## An Ode to Stephen Hawking

Stephen Hawking was undoubtedly one of the greatest theoretical minds since Einstein. It was Hawking and Roger Penrose who first proved, using Einstein's theory of General Relativity, that the Universe must have a beginning, thereby predicting the Big Bang, and that the Universe should contain black holes. Hawking also predicted that there should be microscopic black holes produced from the Big Bang.

One of Hawking's revolutionary theories combined the use of Quantum Mechanics and General Relativity. It is a mammoth challenge to unify Quantum Mechanics and General Relativity, so much so that despite his lifelong efforts, Einstein was not successful in uniting these two concepts. These two theories are the pillars of fundamental physics of the 20th century. That a single theory could combine both these principles was extremely difficult because of the paradox inherent in combining them. The reason for this paradox was that in Quantum Mechanics, by the Uncertainty Principle at very small distances, the energy has to be very large. And according to Einstein's General Relativity, a very large energy, when confined inside a very small distance (called Schwarzschild radius or the event horizon), will collapse into a black hole. Therefore a merger of these two theories would imply that all of space and time would already have collapsed into a black hole and therefore space and time could not exist. This conflict between the two greatest proven theories has confounded the greatest theoretical minds including Einstein. Hawking was the first to calculate the working of Quantum Mechanics at the edge of a black hole. He proved that the quantum processes occurring at the edge of a black hole will cause the black hole to radiate energy. In other words, black holes are not truly black but instead lose energy by Hawking Radiation. Hawking was the first person to calculate this phenomenon by combining the principles of Quantum Mechanics and General Relativity, which proved that black holes are not permanently stable.

The theory of Hawking Radiation not only bridged a gap between phenomena occurring at very large distances and very small distances, but also allayed fears in non-scientific quarters that microscopic black holes produced during the high-energy experiments at the Large Hadron Collider (LHC) at CERN would grow to consume the Earth. Based on Hawking's calculation, I undertook a theoretical exercise, published in a paper titled "Production and Decay of Spinning Black Holes at Colliders and Tests of Black Hole Dynamics" (published 18 December 2002 in Physical Review D 66) which states that the black holes so produced are so microscopic that they would evaporate by Hawking Radiation before they could travel to the next proton or neutron to absorb their energy into its own. This happens because the rate of energy radiation increases drastically with reduction in the size of the black hole. Therefore the black hole evaporates by Hawking radiation very quickly and is never able to grow to dangerous proportions. Hawking radiation was instrumental in allaying the concerns and as recent history has shown, the LHC has operated successfully for nine years making the monumental Higgs Boson discovery.

As we speak, plans are under way to upgrade the LHC in order to operate until 2035 as the world's largest scientific experiment. Thanks to Hawking, we may find that dark matter particles are produced at the LHC. We may also find evidence for additional Higgs Bosons which explain why there is more matter than anti-matter in the Universe. Hawking's legacy has been to unify the understanding of the cosmos from the beginning of time and the edge of the Universe, with the understanding of fundamental particles and interactions at the smallest possible distances.

Hawking was diagnosed at age 22 with Amyotrophic Lateral Sclerosis (ALS), a degenerative nerve disorder known in America as Lou Gehrig's disease (after the Yankee first baseman who died of it), and was given two years to live. The progress of the disease in Hawking's case had been slow, but by the time he became the Lucasian Professor at Cambridge (a chair once held by Isaac Newton and Paul Dirac) he could no longer walk, write, feed himself, or raise his head if it tipped forward. Spending 55 years in a wheel chair without being able to move or speak, Hawking joked that this gave him more time to think. This mind produced the logic which explains how the universe operates from zero to infinity in space and time. Einstein had said that the most incomprehensible thing about the universe is that it is comprehensible. Hawking was a living demonstration of this power of the human mind regardless of any and all possible difficulties faced by the human body. Hawking's life and thought will provide endless inspiration to all of us.

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