Cosmologist Stephen Hawking dies at 76

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Renowned cosmologist, theoretical physicist and author Stephen Hawking died at his home in Cambridge, England early on March 14. He was 76 years old and is survived by his ex-wives Jane Wilde and Elaine Mason, three children and three grandchildren.

There is much to celebrate about Hawking's life. He led a rich scientific career, playing a key role in deepening our understanding of gravitational physics, thermodynamics, quantum mechanics and cosmology. He also wrote numerous books popularizing science, most notably his 1988 work *A Brief History of Time*, which remained on the bestseller list of the *Sunday Times* for 237 weeks.

His achievements are all the more remarkable considering that Hawking contracted motor neurone disease (also known as amyotrophic lateral sclerosis or Lou Gehrig's disease) when he was 21 years old. The disease confined him to a wheel chair and eventually forced him to speak with a speech synthesizer. Despite this, he continued both his work and his life, surviving beyond his original two-year life expectancy for more than half a century. The struggles faced by Hawking and his first wife Jane Wilde as his disease developed were dramatized in the 2014 film, The Theory of Everything.

Hawking was born in 1942 in Oxford, England, where his parents moved to have a child away from the bombs being dropped on London in World War II. When he was 8, he moved to St. Albans where his father, Frank, became the head of parasitology at the National Institute for Medical Research. Through his father's travels abroad and his mother, Isobel's, friends, Hawking spent a significant amount of his youth with the poet Robert Graves (*I, Claudius,* 1934).

He began his physics career at University College, Oxford in 1959 after he found that the university had no pure mathematics program. Though he was not the most diligent student (he claims he only spent 1,000 hours working throughout his undergraduate career, about one quarter that of an average student), he nonetheless developed a firm grasp of theoretical physics and received first-class honors on his degree from Oxford, allowing him to pursue graduate studies at Cambridge.

Stephen's graduate studies were almost immediately halted when he contracted Lou Gehrig's disease. Over the course of several months, as doctors realized that Hawking's particular version of the ailment acted very slowly, Hawking returned to his work on general relativity and cosmology. He obtained his doctorate in 1966 for his thesis, which took the concept of a spacetime singularity that Roger Penrose developed to study black holes and applied the mathematics to the structure of the entire Universe.

Black holes were first predicted by Karl Schwarzschild in 1916, using Albert Einstein's recently published equations of general relativity. Einstein showed that a massive body can bend the path of light as it travels from one point to another. Schwarzschild took this idea and investigated what would happen as the mass of the object increased to an arbitrary high. He found that, eventually, enormous mass produces a region of spacetime that bends light so much that its path becomes a circle and never continues its journey. This object is "black" because no light is emitted from it, and it is a "hole" because neither light nor any form of matter can leave it once inside.

Penrose was studying the mathematics that describes what occurs inside the black hole. He realized that not only does matter get trapped, it becomes denser and denser—infinitely so. At the center of a black hole, he showed that general relativity predicts a point of infinite mass and zero volume, a singularity. Hawking took this insight and combined it with the theory of the expanding Universe. He realized that if one winds back

the evolution of the Universe to the Big Bang, that too had to be one of Penrose's singularities.

Hawking's largest contribution to theoretical physics came from his attempts to combine the physics of black holes with thermodynamics—the theory that describes the relationship between heat and all forms of energy. Hawking used a framework developed by physicist Jacob Bekenstein to show that, contrary to accepted theories, black holes do have a temperature, which means that they must radiate energy and lose mass over time.

While this effect is predicted to be miniscule for known black holes, it contradicted the idea that black holes are eternally growing objects that will eventually contain everything within the Universe. Moreover, the mechanism through which black holes emit radiation requires the inclusion of quantum mechanics into the calculations to make sense. To date, this radiation is the only phenomena which requires the combined mathematics of thermodynamics, quantum mechanics and general relativity to explain.

And while it has yet to be directly or indirectly observed, this "Bekenstein-Hawking" radiation has been generally accepted as true by scientists and has led to a great many other discoveries in theoretical physics and cosmology. It also plays a key role in any theory of quantum gravity—the myriad attempts to fully combine general relativity and quantum mechanics—as one of the primary experimental tests.

Hawking's contributions to the physics of black holes established him as a preeminent scientist of his age. However, it was with the publication of *A Brief History of Time* that he became known throughout the world. The book, written for non-specialists, would be the point of entry for millions of people into an exploration of cosmological phenomena such as the Big Bang and black holes.

Hawking described in language accessible to laymen and young people such complex theories as quantum physics and the still-elusive search for the "theory of everything."

A Brief History of Time was the first of a series of popular scientific books, including *The Universe in a Nutshell, On the Shoulders of Giants,* and *God Created the Integers: The Mathematical Breakthroughs that Changed History*.

Hawking encouraged his reading public to search for rational answers and explanations for everything. "My goal is simple," he said in 1985. "It is a complete understanding of the universe, why it is as it is and why it exists at all." He told *Der Spiegel* in 1988, "We are just an advanced breed of monkeys on a minor planet of a very average star. But we can understand the Universe. That makes us something very special."

Hawking maintained a generally left-wing political stance throughout his life, declaring that the 2003 invasion of Iraq was a "war crime," campaigning against nuclear weapons, opposing the Israeli oppression of Palestinians and speaking out against cuts to Britain's National Health Service, which Hawking maintained was what allowed him to live into his 70s.

Hawking never wavered on his materialist conception of the Universe. Even as his health deteriorated, his deep understanding of the laws of motion that govern matter on cosmological scales led him to reject religion and mysticism as a way of understanding the world. He declared in 2011:

> We are each free to believe what we want, and it is my view that the simplest explanation is there is no God. No one created the universe and no one directs our fate. This leads me to a profound realisation. There is probably no heaven, and no afterlife either. We have this one life to appreciate the grand design of the universe, and for that, I am extremely grateful.