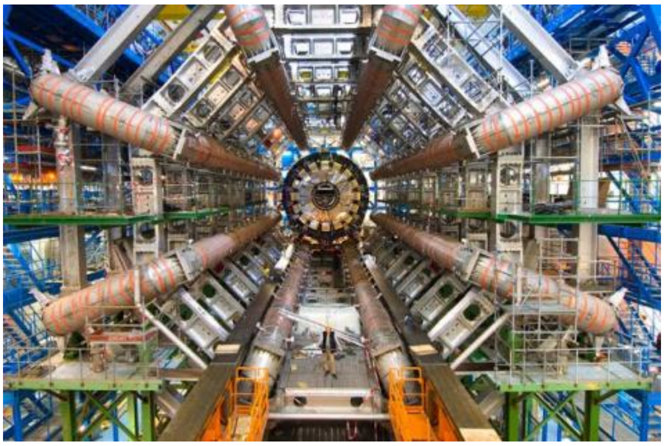
Doubly special relativity

21 March 2011, By Steve Nerlich

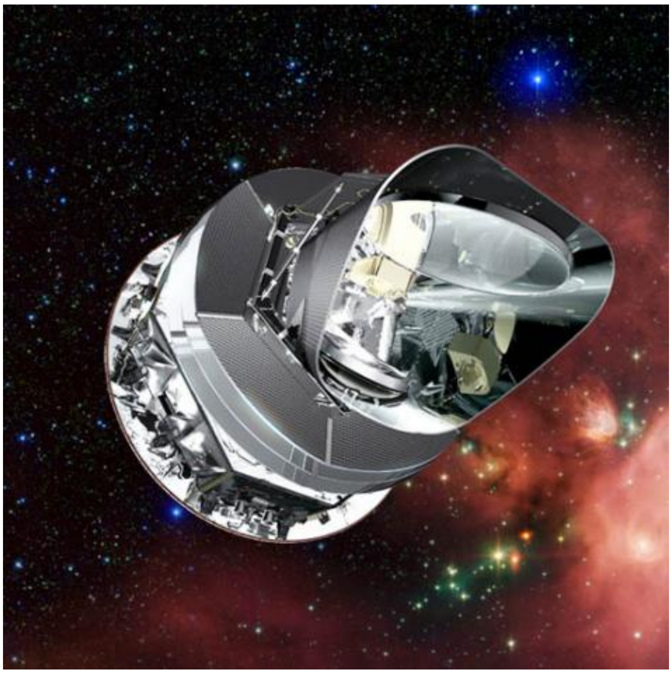


The Large Hadron Collider - destined to deliver fabulous science data, but it remains uncertain if these will include an evidence basis for quantum gravity theories. Credit: CERN

General relativity, Einstein's theory of gravity, gives us a useful basis for mathematically modeling the large scale universe - while quantum theory gives us a useful basis for modeling sub-atomic particle physics and the likely small-scale, high-energy-density physics of the early universe - nanoseconds after the Big Bang - which general relativity just models as a singularity and has nothing else to say on the matter.

Quantum gravity theories may have more to say. By extending general relativity into a quantized structure for space-time, maybe we can bridge the gap between small and large scale physics. For example, there's doubly special relativity.

With conventional special relativity, two different inertial frames of reference may measure the speed of the same object differently. So, if you are on a train and throw a tennis ball forward, you might measure it moving at 10 kilometers an hour. But someone else standing on the train station platform watching your train pass by at 60 kilometers an hour, measures the speed of the ball at 60 + 10 - i.e. 70 kilometers an hour. Give or take a few nanometers per second, you are both correct.



The Planck spacecraft - an observatory exploring the universe and named after the founder of quantum theory. Coincidence? Credit: ESA

However, as Einstein pointed out, do the same experiment where you shine a torch beam, rather than throw a ball, forward on the train - both you on the train and the person on the platform measure the torch beam's speed as the speed of light - without that additional 60 kilometers an hour - and you are both correct.

It works out that for the person on the platform, the components of speed (distance and time) are changed on the train so that distances are contracted and time dilated (i.e. slower clocks). And by the math of Lorenz transformations, these effects become more obvious the faster than train goes. It also turns out that the mass of objects on the train increase as well - although, before anyone asks, the train can't turn into a black hole even at 99.9999(etc) per cent of the speed of light.

Now, doubly special relativity, proposes that not only is the speed of light always the same regardless of your frame of reference, but Planck units of mass and energy are also always the same. This means that relativistic effects (like mass appearing to increase on the train) do not occur at the Planck (i.e. very small) scale - although at larger scales, doubly special relativity should deliver results indistinguishable from conventional special relativity.

Doubly special relativity might also be generalized towards a theory of quantum gravity - which, when extended up from the Planck scale, should deliver results indistinguishable from general relativity.

It turns out that at the Planck scale e = m, even though at macro scales $e=mc^2$. And at the Planck scale, a Planck mass is $2.17645 \times 10\text{-}^{8}$ kg - supposedly the mass of a flea's egg - and has a Schwarzschild radius of a Planck length - meaning that if you compressed this mass into such a tiny volume, it would become a very small black hole containing one Planck unit of energy.

To put it another way, at the Planck scale, gravity becomes a significant force in quantum physics. Although really, all we are saying that is that there is one Planck unit of gravitational force between two Planck masses when separated by a Planck length - and by the way, a Planck length is the distance that light moves within one unit of Planck time!

And since one Planck unit of energy (1.22×10^{19} GeV) is considered the maximal energy of particles - it's tempting to consider that this represents conditions expected in the Planck epoch, being the very first stage of the Big Bang.

It all sounds terribly exciting, but this line of thinking has been criticized as being just a trick to make the math work better, by removing important information about the physical systems under consideration. You also risk undermining fundamental principles of conventional relativity since, as the paper below outlines, a Planck length can be considered an invariable constant independent of an observer's frame of reference while the speed of light does become variable at very high energy densities.

Nonetheless, since even the Large Hadron Collider is not expected to deliver direct evidence about what may or may not happen at the Planck scale - for now, making the math work better does seem to be the best way forward.

More information: Zhang et al. Photon Gas Thermodynamics in Doubly Special Relativity.

Source: Universe Today

APA citation: Doubly special relativity (2011, March 21) retrieved 24 September 2020 from https://phys.org/news/2011-03-doubly-special-relativity.html