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Waltzing pulsars and gravity waves

Huge masses and great speeds make relativistic effects show up, says S.Ananthanarayanan.

Albert Einstein's formulation of nature's laws, of no consequence in daily life, is pivotal to understanding atoms and molecules and also events in the cosmos. Exact verification of *relativity* has been possible in subatomic particles and also in astronomical observations.

Subatomic particles

One of the consequences of Einstein's formulation is that time moves slower for things that are going fast. This is like saying a twin who sets out on a trip, at a speed comparable to the speed of light, will come back younger than his brother who stayed home. Verification of this marvel came from the celebrated Muon experiment of Rossi and Hall in 1941. They measured the number of radioactive subatomic particles, which stream into the earth, at the top of Mount Washington, USA, and again at the base of the mountain. Lesser numbers were expected at the base of the mountain, because some particles decay in the time it takes to cross the 2000 ft from the top.

It was found that even if the particles were taken to be traveling at the speed of light, the fastest way to get around, there were just too many particles left intact at the base of mountain. The explanation was that at the speed of the particles, which was nearly the speed of light, time moved so slowly for the particles that the decay took much longer – and hence the greater numbers at the base, than expected.

Gravity waves

Einstein's work also showed that the effect of masses could be viewed as curvature in space and the work described the connection between energy, forces, gravity and mass. A remarkable consequence of this view is that accelerating an object which has mass would affect the space around the object, which would affect the space surrounding that space and so on. This should then give rise to 'waves' in the nature of space, rather like the ripples that spread out when a pebble is cast into a pond!

The *waves* were worked out to move at the speed of light, but were so feeble, for ordinary masses, that the possibility of detection was remote. Arrangements of the highest sensitivity, to measure differences in length, which compare with intra-atomic distances, over kilometers, have been set up, on the earth or even in orbit around the earth. The Laser Interferometer Gravity Wave Observatory (LIGO), located at two widely separated sites in the USA is one such. The trouble with gravity waves being so feeble is that all kinds of disturbance or *noise* tend to cloud the real signals. LIGO has parallel arrangements at two locations in the belief that such disturbances would affect only one of the sites at a time and could hence be identified.

Neutron Stars

Gravity waves with any hope of being detected arise only in cataclysmic events, like supernovae or collision of black holes. Another area is when neutron stars pair to form binaries. Neutron stars are stars that have compressed, under their own gravity, the very atoms that compose them to consist of pure neutrons. This is one of the densest forms of matter imaginable and because of the shrinking of huge stars to small fractions of the original size, neutrons stars are also spinning like tops – giving off pulses of radiation, as *pulsars*.

When a pair of such stars gets into mutual motion around each other, as a *double star*, we have a case of stellar masses in rapid acceleration, confined to a thumbnail, in cosmological terms. According to the theory of relativity, such an arrangement should radiate copious gravity waves. The fact of radiating and losing energy should then show up as spiraling in of the two stars – like the rocking motion of a child's top speeds up, to make it topple, as the top loses energy due to friction.

A pair of neutron stars like this was discovered by Hulse and Taylor in 1993. The Husle-Taylor pair spins once round in 7.2 hours and the stars are expected to merge in 320 million years. Another pair discovered in 2003 has a period of only 2.4 hours and would merge in just 75 million years. More neutron binaries are expected to be discovered and direct verification of gravity waves may soon happen.