A Scale Factor-Dependent Evolution of the Mass of Elementary Particles as a Solution to the Conundrums in Cosmology

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Being inspired by numbers of too-unlikely-to-be-coincidence relationships between the current universe and its Planck scale precursor, together with the well-known Eddington number riddle, we propose an audacious hypothesis that the mass of elementary particles is proportional to the inverse cubic root of the scale factor of the universe. The hypothesis eloquently explains, within Einstein's original theory of general relativity, why the universe seems to have roughly three times as much of energy as the sum of light and dark matters, and why it seems to accelerate its pace of expansion. Moreover, we provide an alternative formulation that is equivalent to the Riemannian geometry of the general relativity, paving the way for a grand unification of gravity with the other three basic interactions that are described by quantum field theories.

Our observable universe has a radius of $\sim 10^{60}$ times of the Planck length, while its density is $\sim 10^{-120}$ times of the Planck density. The relationship that energy density being proportional to the inverse square (instead of inverse cube) of its radius is conserved in the case of black holes. Suppose that our universe has been evolved all the way from a stage of the Planck scale, the above observation strongly implies the existence of a mechanism that ensures the weighted average pressure of the non-relativistic particles and the vacuum in our universe is negative 1/3 of their combined energy density, which is, according to the second Friedmann equation, the condition that enables a constant velocity expansion of the universe. In contrary, to believe that we are living in a lucky era when the relative amount of ordinary matter and dark matter and dark energy miraculously meet at roughly the same order is too naïve.

In another paper submitted back-to-back with this one, we will address the detailed mechanism that generates matter particles out of vacuum space by the spontaneous symmetry breaking of a binary digital field, which in turn assures the ratio between the non-relativistic matters and the vacuum energy in our universe structurally remains unchanged, together with its profound implications on particle physics.

As Sir Arthur Eddington had famously pointed out, the total mass of our observable universe is equivalent to $\sim 10^{80}$ nucleon mass. Now that the total mass of the universe has increased by $\sim 10^{60}$ folds from the Planck mass, let us hypothesize that the mass of elementary particles generally decreases in an inversely proportional manner to the cubic root of the cosmic scale factor ($\sim 10^{20}$). This hypothesis may seem very blunt at first glance, but it can immediately find a beautiful support. Since the mass of electron and nucleons sit at an order of $\sim 10^{-20}$ times of the Planck mass, our hypothesis further predicts that the hierarchy gap at an order of $\sim 10^{40}$ between the electromagnetic force and gravity would vanish to roughly the same magnitude at the birth of the universe, which I believe is an extremely elegant and appealing story to theoretical and experimental physicists alike. In this paper, we shall witness how this hypothesis might rewrite the whole field of cosmology, solving its most long-lasting conundrums at one shot.

A decreasing electron mass proportional to the cubic root of the cosmic scale factor means the Rydberg constant would be larger in the ancient universe, which further implies that the redshift we are currently observing does not necessarily reflect the true expansion rate of the space, but has to be re-interpreted upward by a power of 3/2. For example, a seemingly 4-fold redshift is indeed an 0.5-fold blueshifted spectrum which was emitted when the cosmic radius was 1/8 of the current one, being actually redshifted by 8 folds. Particularly for small z, by simple math, the true redshift is 1.5 times of the observed one.

Such a non-linear re-interpretation of the raw redshift data would not only explain the dimmer-than-expected type Ia supernovae (compared with the case of constant velocity expansion) around $z\sim 0.5$ (as will be discussed later, they turn brighter from $z\sim 1$ possibly due to an alteration to the chemistry of stellar luminosity in the ancient universe when the mass of nucleons were much heavier), but also reduce the Hubble's constant by a factor of 2/3 (since it is calculated as the slope of the luminosity distance plots against the redshift) which is equivalent to a shrinkage of the critical

density by a factor of 4/9. Given that the ratio between the non-relativistic particles and the vacuum energy is 2:1 in our hypothesis, 8/27 (2/3 of 4/9) or ~29.6% of the current critical density as non-relativistic matter agrees well enough with the latest estimate.

With such a cosmic scale factor or age-dependent evolution of the mass of nucleons, atomic nuclear physics should look quite different in the ancient universe. Its implications may not be restricted to the brighter supernovae at z>1 as mentioned earlier, but could also urge us a re-examination of the well-established theory of the Big Bang nucleosynthesis.

A revised baryon-photon ratio may better reproduce the current relative existence of light elements, solving the so-called cosmic Lithium problem. It may also in turn revise up our estimate of invisible baryonic matters, filling the gap between Omega-m and Omega-b that is currently occupied by the dark matter. However, due to our lack of expertise in the field, we would rather devote this paper as a priming water for further investigations by qualified professionals.

Next, let us present a possible breakdown of the Riemannian geometry of the general relativity into two Newtonian style equations of gravitational potential, which act in synergy to perfectly reproduce the outputs of the Einstein equations.

<First layer of gravitational attraction>
Suppose that both the energy density and pressure are inversely proportional to the cube of the radius.

$$\nabla^2 \phi = 4\pi G(\rho + P)$$

<Second layer of gravitational attraction>
Suppose that the pressure remains constant.

$$\nabla^2 \phi = 4\pi G(2P)$$

It is not so hard to check that the alternative formulation shown in above results in exactly the same outcomes for both the Schwarzschild metric and the FLRW metric.

Interestingly, the critical pressure which leads to zero acceleration in the first layer ($P = -\rho$) is the condition dictated by the second Friemann equation to ensure an evolution in which the energy density remains constant, while that of the second layer ($P = 0$) is the one for an evolution of energy density being inversely proportional to the volume. Such a cross-over relationship indicates that gravitational interaction might be a kind of homeostatic response to any deviation of energy distribution from its preceding configuration.

The concept of space-time curvature in response to energy-momentum tensor is a convenient mathematical tool or a sophisticated analytical language that neatly describes the accumulation of the synergistic outcomes of the two gravitational accelerations contributed from myriads of energy/mass quanta (both static and moving), which is applicable for any arbitrary energy-momentum dynamics. On the other hand, our newly proposed formulation may not provide with us closed form expressions for all kinds of mass distribution. However, as far as their practicability is concerned, the case is not anyhow better for the general relativity either, celebrating its centennial with a handful of rigorous solutions only for the highly symmetric conditions. Most importantly, unveiling the Newtonian structure beneath the theory of general relativity, in other words, becoming free from the fetters of the continuous space-time dogma, is a critical step toward the grand unification of gravity with the quantized theories for the other three forces.

Lastly, we would sincerely ask a favor of those experimental physicists with great creativity to design an experiment to either verify or falsify our hypothesis. With billions of years as the current cosmic age, even experiments overarching several decades may not be long enough to detect the slight change in the mass of elementary particles as the hypothesis predicts. It is far beyond our imagination as for if there are any smart ideas to amplify the effect to a detectable magnitude.

References

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