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Stephen Hawking Dies at 76; His Mind Roamed the Cosmos

A physicist and best-selling author, Dr. Hawking did not allow his physical limitations to hinder his quest to answer "the big question: Where did the universe come from?"

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By DENNIS OVERBYE MARCH 14, 2018

Stephen W. Hawking, the Cambridge University physicist and best-selling author who roamed the cosmos from a wheelchair, pondering the nature of gravity and the origin of the universe and becoming an emblem of human determination and curiosity, died early Wednesday at his home in Cambridge, England. He was 76.

A university spokesman confirmed the death.

"Not since Albert Einstein has a scientist so captured the public imagination and endeared himself to tens of millions of people around the world," Michio Kaku, a professor of theoretical physics at the City University of New York, said in an interview.

Dr. Hawking did that largely through his book "A Brief History of Time: From the Big Bang to Black Holes," published in 1988. It has sold more than 10 million copies and inspired a documentary film by Errol Morris. His own story was the basis

of an award-winning 2014 feature film, “The Theory of Everything.” (Eddie Redmayne played Dr. Hawking and won an Academy Award.)

Scientifically, Dr. Hawking will be best remembered for a discovery so strange that it might be expressed in the form of a Zen koan: When is a black hole not black? When it explodes.

What is equally amazing is that he had a career at all. As a graduate student in 1963, he learned he had amyotrophic lateral sclerosis, a neuromuscular wasting disease also known as Lou Gehrig’s disease. He was given only a few years to live.

The disease reduced his bodily control to the flexing of a finger and voluntary eye movements but left his mental faculties untouched.

He went on to become his generation’s leader in exploring gravity and the properties of black holes, the bottomless gravitational pits so deep and dense that not even light can escape them.

That work led to a turning point in modern physics, playing itself out in the closing months of 1973 on the walls of his brain when Dr. Hawking set out to apply quantum theory, the weird laws that govern subatomic reality, to black holes. In a long and daunting calculation, Dr. Hawking discovered to his befuddlement that black holes — those mythological avatars of cosmic doom — were not really black at all. In fact, he found, they would eventually fizzle, leaking radiation and particles, and finally explode and disappear over the eons.

Nobody, including Dr. Hawking, believed it at first — that particles could be coming out of a black hole. “I wasn’t looking for them at all,” he recalled in 1978. “I merely tripped over them. I was rather annoyed.”

That calculation, in a thesis published in 1974 in the journal Nature under the title “Black Hole Explosions?,” is hailed by scientists as the first great landmark in the struggle to find a single theory of nature — to connect gravity and quantum mechanics, those warring descriptions of the large and the small, to explain a universe that seems stranger than anybody had thought.

The discovery of Hawking radiation, as it is known, turned black holes upside down. It transformed them from destroyers to creators — or at least to recyclers — and wrenched the dream of a final theory in a strange, new direction.

"You can ask what will happen to someone who jumps into a black hole," Dr. Hawking said in 1978. "I certainly don't think he will survive it.

"On the other hand," he added, "if we send someone off to jump into a black hole, neither he nor his constituent atoms will come back, but his mass energy will come back. Maybe that applies to the whole universe."

Dennis W. Sciama, a cosmologist and Dr. Hawking's thesis adviser at Cambridge, called Hawking's thesis in Nature "the most beautiful paper in the history of physics."

Edward Witten, a theorist at the Institute for Advanced Study in Princeton, said: "Trying to understand Hawking's discovery better has been a source of much fresh thinking for almost 40 years now, and we are probably still far from fully coming to grips with it. It still feels new."

In 2002, Dr. Hawking said he wanted the formula for Hawking radiation to be engraved on his tombstone.

He was a man who pushed the limits — in his intellectual life, to be sure, but also in his professional and personal lives. He traveled the globe to scientific meetings, visiting every continent, including Antarctica; wrote best-selling books about his work; married twice; fathered three children; and was not above appearing on "The Simpsons," "Star Trek: The Next Generation" or "The Big Bang Theory."

He celebrated his 60th birthday by going up in a hot-air balloon. The same week, he also crashed his electric-powered wheelchair while speeding around a corner in Cambridge, breaking his leg.

In April 2007, a few months after his 65th birthday, he took part in a zero-gravity flight aboard a specially equipped Boeing 727, a padded aircraft that flies a roller-coaster trajectory to produce fleeting periods of weightlessness. It was a

prelude to a hoped-for trip to space with Richard Branson's Virgin Galactic company aboard SpaceShipTwo.

Asked why he took such risks, Dr. Hawking said, "I want to show that people need not be limited by physical handicaps as long as they are not disabled in spirit."

His own spirit left many in awe.

"What a triumph his life has been," said Martin Rees, a Cambridge University cosmologist, the astronomer royal of England and Dr. Hawking's longtime colleague. "His name will live in the annals of science; millions have had their cosmic horizons widened by his best-selling books; and even more, around the world, have been inspired by a unique example of achievement against all the odds — a manifestation of amazing willpower and determination."

Studies Came Easy

Stephen William Hawking was born in Oxford, England, on Jan. 8, 1942 — 300 years to the day, he liked to point out, after the death of Galileo, who had begun the study of gravity. His mother, the former Isobel Walker, had gone to Oxford to avoid the bombs that fell nightly during the Blitz of London. His father, Frank Hawking, was a prominent research biologist.

The oldest of four children, Stephen was a mediocre student at St. Albans School in London, though his innate brilliance was recognized by some classmates and teachers.

Later, at University College, Oxford, he found his studies in mathematics and physics so easy that he rarely consulted a book or took notes. He got by with a thousand hours of work in three years, or one hour a day, he estimated. "Nothing seemed worth making an effort for," he said.

The only subject he found exciting was cosmology because, he said, it dealt with "the big question: Where did the universe come from?"

He moved to Cambridge upon his graduation from Oxford. Before he could begin his research, however, he was stricken by what his research adviser, Dr.

Sciama, came to call “that terrible thing.”

The young Hawking had been experiencing occasional weakness and falling spells for several years. Shortly after his 21st birthday, in 1963, doctors told him that he had amyotrophic lateral sclerosis. They gave him less than three years to live.

His first response was severe depression. He dreamed he was going to be executed, he said. Then, against all odds, the disease appeared to stabilize. Though he was slowly losing control of his muscles, he was still able to walk short distances and perform simple tasks, though laboriously, like dressing and undressing. He felt a new sense of purpose.

“When you are faced with the possibility of an early death,” he recalled, “it makes you realize that life is worth living and that there are a lot of things you want to do.”

In 1965, he married Jane Wilde, a student of linguistics. Now, by his own account, he not only had “something to live for”; he also had to find a job, which gave him an incentive to work seriously toward his doctorate.

His illness, however, had robbed him of the ability to write down the long chains of equations that are the tools of the cosmologist’s trade. Characteristically, he turned this handicap into a strength, gathering his energies for daring leaps of thought, which, in his later years, he often left for others to codify in proper mathematical language.

“People have the mistaken impression that mathematics is just equations,” Dr. Hawking said. “In fact, equations are just the boring part of mathematics.”

By necessity, he concentrated on problems that could be attacked through “pictures and diagrams,” adopting geometric techniques that had been devised in the early 1960s by the mathematician Roger Penrose and a fellow Cambridge colleague, Brandon Carter, to study general relativity, Einstein’s theory of gravity.

Black holes are a natural prediction of that theory, which explains how mass and energy “curve” space, the way a sleeping person causes a mattress to sag. Light rays

will bend as they traverse a gravitational field, just as a marble rolling on the sagging mattress will follow an arc around the sleeper.

Too much mass or energy in one spot could cause space to sag without end; an object that was dense enough, like a massive collapsing star, could wrap space around itself like a magician's cloak and disappear, shrinking inside to a point of infinite density called a singularity, a cosmic dead end, where the known laws of physics would break down: a black hole.

Einstein himself thought this was absurd when the possibility was pointed out to him.

Using the Hubble Space Telescope and other sophisticated tools of observation and analysis, however, astronomers have identified hundreds of objects that are too massive and dark to be anything but black holes, including a supermassive one at the center of the Milky Way. According to current theory, the universe should contain billions more.

As part of his Ph.D. thesis in 1966, Dr. Hawking showed that when you ran the film of the expanding universe backward, you would find that such a singularity had to have existed sometime in cosmic history; space and time, that is, must have had a beginning. He, Dr. Penrose and a rotating cast of colleagues published a series of theorems about the behavior of black holes and the dire fate of anything caught in them.

A Calculation in His Head

Dr. Hawking's signature breakthrough resulted from a feud with the Israeli theoretical physicist Jacob Bekenstein, then a Princeton graduate student, about whether black holes could be said to have entropy, a thermodynamic measure of disorder. Dr. Bekenstein said they could, pointing out a close analogy between the laws that Dr. Hawking and his colleagues had derived for black holes and the laws of thermodynamics.

Dr. Hawking said no. To have entropy, a black hole would have to have a temperature. But warm objects, from a forehead to a star, radiate a mixture of

electromagnetic radiation, depending on their exact temperatures. Nothing could escape a black hole, and so its temperature had to be zero. “I was very down on Bekenstein,” Dr. Hawking recalled.

To settle the question, Dr. Hawking decided to investigate the properties of atom-size black holes. This, however, required adding quantum mechanics, the paradoxical rules of the atomic and subatomic world, to gravity, a feat that had never been accomplished. Friends turned the pages of quantum theory textbooks as Dr. Hawking sat motionless staring at them for months. They wondered if he was finally in over his head.

When he eventually succeeded in doing the calculation in his head, it indicated to his surprise that particles and radiation were spewing out of black holes. Dr. Hawking became convinced that his calculation was correct when he realized that the outgoing radiation would have a thermal spectrum characteristic of the heat radiated by any warm body, from a star to a fevered forehead. Dr. Bekenstein had been right.

Dr. Hawking even figured out a way to explain how particles might escape a black hole. According to quantum principles, the space near a black hole would be teeming with “virtual” particles that would flash into existence in matched particle-and-antiparticle pairs — like electrons and their evil twin opposites, positrons — out of energy borrowed from the hole’s intense gravitational field.

They would then meet and annihilate each other in a flash of energy, repaying the debt for their brief existence. But if one of the pair fell into the black hole, the other one would be free to wander away and become real. It would appear to be coming from the black hole and taking energy away from it.

But those, he cautioned, were just words. The truth was in the math.

“The most important thing about Hawking radiation is that it shows that the black hole is not cut off from the rest of the universe,” Dr. Hawking said.

It also meant that black holes had a temperature and had entropy. In thermodynamics, entropy is a measure of wasted heat. But it is also a measure of the

amount of information — the number of bits — needed to describe what is in a black hole. Curiously, the number of bits is proportional to the black hole's surface area, not its volume, meaning that the amount of information you could stuff into a black hole is limited by its area, not, as one might think, its volume.

That result has become a litmus test for string theory and other pretenders to a theory of quantum gravity. It has also led to speculations that we live in a holographic universe, in which three-dimensional space is some kind of illusion.

Andrew Strominger, a Harvard string theorist, said of the holographic theory, "If it's really true, it's a deep and beautiful property of our universe — but not an obvious one."

To 'Know the Mind of God'

The discovery of black hole radiation also led to a 30-year controversy over the fate of things that had fallen into a black hole.

Dr. Hawking initially said that detailed information about whatever had fallen in would be lost forever because the particles coming out would be completely random, erasing whatever patterns had been present when they first fell in. Paraphrasing Einstein's complaint about the randomness inherent in quantum mechanics, Dr. Hawking said, "God not only plays dice with the universe, but sometimes throws them where they can't be seen."

Many particle physicists protested that this violated a tenet of quantum physics, which says that knowledge is always preserved and can be retrieved. Leonard Susskind, a Stanford physicist who carried on the argument for decades, said, "Stephen correctly understood that if this was true, it would lead to the downfall of much of 20th-century physics."

On another occasion, he characterized Dr. Hawking to his face as "one of the most obstinate people in the world; no, he is the most infuriating person in the universe." Dr. Hawking grinned.

Dr. Hawking admitted defeat in 2004. Whatever information goes into a black hole will come back out when it explodes. One consequence, he noted sadly, was that one could not use black holes to escape to another universe. “I’m sorry to disappoint science fiction fans,” he said.

Despite his concession, however, the information paradox, as it is known, has become one of the hottest topics in theoretical physics. Physicists say they still do not know how information gets in or out of black holes.

Raphael Bousso of the University of California, Berkeley, and a former student of Dr. Hawking’s, said the present debate had raised “by another few notches” his estimation of the “stupendous magnitude” of Dr. Hawking’s original discovery.

In 1974, Dr. Hawking was elected a Fellow of the Royal Society, the world’s oldest scientific organization; in 1979, he was appointed to the Lucasian chair of mathematics at Cambridge, a post once held by Isaac Newton. “They say it’s Newton’s chair, but obviously it’s been changed,” he liked to quip.

Dr. Hawking also made yearly visits to the California Institute of Technology in Pasadena, which became like a second home. In 2008, he joined the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, as a visiting researcher.

Having conquered black holes, Dr. Hawking set his sights on the origin of the universe and on eliminating that pesky singularity at the beginning of time from models of cosmology. If the laws of physics could break down there, they could break down everywhere.

In a meeting at the Vatican in 1981, he suggested that in the final theory there should be no place or time when the laws broke down, even at the beginning. He called the notion the “no boundary” proposal.

With James Hartle of the Institute for Theoretical Physics in Santa Barbara, Calif., Dr. Hawking envisioned the history of the universe as a sphere like the Earth. Cosmic time corresponds to latitude, starting with zero at the North Pole and progressing southward.

Although time started there, the North Pole was nothing special; the same laws applied there as everywhere else. Asking what happened before the Big Bang, Dr. Hawking said, was like asking what was a mile north of the North Pole — it was not any place, or any time.

By then, string theory, which claimed finally to explain both gravity and the other forces and particles of nature as tiny microscopically vibrating strings, like notes on a violin, was the leading candidate for a "theory of everything."

In "A Brief History of Time," Dr. Hawking concluded that "if we do discover a complete theory" of the universe, "it should in time be understandable in broad principle by everyone, not just a few scientists."

He added, "Then we shall all, philosophers, scientists and just ordinary people, be able to take part in the discussion of why it is that we and the universe exist."

"If we find the answer to that," he continued, "it would be the ultimate triumph of human reason — for then we would know the mind of God."

Until 1974, Dr. Hawking was still able to feed himself and to get in and out of bed. At Jane's insistence, he would drag himself, hand over hand, up the stairs to the bedroom in his Cambridge home every night, in an effort to preserve his remaining muscle tone. After 1980, care was supplemented by nurses.

Dr. Hawking retained some control over his speech up to 1985. But on a trip to Switzerland, he came down with pneumonia. The doctors asked Jane if she wanted his life support turned off, but she said no. To save his life, doctors inserted a breathing tube. He survived, but his voice was permanently silenced.

Speaking With the Eyes

It appeared for a time that he would be able to communicate only by pointing at letters on an alphabet board. But when a computer expert, Walter Woltosz, heard about Dr. Hawking's condition, he offered him a program he had written called Equalizer. By clicking a switch with his still-functioning fingers, Dr. Hawking was

able to browse through menus that contained all the letters and more than 2,500 words.

Word by word — and when necessary, letter by letter — he could build up sentences on the computer screen and send them to a speech synthesizer that vocalized for him. The entire apparatus was fitted to his motorized wheelchair.

Even when too weak to move a finger, he communicated through the computer by way of an infrared beam, which he activated by twitching his right cheek or blinking his eye. The system was expanded to allow him to open and close the doors in his office and to use the telephone and internet without aid.

Although he averaged fewer than 15 words per minute, Dr. Hawking found he could speak through the computer better than he had before losing his voice. His only complaint, he confided, was that the speech synthesizer, manufactured in California, gave him a new vocal inflection.

“Please pardon my American accent,” he used to say.

His decision to write “A Brief History of Time” was prompted, he said, by a desire to share his excitement about “the discoveries that have been made about the universe” with “the public that paid for the research.” He wanted to make the ideas so accessible that the book would be sold in airports.

He also hoped to earn enough to pay for his children’s education. He did. The book’s extraordinary success made him wealthy, a hero to disabled people everywhere and even more famous.

The news media followed his movements and activities over the years, from visiting the White House to meeting the Dallas Cowboys cheerleaders, and reported his opinions on everything from national health care (socialized medicine in England had kept him alive) to communicating with extraterrestrials (maybe not a good idea, he said), as if he were a rolling Delphic Oracle.

Asked by New Scientist magazine what he thought about most, Dr. Hawking answered: “Women. They are a complete mystery.”

In 1990, Dr. Hawking and his wife separated after 25 years of marriage; Jane Hawking wrote about their years together in two books, “Music to Move the Stars: A Life With Stephen Hawking” and “Traveling to Infinity: My Life With Stephen.” The latter became the basis of the movie “The Theory of Everything.”

In 1995, he married Elaine Mason, a nurse who had cared for him since his bout of pneumonia. She had been married to David Mason, the engineer who had attached Dr. Hawking’s speech synthesizer to his wheelchair.

In 2004, British newspapers reported that the Cambridge police were investigating allegations that Elaine had abused Dr. Hawking, but no charges were filed, and Dr. Hawking denied the accusations. They later divorced.

His survivors include his children, Robert, Lucy and Tim, and three grandchildren.

‘There Is No Heaven’

Among his many honors, Dr. Hawking was named a commander of the British Empire in 1982. In the summer of 2012, he had a star role in the opening of the Paralympics Games in London. The only thing lacking was the Nobel Prize, and his explanation for this was characteristically pithy: “The Nobel is given only for theoretical work that has been confirmed by observation. It is very, very difficult to observe the things I have worked on.”

Dr. Hawking was a strong advocate of space exploration, saying it was essential to the long-term survival of the human race. “Life on Earth is at the ever-increasing risk of being wiped out by a disaster, such as sudden global nuclear war, a genetically engineered virus or other dangers we have not yet thought of,” he told an audience in Hong Kong in 2007.

Nothing raised as much furor, however, as his increasingly scathing remarks about religion. One attraction of the no-boundary proposal for Dr. Hawking was that there was no need to appeal to anything outside the universe, like God, to explain how it began.

In “A Brief History of Time,” he had referred to the “mind of God,” but in “The Grand Design,” a 2011 book he wrote with Leonard Mlodinow, he was more bleak about religion. “It is not necessary to invoke God to light the blue touch paper,” he wrote, referring to the British term for a firecracker fuse, “and set the universe going.”

He went further that year, telling The Guardian: “I regard the brain as a computer which will stop working when its components fail. There is no heaven or afterlife for broken-down computers; that is a fairy story for people afraid of the dark.”

Having spent the best part of his life grappling with black holes and cosmic doom, Dr. Hawking had no fear of the dark.

“They’re named black holes because they are related to human fears of being destroyed or gobbled up,” he once told an interviewer. “I don’t have fears of being thrown into them. I understand them. I feel in a sense that I am their master.”

Correction: March 14, 2018

An earlier version of this obituary misstated the year Dr. Hawking was appointed to the Lucasian chair of mathematics at Cambridge University. It was 1979, not 1982. The earlier version also misstated part of the title of Martin Rees, a longtime colleague of Dr. Hawking’s. He is the astronomer royal of England, not Britain.

Correction: March 19, 2018

An earlier version of this obituary misstated the year of a meeting at the Vatican that Dr. Hawking attended. It was 1981, not 1982.

Correction: March 20, 2018

An earlier version of a picture caption with this obituary misstated the year the photo of Dr. Hawking and his first wife, the former Jane Wilde, was taken. It was 1988, not 1990.

Matthew Haag, Matt Stevens and Gerald Jonas contributed reporting.

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