Quantizing the flow of known forms of Energy at the Quantum Level.

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Abstract

One of the most successful theories of the twentieth century, quantum mechanics, is plagued by the possibility of infinite quantum fluctuations of all forms that energy and momentum can take. This possibility arises from the most basic tenet of quantum mechanics, the uncertainty principle. Features we regard as obvious and so basic as to be beyond question, such as that objects have definite positions and speeds and specified energies at specified moments, are now replaced by the uncertainties of quantum mechanics.

Even empty space is teeming with the frenetic borrowing and pay back of energy by virtual particles that flash in and out of existence. At smaller and smaller distances and time scale the chaotic fluctuations of energy levels increase. Known forms of energy, such as an electron/positron pair annihilating, can be quantized. The ground state energies of fermions with negative energies and bosons with positive energies are expected to cancel each other out in super-gravity theories. Unknown forms of energy include dark energy and the possibility of unknown particles being created at such high energy levels.

Introduction

In quantum mechanics, the gentle smooth curving of space-time of general relativity, gives way to an unfamiliar part of the universe in which everyday expectations of up, down, back and forth have no meaning. In terms of classical reasoning space is empty with zero gravitational field. Quantum mechanics changed all this. Quantum mechanics showed that even gravity fluctuates at ever smaller distances and time scales. At the macro scale these violent undulations of energy and gravity cancel each other out and we are not aware of it.

At typical quantum levels, such as the Planck length of 10^{-35} centimetres and the Planck time of 10^{-43} seconds, virtual particles are flashing in and out of existence, created from borrowed energy which has to be paid back within the time limits set by quantum mechanics. Given enough energy an electron and its antiparticle, the positron and more massive particles like muons and taus can be created in this way. The particles create and respond to gravity. The creation and annihilation of virtual particles give rise to the fluctuation of energy levels (including the energy of the strong and the weak nuclear forces) and the gravitational field. This is a furious activity reflected in the furious fluctuations of energy levels which gave rise to the notion of infinite energy fluctuations at the quantum level. It can be shown, however, that known forms of energy (such as the energy released when known particles and its antiparticles annihilate) can be quantized. If the fluctuation of energy at the quantum level, and of course gravity, were indeed infinite, the curvature of spacetime would also be infinite, and observation show that this is not the case.

Discussion

An important step in the discovery of the quantum theory was the hypothesis by Max Planck in 1900 that light always comes in packets called quanta. Planck's quantum hypothesis clearly explained the observations of the rate of radiation from hot bodies.

In terms of Planck's quantum hypothesis

$$E = nhf \quad n = 0,1,2,3..... \tag{1}$$

Where n is a positive integer, a particle has a finite amount of energy.

A very important consequence of Einstein's relativity is the relation between mass and energy. In terms of Einstein's

$$(E_0) = mc^2 \tag{2}$$

each particle has a rest energy. Applying Einstein's notion that the speed of light appears the same to everyone means that nothing can exceed the speed of light. Energy is used to accelerate anything. To accelerate an object means to increase its mass, whether it is a spaceship or a particle. At the quantum level, on smaller and smaller scale, the appearing and vanishing particles will have more and more momentum and have more energy. When a particle (or any other object) is accelerated from rest to a speed, it acquires kinetic energy in addition to the rest energy. Cutnell and Johnson (2001) showed that the total energy (rest plus kinetic energy) E of the moving particle is related to its mass and speed by

$$E = \frac{mc^2}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{3}$$

Any excess energy when a particle/antiparticle pair forms, goes into the momentum of the particle. However a moving particle "acquires" kinetic energy. Using equations (2) and (3) above the kinetic energy of a moving particle (total energy minus rest energy) can be written as

$$KE = mc^2 \left(\frac{1}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \right) \tag{4}$$

Therefore, an electron ($m = 9109 \times 10^{-31}$ kg) accelerated from rest to a speed of $= 0.9995c$ in a particle accelerator, has a rest energy of 0.511 MeV. The total energy of the electron is

16.2 MeV. The kinetic energy is the difference between the total energy and the rest energy, and is 15.7 MeV.

The nucleus of an atom is held together by a binding force called the strong nuclear force. Therefore energy is required to separate the nucleus into its constituents protons and neutrons and such energy appears as an extra mass of the separated nucleons. Cutnell and Johnson (2001) pointed out that the binding energy of a nucleus can be determined by

$$\text{Binding energy} = (\text{Mass defect})c^2 = (\Delta m)c^2 \quad (5)$$

Hawking S. (1993) found that the protons and neutrons are held together in the nucleus by nuclear bonds of about 10^9 eV.

Indications are that that there may be a number of layers of structures at higher and higher energies at smaller and smaller scales of distance and time. Increasingly massive particles will form from borrowed energy at the quantum level. However, at the Planck length of 10^{-33} cm or an equivalent very high energy of 10^{28} ev and at shorter scales of length it is expected that spacetime will cease to behave as a smooth continuum and become like foam like structure due to the quantum fluctuations of the gravitational field.

Limited current technology means that the energies of about 10^{10} eV can be experimentally probed. There is a large region of unexplored energies between this level and the ravitational cut off at 10^{28} eV. Theoretically there should be no infinities of energy levels at the quantum level. Hawking S. (2001) found that in the super gravity theory bosons with positive groundstate energies and fermions with negative groundstate energies should cancel each other out, eliminating the biggest infinities. Infinite fluctuations of energy levels and gravity at the quantum level will result in the infinite curvature of spacetime and experience taught us that this is not the case.

Conclusions

It is concluded that all known forms of energy at the quantum level can be quantized. There are indications that the unexplored energies at the quantum level cannot be infinite, since this would mean that spacetime is infinitely curved.

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