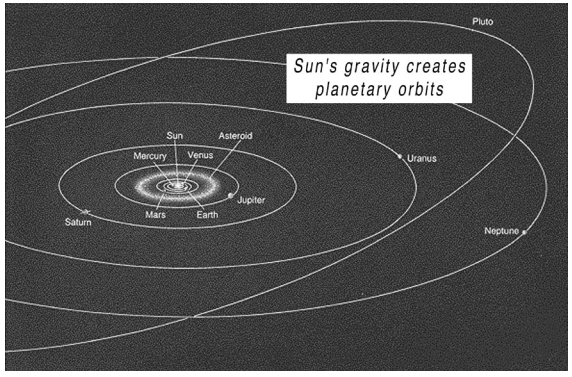
National Aeronautics and Space Administration

Newton's Gravity or Curved Spacetime?

Gravity ProBe

According to Newton's theory of gravity (1687), all masses pull on each other with an invisible force called "gravity". This force is an inherent property of matter, and is directly proportional to an object's mass. In our solar system, the Sun reaches out across enormous distances and pulls smaller masses, like planets, comets, and asteroids, into orbit around it using its force of gravity.

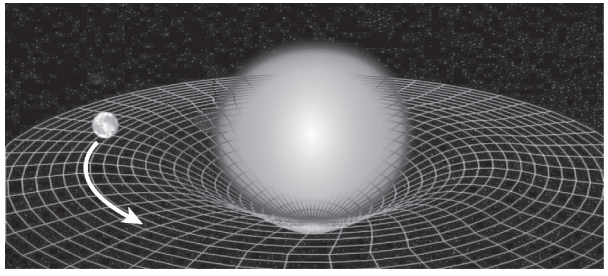


In the early 20th century, Einstein discovered a contradiction between Newton's theory of gravity and Einstein's theory of special relativity (1905). In special relativity, the speed of light is the speed limit of all energy in the universe. No matter what kind of energy it is, it cannot transmit across the universe any faster than 299,792 km/sec. Yet Newton's theory assumed that the Sun's force of gravity is *instantaneously* transmitted to the planets, at a speed much faster than the speed of light. Was gravity unique in its ability to fly across the universe, or did masses react to each other for a different reason?

In 1916, Einstein published his theory of general relativity, which transformed space from the Newtonian idea of vast emptiness to an ephemeral fabric of spacetime, which "grips" matter and directs its course through the universe. The spacetime fabric spans the entire universe and is intimately connected to all the matter and energy within it.

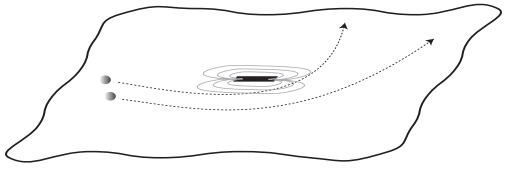
How does this change in thinking explain the motion of the planets, or the orbits of the moon and satellites around Earth? Theoretically, when a mass sits in this spacetime fabric, it will deform the fabric itself, changing the shape of space and altering the passage of time around it.

In the case of the Sun, the spacetime fabric would curve around it, creating a "dip" in spacetime. As the planets (and comets and asteroids) travel across the spacetime fabric, they would respond to this dip and follow the curve



in spacetime and travel around and around the Sun. As long as they never slow down, the planets would maintain regular orbits around the Sun, neither spiraling in toward it nor flying off into outer space.

To create a simple model of this idea, place a heavy weight in the center of a suspended bedsheet. Roll some small balls across the sheet at different points and observe how they curve in toward the central weight.



The balls are not "pulled" in by the mass's gravity; they are simply following the curve in spacetime caused by the mass's presence.

For more information, comments or questions, contact GP-B at www@relgyro.stanford.edu or visit http://einstein.stanford.edu/

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