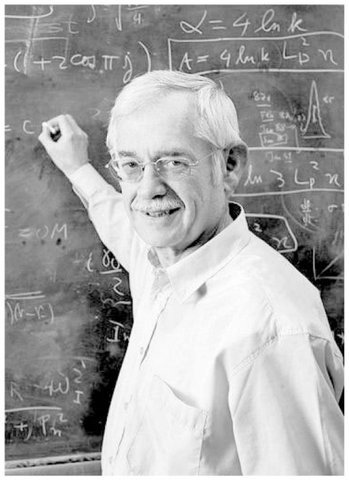
Raphael Bousso, of the University of California, Berkeley, who was both a student of Dr. Hawking's and a friend of Dr. Bekenstein's, called Dr. Bekenstein's proposition "among the most daring, yet elegant, arguments that I've seen in physics."

Dr. Hawking denounced the idea. According to classical physics, anything with entropy had to have a temperature, and anything with a temperature — from a fevered brow to a star — must radiate heat and light with a characteristic spectrum. But a black hole could not radiate, and thus it could have no temperature and therefore no entropy.

Or so everybody thought until 1974, when Dr. Hawking did a prodigious calculation including quantum theory, the strange rules that govern the subatomic world, and was shocked to find particles coming away from the black hole, indicating that it was not so black after all.

Afraid he had made a mistake, Dr. Hawking, as he wrote in his book "A Brief History of Time," kept his calculation quiet at first. "I was afraid," he said, "that if Bekenstein found out about it, he would use it as a further argument to support his ideas about the entropy of black holes, which I still did not like."

He was finally convinced, Dr.



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A Bekenstein theory won over a skeptical Stephen Hawking.

Hawking wrote, when he recognized that the radiation from the black hole would have the same characteristic heat spectrum as heat, just as Dr. Bekenstein's theory had implied.

Today it is called Bekenstein-Hawking radiation, and its discovery is considered a landmark in the quest, so far unfinished, to fulfill the Einsteinian dream of a unified theory of both the gravity that bends the cosmos and the quantum chaos that lives inside of it, so-called quantum gravity.

Dr. Bekenstein received the Wolf Prize in 2012 and the American Physical Society's Einstein prize this year. Both have often been precursors to the Nobel Prize. (The Nobel is not awarded posthumously.)

Lee Smolin, a theorist at the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, said, "No result in theoretical physics has been more fundamental or influential than his discovery that black holes have entropy proportional to their surface area."

Dr. Bousso called Dr. Bekenstein "one of the very few giants in the field of quantum gravity."

Jacob David Bekenstein was born in Mexico City on May 1, 1947, to Joseph Bekenstein, a carpenter, and the former Esther Vladaslavotsky, a homemaker. Jewish immigrants from Poland, they had met in Mexico during World War II.

Inspired by the launch of the Russian satellite Sputnik in 1957, Jacob and his friends gathered after school to launch rockets.

He became an American citizen in 1968 while attending the Polytechnic University of Brooklyn, now part of New York University, from which he graduated in 1969. He maintained American and Israeli citizenship.

He went on to graduate school at Princeton, gaining a Ph.D. in 1972 under John Wheeler, the teacher and visionary who popularized the term black hole.

After a postdoctoral stint at the University of Texas at Austin, Dr. Bekenstein moved to the Ben-Gurion University of the Negev in Beersheba, where he eventually became chairman of the astrophysics department. In 1990 he joined the faculty of the Hebrew University of Jerusalem.

He is survived by his wife, Bilha Bekenstein; three children, Yehonadav, Uriya and Rivka Bekenstein, all of them scientists; his sister, Bella; and six grandchildren.

It was in his doctoral thesis in 1972 that Dr. Bekenstein made his breakthrough.

As both he and Dr. Wheeler later recalled, it all started over tea. What, Dr. Wheeler asked his student, would happen if you poured a hot cup of tea into a black hole?

If the hot tea went into a black hole, it would take its heat and entropy with it, causing its entropy to disappear from the universe, because black holes, according to the prevailing view, were not allowed to have temperature or entropy. That meant the entropy of the universe would decrease, going against the second law of thermodynamics, one of the pillars of physics and one of the great pessimistic statements of civilization.

The law decrees that entropy or disorder always increases in a closed system, like a car engine or the universe. Whatever you do, you always waste a little energy that cannot be retrieved. This means, among other things, that perpetual-motion machines are impossible.

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"So either the second law of thermodynamics is irrelevant or it isn't working," Dr. Bekenstein told an interviewer from the website Haaretz.com in 2012. This was a serious consequence for a law of physics that had served well for 150 years. "I tried to find a way to save it and fix things up."

His solution was to attribute entropy to black holes, bringing them into the realm of thermodynamic law. "My idea was that when you throw into a black hole some entropy, from a cup of tea for example, the black hole's surface area grows a bit, so the entropy created in the black hole offsets the entropy of the tea and anything else that was thrown into it."

Today Dr. Bekenstein's idea is the cornerstone of attempts to unite quantum theory with Einsteinian gravity, to produce a theory of quantum gravity that can explain what happened in the Big Bang or in a black hole.

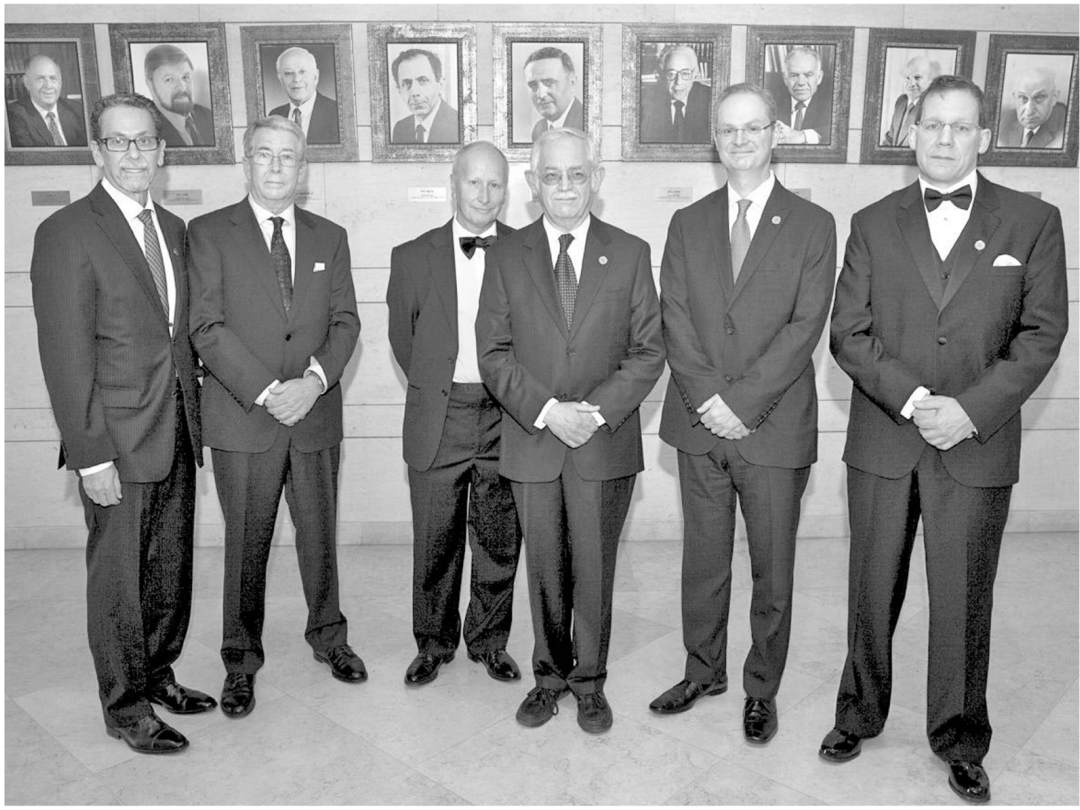
Disorder is just lost information, so among its more profound implications is that the amount of information that can be stored in a region of space is determined by the area of a surface surrounding it and not, as one might expect, by the volume inside. This means that a black hole — and perhaps the universe itself — is like a hologram, in which three-dimensional information is encoded on a two-dimensional surface. Physicists are still grappling with what that means for the universe.

Dr. Bekenstein went on to develop what is called the Bekenstein Bound, showing that there is a limit to how much information can be packed into a region with finite space and finite energy. Among other things, it suggests that the storage capacity of a human brain, though very large, is finite and at least in principle could be uploaded to a machine.

At a conference commemorating the 40th anniversary of Dr. Bekenstein's discovery, Ted Jacobson, a theorist from the University of Maryland, said, "To end on a note of unbridled hyperbole, we can say that in discovering black entropy, Jacob touched on the origin of all that we see, all that we are, and all that will ever be, and brought it closer to us."

In the Haaretz.com interview, Dr. Bekenstein put it more modestly. "I look at the world as a product of God," he said. His job as a scientist, he added, was to figure out how it works.

"I feel much more comfortable in the world because I understand how simple things work," he said. "I get a sense of security that not everything is random, and that I can actually understand and not be surprised by things."



MENAHEM KAHANA/AGENCE FRANCE-PRESSE — GETTY IMAGES

Jacob Bekenstein, third from right, who won the 2012 Wolf Prize in physics, often a forerunner for a Nobel, with recipients in other fields at ceremonies at Israel's Parliament in Jerusalem.