Resource - String Theory: Newton's Embarrassing Secret

In the late seventeenth century, Isaac Newton concluded that the orbital motion of the Moon around Earth was caused by the same force that made apples fall from trees. As the Moon orbits, it falls toward Earth. But because it also moves laterally, the Moon actually falls past Earth. Newton realized that the only force that could explain why the Moon didn't just continue along a straight path and fly off into space was an attraction between the two masses: gravitational force. Furthermore, Newton determined that gravity acts on all objects in the universe and that it is mutual between any two objects -- between Earth and the Moon, between the Sun and Earth, or between Earth and an apple.

In reaching his conclusions, Newton had refined the work of earlier astronomers Galileo and Kepler by providing explanations for what they were unable to explain. He formulated equations that described with great accuracy the strength of gravity -- equations that are still valid today. But Newton himself had difficulty explaining one very important thing about gravity: He had no idea how gravitational force worked.

In the early twentieth century, Albert Einstein developed his special theory of relativity, which led to new formulations of all of Newton's theories relating to energy, forces, and the relationship between space and time. His conclusions were based largely on a careful analysis of how light waves are observed to behave in different frames of reference moving with respect to one another. Later, Einstein developed a general theory of relativity that explains gravity and the geometry of the universe. In this latter theory, Einstein further developed his understanding of a four-dimensional continuum, in which time and space are not separate but instead bound together. He used this concept of "space-time" to help him explain Newton's incomplete understanding of gravity.

Einstein concluded that an object's motion due to gravity could be understood not as a response to a force, but as free and unforced movement in a region of space and time that had been distorted by the presence of a mass. We feel gravity on Earth because Earth's mass causes a curvature of space-time. Our bodies respond to that curvature by accelerating toward Earth's center. What's more, the larger the mass, the greater the curvature. The obvious curved path we see a tossed object take at Earth's surface is not the curvature of space-time Einstein is talking about. His curvature is in a four-dimensional space, with time as the fourth dimension, and is more subtle than that. Still, that more-subtle curvature does explain the path in three-dimensional space we see before us.

Questions for Discussion

- What was the first force to be understood scientifically?

- What was Newton's embarrassing secret?

- What does it mean to say that the velocity of light is a kind of "cosmic speed limit"?

- Describe Einstein's thought experiment (the "cosmic catastrophe"). How did it prove that Newton's theory of gravity was wrong?

- What would have to be true about the "speed of gravity" for Newton to be right?