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Research paper

Inflation, dark energy, and dark matter

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Abstract

Inflation leads to $\Omega=1$ for the big bang universe, and which is indeed observed. However, the presence of two mysterious constituents in the big bang universe – dark energy and dark matter – also produces $\Omega=1$. This paper utilizes propositions about the nature of dark energy and dark matter to trace their origins to the contents of the inflationary universe.

Keywords: *Cosmology; Cosmological Constant; Dark Energy; Dark Matter; Inflation.*

1. Introduction

Inflationary universe leads to $\Omega=1$ for the big bang universe (Guth [2]). However, the presence of dark energy and dark matter in the big bang universe also yields $\Omega=1$, as in $\Omega_{\text{baryonic matter}}+\Omega_{\text{dark matter}}+\Omega_{\text{dark energy}}=1$. Also, the accelerating expansion of the inflationary universe as well as the present acceleration of the big bang universe are both described by the cosmological constant. The acceleration of the inflationary universe is driven by the false vacuum of the Higgs-like scalar field ϕ, called the inflaton field.

The late-time accelerating expansion of the big bang universe is attributed to dark energy. The nature of dark energy remains elusive. Experiments to identify the quantum mechanical properties of dark matter are also ongoing. This author has made classical propositions about the nature of dark energy and dark matter, both of which can be related to the accelerating expansion of the universe. Since the acceleration of the big bang universe and the inflationary universe are both described by the cosmological constant, it may be possible to trace the origins of dark energy and dark matter in the big bang universe to the contents of the inflationary universe.

2. Inflation and dark energy

In earlier papers "Dark Energy" and "The Nature of Dark Energy and Dark Matter" (Kalita [3], [4]), it has been proposed that the accelerating expansion of the universe is due to the cosmologicalization of the principle of equivalence. The principle of equivalence recognizes momentary equivalence between the gravitational force experienced by the gravitational mass of an object situated on a gravitational surface and the inertial force generated on the inertial mass of an object in an accelerating frame of reference. In the proposed cosmologicalization of the principle of equivalence, in an expanding spherical distribution of matter, spacetime itself acts as the accelerating frame of reference of the inertial mass of an object on the surface of the sphere, and the inertial force thus generated is momentarily equivalent at a certain radial distance to the gravitational force experienced by the gravitational mass of the object. The acceleration of the spacetime frame of reference is parametrized by the cosmological constant, as in $\frac{\Lambda c^2}{3}R$. The spacetime accelerating frame of reference is responsible for the accelerating expansion of the universe, and objects whose inertial mass is accelerated by the spacetime frame of reference, due to the cosmologicalization of the principle of equivalence, are the visible matter in the universe.

The big bang universe was preceded by the inflationary universe. The accelerating expansion of the inflationary universe was driven by the false vacuum. The false vacuum contains virtual particles. Inflation ends with the decay of the false vacuum, whereby real particles are produced and thermalized (Linde [5]; Albrecht and Steinhardt [1]), and which initially would consist of neutrinos, and subsequently with the electroweak symmetry breaking other particles would also emerge, and all of which constitute the visible matter in the universe. As proposed, the inertial mass of the visible matter in the universe is involved in the cosmologicalization of the principle of equivalence – which is responsible for the late-time accelerating expansion of the big bang universe.

3. Inflation and dark matter

In an earlier paper "The Nature of Dark Energy and Dark Matter" (Kalita [4]), it has been proposed that dark matter is impressional inertial mass objects which are in cosmological freefall, because of the cosmologicalization of the weak principle of equivalence. The weak principle of equivalence conveys the universality of freefall, manifesting the equivalence of gravitational and inertial mass. The universality of freefall can also be demonstrated by comparing the gravitational mass of an object in freefall with the inertial mass of a stationary object, which when observed with respect to an accelerating frame of reference gives the impression that the inertial mass of the object is also in freefall. Now in the cosmologicalization of the weak principle of equivalence, instead of the impression of freefall of a stationary inertial mass object with respect to an accelerating frame of reference, we have an object with impressional inertial mass on the surface of an expanding spherical distribution of matter, and which is in cosmological freefall in spacetime accelerating frame of reference, and whose acceleration is parametrized by the cosmological constant, as in

$\frac{\Lambda c^2}{3}R$. It is objects with impressional inertial mass, which are not directly detectable, that are proposed be the dark matter in the universe.

In the inflationary universe, accelerating expansion occurs due to the presence of the false vacuum, which consists of virtual particles. Thus, classically, there is no identifiable presence of inertial mass objects in the inflationary universe.

During inflation the scale factor $a(t)$ expanded exponentially: $a(t) \propto e^{Ht}$, where between time t_i when inflation began and time t_f when inflation ended, the scale factor increased by a factor

$$\frac{a(t_f)}{a(t_i)} = e^N \tag{1}$$

Where $N \equiv H(t_f - t_i)$; N is the number of e-foldings of inflation, and H is the Hubble constant.

In conventional acceleration, in one unit of time the distance increases by an amount greater than the previous one. Because cosmological acceleration of inflation is roughly exponential, in one e-folding time of ~ 10^{-37} sec the scale factor $a(t)$ almost doubles, i.e., increases by almost the same amount as the previous one. In other words, in one e-folding time, the inflationary universe is expanding with almost uniform velocity. It is the series of e-fold expansions over e-folding times that amounts to acceleration. Thus we have a dynamically dual situation of both acceleration as well as uniform motion, depending on how we consider time: if we consider one e-folding time there is near uniform expansion, while if we consider a series of e-folding times there is accelerating expansion.

We know that inertia is the resistance of an object to acceleration. Thus for inertial mass of objects to be manifested there has to be acceleration of those objects. If the expansion in one e-folding time in the inflationary universe is near uniform, inertial mass would therefore be not identifiably manifested. Because there is acceleration over a series of e-folding times, however, we may therefore infer the existence of inertial mass even though it is not identifiably manifested. We may call it inferred inertial mass – which can be of two forms: 1. Inferred inertial mass of the virtual particles of the false vacuum, which is driving the accelerating expansion of the inflationary universe; inferred inertial mass would be consistent with the fact that virtual particles are not classically manifested. 2. Inferred inertial mass which is piggybacking on the accelerating expansion of the inflationary universe. This is analogous to how in the big bang universe, where according to present proposition impressional inertial mass objects/dark matter is in cosmological freefall, due to the cosmologicalization of the weak principle of equivalence, and the cosmological freefall is made possible because of the accelerating expansion of the universe, due to the cosmologicalization of the principle of equivalence, involving the inertial mass of objects. In the inflationary universe, its accelerating expansion is driven by virtual particles, whose inertial mass is not classically manifested but inferred due to the accelerating expansion, and furthermore there is inferred inertial mass of another form, which piggyback on the accelerating expansion, and which may therefore be considered to be in cosmological freefall.

According to present proposition, dark matter is impressional inertial mass objects in cosmological freefall. Since impressional inertial mass objects are in cosmological freefall, they would be in a locally inertial frame of reference. We may go a step further and state that not only are impressional inertial mass objects in a locally inertial frame of reference, but that impressional inertial mass objects are themselves locally-inertial-frame-of-reference objects – henceforth called locally inertial objects – and whereby, because of local absence of acceleration, their inertial mass would not be identifiably manifested, but because they are in cosmological freefall, we may therefore infer the existence of their inertial mass.

[The meaning of here-proposed locally inertial objects as dark matter may be further clarified in the following way. We know that objects in gravitational freefall are weightless because their inertial mass and gravitational mass are equivalent, and the gravitational force acting on the gravitational mass exactly cancels the inertial force generated on the inertial mass of the object. According to present proposition, for a locally inertial object in cosmological freefall it is the inertial mass of the object that is feeling the force of antigravitational motion. At the same time inertial force is being generated on the inertial mass of the object. It may therefore be argued that in cosmological freefall, not only does the anti-gravitational force cancel the inertial force on the object, but because inertial mass is associated with both the forces, inertial mass cancels itself as well. Thus we are left with no net inertial mass in the object, and only the equivalent gravitational mass survives and is detectable through its gravitational effect. If inertial mass is taken to be material, then visible matter is directly detectable because of its inertial mass, while the net absence of inertial mass in locally inertial objects/dark matter should mean that dark matter should be immaterial, and therefore directly undetectable. Dark matter may therefore be seen as purely gravitational spacetime objects – somewhat reminiscent of much larger and more gravitationally powerful spacetime objects like black holes, though of course black holes are an outcome of gravitationally collapsed matter, while dark matter as gravitational spacetime objects would be pre-existing.]

When inflation ends, the expansion would no longer be exponential, and the expansion therefore would no longer be of uniform velocity in one e-folding time. Thus it now becomes possible for inertial mass to emerge as local objects. It is proposed that when inflation ends, the inferred inertial mass of a portion of virtual particles converts into inertial mass of real particles, i.e., visible matter; while the other type of inferred inertial mass, which is in cosmological freefall, converts into impressional inertial mass objects/locally inertial objects/dark matter, in cosmological freefall.

4. Conclusion

Inflation requires that $\Omega = 1$ in the big bang universe, and which is indeed observed. However, the presence of dark energy and dark matter also produces $\Omega = 1$. It is here shown that the presence of dark energy and dark matter in the big bang universe can be traced back to the contents of the inflationary universe.

It is proposed that the inflationary universe contains inferred inertial mass, a portion of which belongs to the virtual particles of the false vacuum, which drives the accelerating expansion of the inflationary universe. When inflation ends, inferred inertial mass of a portion of the virtual particles converts into inertial mass of real particles, i.e., visible matter in the big bang universe. The proposition of the cosmologicalization of the principle of equivalence requires that the inertial mass of visible matter be in a spacetime accelerating frame of reference, which is responsible for the late-time accelerating expansion of the universe.

It is also proposed that a portion of the inferred inertial mass is in cosmological freefall in the inflationary universe. When inflation ends, the inferred inertial mass in cosmological freefall converts into dark matter in the big bang universe, which is proposed to be impressional inertial mass objects/locally inertial objects in cosmological freefall, due to the cosmologicalization of the weak principle of equivalence.

Classically, it may therefore be stated that it is the 'nothingness' of a portion of inferred inertial mass that drives the accelerating expansion of the inflationary universe, while it is the 'somethingness' of inertial mass of visible matter that drives the late-time accelerating expansion of the big bang universe.

References

[1] Albrecht A & Steinhardt PJ (1982) Cosmology for Grand Unified Theory with Radiatively Induced Symmetry Breaking. Physical Review Letters 48(17), 1220-1223. https://dx.doi.org/10.1103/PhysRevLett.48.1220.

[2] Guth A (1981) Inflationary Universe: A Possible Solution to the Horizon and Flatness Problem. Physical Review D 23(2), 347-356. https://dx.doi.org/10.1103/PhysRevD.23.347.

[3] Kalita R (2015) Dark Energy. Journal of Modern Physics 6, 1007-1011. https://dx.doi.org/10.4236/jmp.2015.67105.

[4] Kalita R (2014) The Nature of Dark Energy and Dark Matter. International Journal of Astronomy 3(18), 18-21. https://dx.doi.org/10.5923/j.astronomy.20140301.02.

[5] Linde AD (1981) A New Inflationary Universe Scenario: A Possible Solution of the Horizon, Flatness, Homogeneity, Isotropy and Primordial Monopole Problems. Physics Letters B 108B (6), 389-393. http://dx.doi.org/10.1016/0370-2693(82)91219-9.

[6] Linde AD (1986) Eternally Existing Self-Reproducing Chaotic Inflationary Universe. Physics Letters B175, 395-400. http://dx.doi.org/10.1016/0370-2693(86)90611-8.

Appendix

As the universe expands, and even if according to present proposition dark energy were to be time varying, and assuming variable dark energy density ρ_ϕ does not decrease faster than matter density ρ_{Matter}, eventually we would have Ω_ϕ ~ 1, and the expansion would then be almost exponential, and the Hubble parameter H would be nearly constant. Apart from the large time scale over which the expansion would be exponential, and unless there is some fundamental constraint of a minimum e-folding time, such a universe would be dynamically indistinguishable from an inflationary universe.

Now according to present proposition, because the expansion is almost exponential in the inflationary universe, inertial mass cannot manifest directly – its presence can only be inferred. There is therefore the possibility that when Ω_ϕ ~ 1 in the big bang universe and it expands almost exponentially, inertial masses in it would also no longer be able to manifest directly. At that point the big bang universe would therefore be not only dynamically but also constitutively indistinguishable from an inflationary universe. Such a transition into an inflationary universe could also allow its rate of expansion to be a free parameter, and it may expand at an 'inflationary rate'. Eventually, the potential of the scalar field $V(\phi)$ rolls down to produce a big bang universe, though its parameters would probably be different from that of the present big bang universe. Thus, the universe could, perhaps endlessly, cycle through inflation and big bang. Such a scenario would be a variation on the multiverse theory of eternal inflation, where big bang universes are continually created out of an eternally inflating universe (Linde [6]).