Particle Mass in a Cosmological Perspective

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The problem

One of the major unsolved problems in physics today concerns the origin of particle rest mass. Einstein attempted to explain the rest masses of elementary particles as singularities in space-time. Present efforts aimed at unifying the forces in the Universe are intimately related to this idea, and the approach taken by the majority of researchers is to invoke rescaling during the expansion of the Universe since the Big Bang.

A lot is known today about relations between elementary particles, their energy levels and their forces, as expressed in the successful quark theory. However a few problems remain unsolved: Why do particles have the observed spectrum of masses? Why is the mass of the neutron on the order of 10^{-27} kg and not for example one kilo? How do particles confine their energy? What is the basic material of which they are made? Why do they exist at all? The answers to the above questions are embedded in our knowledge of cosmology, relativity theory and quantum physics.

Recent experiments based on the Bell inequalities, especially those conducted at the Institut d'Optique Théorique Appliqué in Paris, have verified that quantum laws govern systems of photons over larger distances in space. This suggests that quantum conditions can be extrapolated to universal dimensions.

The solution

An analysis of the cosmological redshift leads to the identification of a minimal energy quantum, or elementary quantum (EQ) in the Universe. The EQ corresponds to a standing wave across the gravitational diameter of the Universe itself, the observable Universe being treated as a large black hole. The entire energy of this Metagalaxy is made up of approximately 10^{120} EQ, each having energy equal to the product of Planck's constant and Hubble's constant (hH_0). The gravitational force constant is thereby directly linked to the mass of the observable universe.

Cosmological redshift

During its passage through vacuum space, the photon will encounter EQ with randomly distributed momenta. The result of the interaction between the photon and EQ is a loss of energy (and equivalent mass) as well as momentum in its direction of movement, the loss corresponding to one EQ for each EQ encountered. If the numerical density of elementary quanta in space is r_n, the cross section for the interaction between a photon and an EQ is r_q, then in time Δt the photon covers a space $r_q c\Delta t$ and interacts with $r_n r_q c\Delta t$ EQ. Assuming that its energy corresponds to N EQ, the photon will lose

$$\Delta \mathrm{N} = -\, r_n r_q c\Delta t$$

EQ in time Δt.

Further, if the cross section for interactions between EQ is s_{eq}, and assuming the photon to be a system of elementary quanta able to interact individually with other EQ in space, the total cross section for the photon energy loss process would be Ns_{eq}, giving

$$N(t) = N(0)\exp(-r_n s_{eq} ct), \tag{1}$$

or, where E_q is photon energy,

$$E_q(t) = E(0)\exp(-r_n s_{eq} ct) \tag{2}$$

The redshift for a cosmological photon thus takes the form

$$z = \exp(r_n s_{eq} ct) - 1 \tag{3}$$

or

$$z \sim r_n s_{eq} ct \tag{4}$$

This expression can be compared to the equivalent form of Hubble's law ($z = H_0 t$) for the redshift of light from distant galaxies. Normally, this relation is explained by the theory of an expanding universe. However, in the above alternative theory, we assume that Hubble's constant applies to the understanding of z given above, *i.e.*, that the redshift depends only on the distance travelled by a photon in space. Using the observed value of Hubble's constant in our formulae, we have

$$H_0 = r_n s_{eq} c \tag{5}$$

and the mean free path, identified with the wavelength of the EQ, becomes

$$l_{eq} = l_{eq} = \frac{1}{r_n s_{eq}} \tag{6}$$

or

$$l_{eq} = \frac{c}{H_0} \tag{7}$$

and the frequency of the EQ can be established as

$$n_{eq} = \frac{c}{l_{eq}} = H_0 \tag{8}$$

which might be thought of as the "resonance" frequency of space ($H_0 \sim 10^{-18}\text{s}^{-1}$).

Particle masses

We now transfer the concept of a mass condensation to a "miniature universe," which is locally confined within an event horizon within the large-scale Universe. This isolated energy system forms its own quantum conditions, again with a minimum energy quantum corresponding to a wave across the gravitational diameter, and with a gravitational force constant of its own depending on its mass. It is now possible to calculate the number of elementary energy quanta that will generally make up such a local energy condensation. We find naturally that the smaller the mass of the singularity, the larger the constituent elementary quantum. This relation creates a mathematical series that is brought back to a starting point with the case where only one elementary quantum builds up the entire energy of the smallest local "universe." This case generates the mass of the lightest of the elementary particles subject to the strong nuclear force, the π-meson group, while the mass of the nucleon group is given by the case of 18 elementary quanta (the value of Hubble constant used for the numerical calculations is consistent with a Hubble time of 12×10^9 billion years.

Particles as energy systems

The clue to understanding elementary particles as singularities in space-time was provided by an analysis of light particles (the photons) in the cosmic redshift. We deduce that the photons move in space with a group velocity just below the velocity c, while the theoretical velocity of light is only applicable to an ideal case of energy transfer, since vacuum space has a non-zero energy density. Ideal information transfer applies to a spiral along the photon pattern. The EQ can be seen as the limiting case of a standing wave across the Universe: it has zero group velocity. The energy of a photon is relativistic energy with the elementary quantum as the rest state, and therefore depends on the photon group velocity. The energy in the system of the photon itself can be described as a rotating system—a disc with peripheral velocity equal to the group velocity.

In the system of an observer, the circumference of that disc will appear Lorentz contracted, giving the periphery of the spiralling information front of the photon. When the energy is high enough, the circumference shrinks to that of a black hole containing the photon energy. This happens for a certain distinct energy, which is found to be below the energy of the π-meson, and above the energy of the μ-meson. Hence, this case separates the particles subject to the strong nuclear force from the lighter particles. The dimension of a particle—here the quark—is then that of a black hole or infinitely small point in the system of an observer, while it is considerably larger in the rotating system of photon energy, where the circumference is on the order of the particle elementary wavelength (equal to or greater than the Compton wavelength). This explains the observed pointlike properties of quarks in scattering experiments as well as their so called “bag”-confinement.

The force law

The particle force can be expressed in terms of Newton’s constant (G_0) in the large scale Universe, by replacing the mass of the

Universe with the mass of the particle system. The fine structure constant of this force turns out to be a function of the number of elementary quanta in the particle system. For example, in the case of an interaction between two nucleons isolated in a compound nucleus, the calculated constant is approximately equal to 20, which is the proper magnitude for the strong nuclear force. Identifying the electromagnetic force with the quantum force in a particle system built on two elementary quanta gives an estimated proper value of the electron mass. The electromagnetic force, the gravitational force and the strong nuclear force are thus brought together in one quantum law.

Table and Formulas

A) The force constant of an isolated quantum system:

$$G_p = \sqrt{\frac{G_o c^3}{4 H_o M_p}}$$

B) The ground state mass of an isolated quantum system:

$$M_p = \sqrt[3]{\frac{K^2 h^2 H_o}{4 G_o c}} \qquad K = 1, 2, 3 \ldots$$

C) Table

Comparison between the above mass-formula, and the mass-spectrum for the lighter elementary particles.

The value used for Hubble's constant is: $H_o = \left[12 \cdot 10^9 y\right]^{-1} = 2.64 \cdot 10^{-18} s^{-1}$

Observed data		Estimated quantum number			Quantum mass m(k) (GeV)
Particle groups	Mass (GeV)	K_{est}	K	K/6	
1) Baryons: p n	0.938; 0.940	17.97	18	3	0.94
Λ	1.116	23.28	23	3+5/6	1.11
Σ	1.189; 1.192; 1.197	25.71	26	4+2/6	1.20
Δ_r	1.236	27.13	27	4+3/6	1.23
Ξ	1.315; 1.321	29.88	30	5.	1.32
Σ_r	1.379	31.98	32	5+2/6	1.38
2) Mesons: π	0.140; 0.135; 0.140	1.02	1	1/6	0.14
K	0.494; 0.498	6.90	.7	1+1/6	0.50
η_r	0.548	8.01	8	1+2/6	0.55
ω_r	0.783	13.68	14	2+2/6	0.79
φ_r	1.019	20.31	20	3+2/6	1.01