Dark Matter models the Gravitation of the Expanding Universe

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Abstract

All ordinary matter, extending from the dense past to the dilute present, causes gravitation across the universe. Motions deriving from this tiny universal gravitational field are on display over vast distances. On the one hand, distant galaxies move away; on the other, galaxies in clusters move about. Also, stars and gas clouds orbit around in balance with the local galactic and universal gravitation. This insight into galaxy velocity dispersion and rotation renders dark matter and modified gravity hypotheses redundant.

Keywords: dark matter, gravitation, graviton, modified gravity, photon, vacuum

Introduction

The dark matter hypothesis is not only questioned by missing particles but also by astronomical observations.[1-4] For example, why would dark matter hold acceleration from falling nowhere below about 10^{-10} m/s^2?[5] Why does the law of gravitation, modified by this tiny acceleration parameter, fit many data so well?[6,7] Why does dark matter spread far out from galaxies rather than confining into them?[8] Yet, why is dark matter nowhere fully free from luminous matter? Why do galaxies and their satellites align along a single plane?[9]

We do not take up these questions as if no answers had been provided, but because the questions themselves may imply problems with premises. Therefore, let us reconsider the primary question: Could all ordinary matter account for the observed universal acceleration of about 10^{-10} m/s^2?

The gravitation due to the expansion

We build upon the understanding that the universe is expanding. Thus, the distant early universe is dense and the nearby present is sparse. By the law of gravitation, this isotropic gradient in all mass M across the radius $R \equiv ct$, about 13.8 billion light years, causes acceleration $a_R = GM/R^2 = c/t$ of the order of 10^{-10} m/s^2. The universal gravitation due to the expansion is seen in the redshifts of receding distant objects, e.g., type 1a supernovae.[10]

Rather than modeling the expansion by a metric scale factor, let us examine the gravitational effects of the expansion. In line with Einstein lecturing in Leyden (1920), "There can be no space nor any part of space without gravitational potentials; for these confer upon space its metrical qualities, without which it cannot be imagined at all. The existence of the gravitational field is inseparably bound up with the existence of space."[11]

The proposed universal gravitational potential builds up with distance r from galaxies as their number $\propto r^2$ overpowers the $1/r$-potential.[12,13] By classical physics, every body immersed in this physical plenum perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.[14]

Quantitatively speaking, the vacuum energy density $\rho = c^2/4\pi Gt^2 = GM^2/4\pi R^4 \approx 10^{-9}$ J/m^3, gauged by WMAP,[15] integrates to the gravitational potential $U = -GM^2/R$ of all mass with total energy Mc^2. This balance equation of the universe, i.e., the virial theorem

$$\begin{aligned} 2K + U = 0 &\Leftrightarrow Mc^2 = \frac{GM^2}{R} \\ &\Leftrightarrow a_R = \frac{GM}{R^2} = \frac{c^2}{R} = \frac{c}{t} \equiv cH, \end{aligned} \tag{1}$$

entails acceleration $a_R \approx 6.87 \cdot 10^{-10}$ m/s^2 of the expansion happening per definition at the Hubble rate $H \equiv 1/t$.

The above back-of-an-envelope calculation should not be mistaken for coincidence or numerology between the outward radial acceleration a_R, known as the Hubble flow, and the inward acceleration per orbital cycle $a_R \approx 2\pi a$, deemed as modified gravity.[16,17] In fact, we argue that the outward and inward fluxes, balancing each other at a distance of about 4 million light-years,[18] are both manifestations of the universal gravitation, i.e., the tiny density gradient across the cosmos from the beginning to the present.

The substance of gravitation

As by Eq. 1, Feynman wondered why the energy of all space, free of matter, equals the energy of all matter.[19] However, the ΛCDM concordance model does not explain why the energy density $\rho = \rho_c$ is precisely critical. Instead, the cosmological constant $\Lambda \approx 1/R^2$ is fitted to the observed flatness.[20,21] But, is the cosmos ballooning through intrinsic metric expansion without any cause? Or does the flatness $\Lambda \equiv H^2/c^2 = 4\pi G\rho_c/c^4$ follow from matter transforming into the physical space, e.g., in reactions akin to annihilation? After all, elementary particles emerge from the vacuum in high-energy reactions and submerge into it.

Although the readily detectable radiation accounts only for a tiny fraction ($\sim 10^{-4}$), the gross energy density of the vacuum is not without physical form. Namely, cosmic background radiation, having the structure of the black body spectrum, discloses that empty space is not without structure.[22] The photons do not distribute randomly but by the Bose-Einstein statistics.

So, let us postulate anew[23,24] that space emerges from matter since the proposal does not go against empirical evidence and solves the flatness problem. And, let us focus on motions of the relativistic void, i.e., light-like substance, coupling to bodies instead of just assuming bodies themselves attracting one another.

By this reasoning, effluxes of space, emerging from reactions in numerous celestial bodies, disperse distant galaxies apart. The velocity asymptote $c^4 = a_R GM$ follows from Eq. 1. Thus, matter transforming into space powers the expansion by $P = Fc = Ma_R c = c^5/G$ and generates the pressure $p = F/A = c^4/4\pi R^2 G = \rho_c$.

Since the efflux of space from reactions within the Local Group to the distant universe exceeds the influx therefrom, the Milky Way, Andromeda, and other nearby galaxies approach one another. Given that forces tally where fluxes tally, the Hubble flow begins beyond the zero-velocity radius $r_o = GM_o/c^2$ that relates to $R = GM/c^2$ as the Local Group mass M_o relates to M of the universe.[18,25,26]

Hubble's law, correlating the radial velocity u with distance r via the expansion rate H, suggests the same scaling relation

$$\frac{c^2}{R} = \frac{(u - u_o)^2}{r - r_o} \tag{2}$$

for receding and nearing bodies.[26,27] When $r < r_o$, a body spirals inward as fluxes of space spread outward into the sparser surroundings. Thus, the circumference $2\pi r$ shortens, graviton by graviton, as much as the distant space lengthens along with radius r. Therefore the inward and outward acceleration relate as $a = a_R/2\pi$. Eventually, the body gains an orbital velocity v balancing by v^2/r the universal acceleration a and the galactic acceleration a_o. Then, as per Newtonian dynamics, the inward pulling efflux and the outward pushing influx tally.

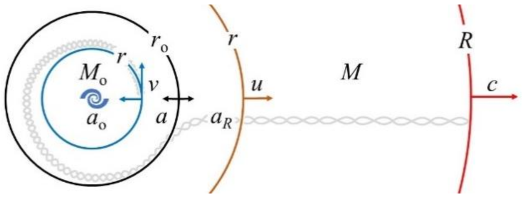

Fig. 1. Within a radius r_o confining mass M_o, graviton efflux exceeds influx from distant sources; thus, a body spirals inward until v^2/r equates the universal a and local a_o acceleration. Beyond r_o, the influx exceeds the efflux; thus, the body recedes at speed $u < c$. At R, enclosing all mass M, the total graviton flux generates the expansion at the speed of light c.

Inferences

At a dynamic steady state, integrated over its characteristic period,

$$\int (\mathbf{v}\cdot d_t\mathbf{p} + \mathbf{v}\cdot\nabla U)dt = 0 \tag{3}$$

momentum **p** and acceleration **a** are orthogonal. Then v^2/r balances both the galactic acceleration $a_o = GM_o/r^2$, due to the central mass M_o within the circumference $2\pi r$, and the universal acceleration $a = GM/2\pi R^2$, due to all mass M within the radius R of the expanding universe according to

$$\frac{v^2}{r} = a + a_o = a_o\left(1 + \frac{a}{a_o}\right) = \frac{GM_o}{r^2}\left(1 + \frac{1}{2\pi}\frac{Mr^2}{M_o R^2}\right). \tag{4}$$

Near the galactic center, $a \ll a_o$. Hence bodies, such as stars in clusters,[28] do not display much of the feeble universal gravitation, customarily mistaken for dark matter.

Conversely, far away from the luminous edge, $a \gg a_o$. Hence $v^2 a_o/r \approx aGM_o/r^2$ limits asymptotically to the Tully–Fisher relation $v^4 = aGM_o$. For example, orbital velocities of dwarf galaxies profile Eq. 4 due to their low amounts of baryonic rather than high amounts of dark matter.[29,30]

A closer match with a given observed rotation curve beyond the point-mass approximation would employ a detailed mass distribution $M_o(r)$ instead of an interpolation[31,32] from the dense galactic surroundings to the sparse universal voids.

The flat tail of the orbital velocity curve tells that faraway, the universal curvature $1/R$ dominates the curvature $1/r = a/v^2$ of a bound geodesic. Beyond r_o, a body escapes along an open geodesic. As by special relativity, a line is truly straight only in an ideal Euclidean flatness without bodies.

Just as stars in galaxies orbit around, galaxies in clusters move about to balance the local and universal gravitation.[33,34] Therefore, the Faber–Jackson relation, ranging from globular clusters to clusters of galaxies including high- and low-surface brightness objects, discloses the universal acceleration a.[35]

Under the central force $\mathbf{F} = M\mathbf{a}$ of the expansion, satellites of the Milky Way, Andromeda Galaxy, and other spirals home in on the galactic plane because space, the substance of gravitation, zeros in on the free energy minimum of least curvature. So, a galaxy punched by another realigns for the same reason as a poked top reorientates.

Discussion

The proposed gravitation of all ordinary matter, manifesting itself in the galaxy rotation and velocity dispersion, is a transparent, omnipresent plenum – hence easily mistaken for dark matter halo. However, compared with dark matter models, the agreement of Eq. 4 with data is impressive with only one adjustable parameter, the mass-to-luminosity ratio.[3,36] Thus, the universal gravitation due to the expansion explains the lion's share of the observed acceleration.

Moreover, modeling data by dark matter is not easy. For example, fine features of orbital velocity profiles tend to get smeared out.[37] Likewise, dark matter must be carefully tuned to reproduce the same orbital velocities for varying spreads of a given luminosity.[38] Also, the rotation curves of dwarf and low surface brightness galaxies are hard to replicate.[39] And velocity dispersions of galaxies in clusters are hard to mimic by sprinkling dark matter[40] or supplementing the law of gravitation with a tiny term[41]. Conversely, our proposal would prove wrong if dark matter particles were found.

The expansion given in terms of matter transforming into the vacuum contrasts parametrizing the expansion with evolving scale factor. Consequently, interpretations of astronomical observations differ too. Specifically, the least-time passage of light from the past dense universe to the present sparse surroundings leaves no room for dark energy.[10] Data by this interpretation does not warrant an accelerating expansion but speaks for the decelerating rate $d_tH = -1/t^2$. The expansion slows down as the fueling matter exhausts. The universe becomes colder and darker.

Like Newton[42] and Faraday[43], also Einstein[11] reasoned that ponderable matter and physical space comprise the same fundamental constituents. As matter-bound quanta transform into spatial ones, the universe is on its way to heat death, the final state of ever diluting and cooling photon gas. Accordingly, the sparsest space is the nearest, the local hole.[44,45]

Although modeling is catching up with data, in the final analysis, a model without a constraining axiom can be made to fit data but not falsified with the data it models. In contrast, the axiomatic principle of least action $d_t2K = -\mathbf{v} \cdot \nabla U + d_tQ$, equating changes in kinetic energy $2K$ with changes in scalar U and vector Q potentials, is falsifiable.[10,22,46,47] Expressly, galaxies are not exactly stationary but dissipative structures $d_tQ \neq 0$. Stars are shining, and other celestial mechanisms, notably black holes, are devouring matter and jetting out quanta.

In addition to the galaxy rotation and velocity dispersion, the gravitational bending of light is seen to evince dark matter. However, the incorrect inference follows from omitting parallax between the rays recorded during an eclipse and from a night sky. The correct conclusion about the gravitational deflection[48] and delay[49] by the principle of least action does not leave room for dark matter.[10]

Furthermore, independently from metric modeling the expansion in dark energy and dark matter terms, the rate $H \equiv 1/t = (\Delta\theta)^2 d_l d_s / d_{ls} R \Delta t$ can be determined from the time delay Δt between images,[50] separated by $\Delta\theta$, of a variable source at a distance d_{ls} from a gravitational lens at d_l.[51] A lensing mass M_o relates to the mass M of the universe by $\Delta t/t = (2\pi)^2 M_o/M$.[46]

Regardless of the lumpiness of the nascent universe, the large-scale isotropy and uniformity follow from the expansion where matter transforms into space. This least-time flattening out density differences solves the horizon problem. For example, per the least-time principle, the most massive stars shine the brightest and the shortest time, well below 100 million years; small stars can glitter for over 100 billion years. Over time, there will be only small differences – as observed.[52] Thus, the highly uniform cosmic background radiation and large-scale isotropic distribution of matter stem from the common cause, not causation across the horizon.

In hindsight, when not knowing how bodies out there exert effects over here, the gravitation due to all matter was bound to be omitted from the balance equation with kinetic energy (Eq. 3). Now, realizing that the physical vacuum embraces and affects everything, makes inertia transparent as an immediate reaction to any action.

Since gravitation and electromagnetism share the same form, could it be that photons, but paired in opposite polarizations, embody the void?[22] The vacuum comprising photons in these pairs would be without net electromagnetic force. Furthermore, the proposed photon pair is indistinguishable from the theorized graviton, a massless spin-2 particle.[53] The massless photon qualifies for the groundstate substance because it does not decay. Conversely, empirical evidence against the paired-photon vacuum would question the proposed explanation of galaxy rotation and velocity dispersion.

In contrast to the light-carrying luminiferous ether, the proposed light-embodying substance as a relativistic ether makes sense of classical experiments, such as those carried out by Arago, Fizeau, Michelson and Morley, and modern measurements, such as those named after Casimir, Aharonov and Bohm. The paired-photon vacuum is easily mistaken for nothingness when probed with photons, but its coupling manifests unmistakably as mass when probed with particles. Perhaps more pertinently, the paired-photon vacuum renders abstract spacetime into concrete, empirically quantifiable substance.

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