A Brief History of Time

Author: Stephen Hawking

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In *A Brief History of Time,* Stephen Hawking sets out on a quest to lay out the history of mankind’s understanding of the universe. He then attempts to figure out the necessary components that a completely unified theory of the universe would require. It is important to note that this book was published in 1998, as a result, there have been new developments in our understanding of the universe.

In 340 B.C.E. Aristotle declared that the earth was a round sphere, giving three proofs; however, Aristotle still held firm to the belief that the earth was stationary—the center of the orbits. Ptolemy produced a model of the orbits in around 100 C.E. that largely explained the orbits accurately, while leaving the earth at the center.

In 1514, Nicholas Copernicus, circulated the first heliocentric model—one with circular orbits. In 1609, with a telescope, Galileo Galilei saw moons orbiting Jupiter and proved that things do not have to orbit the earth. Johannes Kepler added to the precision of the theory by making the orbits elliptical; this prediction finally matched the observed orbits. Kepler could not reconcile the elliptical shape with the fact that magnetic fields caused the orbits around the sun. Isaac Newton cleared this up with his law of universal gravitation. It also helped to once and for all prove that the moon orbited the earth while the earth orbited the sun.

The ancients assumed that the universe and the human race, had and will, exist forever. They claimed that if there was indeed a beginning, there would be infinite time predating it; what would cause the universe to start at a particular time? St. Augustine said time is a property of the universe and therefore did not exist before creation. During the time when it was thought that the earth was static, both a beginning and no beginning where consistent with observation.

According to Newton, there is no absolute space, but there is absolute time. Maxwell predicted that light waves should travel at a fixed speed. They needed to measure the speed relative to something, so, they created something called “ether”—similar to how sound moves through air, light moves through ether. In 1905, Albert Einstein pointed out that if one abandons the notion that time is fixed, there is no need for the ether. With his theory, he discovered a 4-dimensional spacetime. The theory of relativity postulated that the laws of science are the same for all freely moving observers. This was extended from Newton’s laws of motion to Maxwell’s theory of light. The equivalence of mass and energy— E=mc^2—also comes from the theory; this law holds matter back from travelling at or higher than the speed of light. The more energy something has due to its speed, the more mass it will have, and as it reaches the speed of light, it would take infinite energy to accelerate it further.

In 1929, Edwin Hubble observed that in every direction, galaxies are moving away from us, meaning that the universe is expanding. This meant that at some point in time, everything was in the same place and the density was infinite. Alexander Friedmann concluded that the earth isn’t static 7 years prior by assuming that space looks identical in every direction no matter where one is observing from—this assumption is true on large scales. Penzias and Wilson confirmed this assumption when they detected the cosmic microwave background, which was the same in every direction.

The point of infinite density that we previously mentioned is an issue for mathematics, general relativity predicts a point in the universe where the theory itself breaks down. One could therefore not determine the events that would arise from this singularity or predict what, if anything, came before. Penrose discovered—conceptually—singularities, emerging from the collapse of a star; a star collapses to zero volume and infinite density, creating a black hole. Using this idea and running time backward, Penrose and Hawking proved that there was a big bang singularity provided that general relativity is correct and there is as much matter in the universe as we observe.

Werner Heisenberg formulated the uncertainty principle which states that one cannot accurately measure the speed and velocity of a molecule. This shut down the possibility of measuring the location and velocity of everything at one point in time and then having the ability to predict any other point. Instead particles now had “quantum states” which were a combination of location and velocity. Quantum mechanics introduced randomness, the fact that experiments generally will show the same conclusion on a large scale is really governed by entropy and probability.

Hawking continues to explain the 4 force carrying particles. The weak gravitational force acts over long distances, is always attractive, and matters much more on big scales. The electromagnetic force dominates at the molecular level and is the cause of the electrons orbiting the nucleus. The weak nuclear force, responsible for radioactivity, was found to be made up of one particle that has three different states at low energy. Theories were then developed that unify the electromagnetic and weak nuclear forces. The strong nuclear force—gluons—hold the quarks together and at extremely high energies may be able to be free particles. Grand unifies theories (GUT) were then postulated that make a similar claim to the theory that unified the weak nuclear force; at some extremely high temperature, the electromagnetic, strong and weak nuclear forces are really the same force, and at other energies, they are just different aspects of the unified force. GUTs, however, do not include gravity.

A glimpse of a quantum theory of gravity came with Hawking’s research of black holes. When a star runs out of energy, it starts to cool and contract. A star above a certain mass would have to collapse to infinite density. Light, since it moves at a finite speed, cannot escape the gravitational field. and thus, neither can anything else. Penrose and Hawking showed that in a “black hole” there is a singularity of infinite density and spacetime curvature. After collapse, a black hole settles down into a state where it may rotate but not pulsate, its size and shape depend only on its mass and rate of rotation. Most of the information about the body that created it is lost in the process. Although they do not emit light, they can be detected by the gravitational affects they have on nearby objects. Black holes have entropy and therefore must also have temperature. It must then also emit radiation in order to not contradict the second law of thermodynamics.

Hawking found that they do indeed emit radiation like a black body. Instead of particles coming from the black hole, they come from the empty space around it. Particle antiparticle pairs are created, with positive and negative energy. The negative energy particle falls into the black hole and the other escapes—to an observer at a distance, it looks like the positive energy particle was emitted by the black hole. The positive energy of the outgoing radiation would be balanced by the negative energy that flowed in. Radiation from black holes was the first example of a prediction that depend on both quantum mechanics and general relativity.

Through the combination of quantum mechanics and general relativity, it becomes possible that spacetime forms a finite space of 4 dimensions with no singularities or boundaries. This theory could explain both large scale uniformity of our universe as well as departures on a small scale. It also would succeed in getting rid of points were the theories predict their own demise at singularities.

**Source**

Hawking, Stephen. *A Brief History of Time*. Bantam Book Trade Paperbacks New York, 1998.