General Relativity

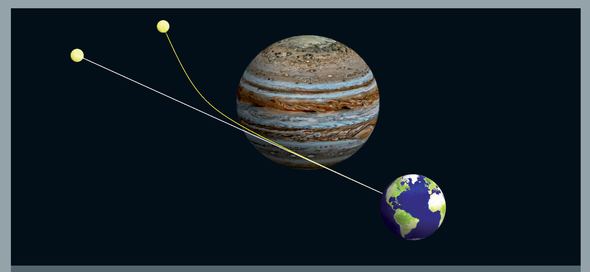

Illustration of the bending of starlight by planets (ICCUB)

Light bending

According to General Relativity, light rays bend when travelling in the deformed spacetime close to very massive objects, like planets, stars or galaxies. This phenomenon causes strange optical distortions.

Orbits of GPS satellites (NOAA)

Everyday-life applications

The GPS system is used to determine our location. This is achieved via the exchange of signals between satellites orbiting the Earth and a receiver, like our mobile phone.

According to General Relativity, the clocks on the satellites run faster than the clocks on the ground: they speed up by 25 nanoseconds every minute. If this effect were not taken into consideration, after only two hours our GPS navigator would estimate our position with an error of one kilometre.

In Newton's theory, gravity is understood as an attractive force between objects. Even though that theory is very successful at describing our everyday life, it fails when gravity is very strong and things move at velocities that approach the speed of light, c = 299,792,458 m/s.

General Relativity is able to describe what happens in those situations well. It combines space and time into a single concept, called spacetime, where it is impossible to travel faster than light.

Matter, such as planets, stars and galaxies, curves spacetime as illustrated in the background. At the same time, the deformed spacetime controls how everything moves in it.

General Relativity, which celebrated its 100th anniversary in 2015, has been tested and confirmed by many different experiments and astrophysical observations.

It even predicts that gravity is not always attractive. For example, dark energy produces repulsion, leading to the accelerated expansion of the universe.

Gravitational effects on spacetime
(ICCUB, background (NASA, ESA, G. Illingworth, D. Magee, and P. Oesch (California U., Santa Cruz), R. Bouwens (Leiden U.), and the HUDF09 Team), planets (CC))

1915 Einstein publishes the theory of General Relativity.

1919 During a solar eclipse, Eddington confirms light bending.

1959 Pound and Rebka confirm that massive bodies stretch the wavelength of light, making it redder.

1968 By bouncing radio waves off Mercury and Venus, Shapiro confirms that massive bodies delay light beams.

1973 The GPS project is born in the United States.

1976 NASA's 'Gravity Probe A' confirms that time runs slower when gravity is strong.

2011 NASA's 'Gravity Probe B' confirms that the Earth's rotation drags spacetime around with it.