Are Energy and Space-time Expanding Together?

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Assuming the universe has permanent critical density gives energy non-conservation, a linear increase of the universe total energy as a function of time. It enables to compute the universe densities of matter, dark matter, and dark energy as distinct effects of a unique source, where dark matter is stress. We show coherence with the Schwarzschild and the Schwarzschild-de Sitter solutions from which we compute the term Λ as geometrical effect of expansion. In this context, we show that MOND is consequence of the universe expansion and compute its parameter value and time evolution.

1 Introduction

This paper follows [1], where we find that energy "is" the universe expansion, and complements the analysis. But here we proceed from side-thinking: The next theory of gravity, if any, will have to recover the Einstein field equations (EFE). Therefore correlations between quantities considered independent in general relativity (GR), are instructive as to the object and contents of a better theory. Then in order to find new correlations we shall rely on a) the geometry of existing EFE solutions, and b) one coincidence which is critical density.

1.1 Coincidences

According to the Planck mission (PM) 2015 results [10], it seems that the universe has critical density:

$$\rho_T = \frac{3\,H^2}{8\pi\,G}\,, \tag{1}$$

where G is Newton's constant, and H the Hubble parameter. Note, with respect to [1], that we compute ρ_T from (1) instead of the total dark fields density. Taking $H = 1/T$, where T is the universe age and the distance to the cosmological event horizon $R_U = c\,T$, it also reads:

$$2\,G = \frac{R_U\,c^2}{M_T}\,, \tag{2}$$

where $M_T\,c^2$ is the total energy of the observed universe. Then (1-2) uncovers a symmetry of the Schwarzschild solution:

$$\frac{R_s}{r} = \frac{R_U\,M}{M_T\,r}\,, \tag{3}$$

where gravity is the interaction of all energies of the observed universe; that is to say Mach's principle. But (1) also reads:

$$M_T c^2 = \frac{P_p\,T}{2}\,, \tag{4}$$

which means that the energy of the observed universe grows linearly according to half the Planck power $P_p = c^5/G$. We see that the same equation (1) takes 4 forms which can be given very large significance ranging from the simplest system (3) to cosmology (4) and the absence of a big bang.

Now take the Bekenstein-Hawking area-entropy law:

$$S = \frac{K\,A\,c^3}{4\,G\,\hbar}\,, \tag{5}$$

which states that the entropy S associated with an event horizon is its area A divided by $4G$ [2] [3] (where K and $\hbar$ are Boltzmann and the reduced Planck constants respectively). It also applies to the de Sitter cosmological event horizon [4] seen at R_U:

$$S = \frac{4\pi\,K\,R_U^2\,c^3}{4\,G\,\hbar}\,. \tag{6}$$

Now injecting (1) in (6) gives:

$$\frac{\hbar}{K} \times \frac{S}{M_T\,c^2} = 2\pi\,T\,, \tag{7}$$

which means that the ratio between entropy S and energy $M_T\,c^2$ at any given epoch, "is cosmic time" – or the opposite, entropy is accumulation of action in the manner of an old de Broglie conjecture about the physical significance of $h\,S = K\,A$ which associates an action A and an entropy S to any piece of energy.

Using GR the probability for the "coincidence" (1) to be observed is about zero, there is not even a theoretical reason for the order of magnitude to ever come out; secondly (2) and (7) establish a simple, clear, and unexpected quantitative fit between gravity, cosmic time, energy, and entropy – where energy is not supposed to be. So maybe this is a big deal and we shall assume that (1) is not a coincidence but a law of nature ruling the universe expansion together with its energy.

Consider now the FLRW metric with a positive cosmological term and homogeneous density - that is to say the ΛCDM model. Assuming that (1) is not just a coincidence implies that it is valid at any epoch; then using (4) since the FLRW metric describes a simple 4-ball, we can slice it with 4-spheres centered at the origin, of radius r and thickness $2\,l_p$ (both along the light cone), and each slice adds an identical energy increment M_p, the non-reduced Planck mass, and it looks like the universe is a Planck power space-time generator.

The visible matter field exists "now" at the surface of the 4-sphere while M_T, as defined from R_U, is causal and occupies the light cone. Then a geometrical ratio exists between the two quantities, which evolve together. Simple integration gives $2\pi^2$ the 4-sphere surface coefficient and removing the "surface" we get the total dark field density ρ_D:

$$\rho_D = \rho_T \times \frac{2\pi^2}{1+2\pi^2} = 8.98 \times 10^{-27}\,\mathrm{kg\,m^{-3}}\,, \tag{8}$$

which agrees with PM results. The difference $\rho_V = \rho_T - \rho_D$ is the visible matter density and represents 4.82% of the total density ρ_T where the PM found 4.86 (8)%.

So, computing matter density ρ_V from geometry and (1) is totally abnormal in GR; we can even say irrelevant. But at the opposite, if those quantities *and others* are calculable, GR is incomplete and we can even say that it misses a fundamental point. In the remainder of this paper we shall analyze the consequences of (1) and (8) and check if nature agrees.

1.2 Premises

Noether's theorem is the basis of conservation laws; it is used to evaluate energy conservation, and it works perfectly in quantum field theory. In GR, an area in which energy is assumed constant is defined by physical rods and clocks.

But how do we measure the rod? Essentially by decree of conservation. We define a-priori what a meter is and the postulate is that a rod does not evolve; up to now, there is no experimental results which is recognized to require any change to this postulate. But we cannot physically compare rods between distinct epochs. Even though GR studies the transfers of clocks and rods between distinct space-time locations, it assumes that no hidden source comes to expand its energy – and this is what (2) states: G is assumed constant, then the total energy M_T evolves in proportion of R_U, and we measure that the observable universe radius $R_U = c\,T$ grows.

It can be interpreted in different manners and we have to choose one that can be logically understood and requires minimal hypothesis. In the next sections we shall proceed from the four premises hereafter which were chosen appropriately, explaining how (2) physically works; we shall then use three EFE solutions to show coherence with existing theory and unexplained experimental data. Premises are:

- P1: The universe proceeds from the FLRW metric with cosmological term $\Lambda > 0$.
- P2: The observable matter field (particles) rests at the surface of a 4-sphere.
- P3: A mechanism exists inflating the 4-sphere and expanding masses and energy; both effects are simultaneous.
- P4: The metric expansion includes inflation of the 4-sphere radius and a reduction of particles wavelengths; energy condenses permanently and progressively.

Those premises are easily justified:

- P1 agree with the best verified model, and
- P2 is direct consequences of the "coincidences".
- P3 and P4 must be taken together; the feed mechanism in P3 could be just the radial expansion of a 4-ball in a preexisting 4-dimensional space filled with constant energy density. The sphere expands and masses increase reducing wavelengths; this is permanent and progressive condensation, hence P4.

2 The dark fields and the expansions

2.1 Expansion in the Schwarzschild solution

We first use the Schwarzschild solution to study the effects of (2) and expansion at different heights in the gravitational pit of a central mass M (the basic test case) and assume the system far away from other gravitational sources. With respect to (2), M_T is variable in time but constant in space ($M_T \sim T$), so M is also variable in time. At the opposite since gravitation is a retarded interaction, the metric in r is retarded and the Schwarzschild solution must be modified accordingly. Hence, using P3-P4, r and M (or R_s) expand; with respect to [1], introducing new ad-hoc parameters α, β to separate the effects of energy and space expansion, we write from (2):

$$\frac{R_s}{r} = \frac{R_U\,M}{M_T\,r} \to \frac{R_U\,M}{M_T\,r} \times \frac{1-\alpha\,Hr/c}{1+\beta\,Hr/c}\,. \tag{9}$$

Gravitation is retarded; a signal goes from M to r. Hence the correction at the numerator of (9) denotes that when the signal was emitted the mass M was lesser than expected in GR. Secondly, the additional delay we introduce comes from expansion. Then at the denominator, r "looks" advanced because the signal dilutes more than with a static r, and we expect $\beta = 1$. Second order limited development yields:

$$\frac{R_U\,M}{M_T\,r} \to \frac{R_U\,M}{M_T\,r} - (\alpha+\beta)\,\frac{M}{M_T} + \beta(\alpha+\beta)\,\frac{M\,r}{M_T\,R_U}\,. \tag{10}$$

Now examine this expression:

- The first term is nominal and now corresponds to a static field.
- The middle term cannot be seen negligible since it addresses identically all masses of the universe. It must be integrated to M_T, giving -1 *which is the flat metric and it denotes its production*; from (8), $\alpha + \beta = 2\pi^2$.
- Therefore the right hand term must also be integrated to M_T giving $H\,r/c$, or a cosmological term $H\,c$ with unit of acceleration; and we find $\beta = 1$.

Note that we use a limited development in r so we cannot integrate to R_U, but we can still integrate to M_T as the middle term of (10) requires. Overall, after integration to M_T we get:

$$\frac{2\,G\,M}{r\,c^2} = \frac{R_U\,M}{M_T\,r} \rightarrow \frac{2\,G\,M}{r\,c^2} - 1 + \frac{r}{R_U}. \qquad (11)$$

We shall now analyze this modified solution and show that the two new terms correspond to dark energy (DE) and dark matter (DM) – meaning exactly.

2.2 Dark energy and dark matter

The limited development above corresponds to a unique field that we split in three non-independent components. In [1], we analyzed the relations between the two new components; we showed that considering the first as an energy field X and the second as stress leads to:

$$M_{se(R)}\,c^2 = \frac{1}{2}\int_0^R \left(4\pi\,\rho_X\,r^2\right)(H_R\,c\,r)\;dr = \frac{3}{8}\,M_{X(R)}\,c^2\,,$$

where $M_{X(R)}$ is the energy of the field X in a 3-sphere of radius $R \ll R_U$, while $M_{se(R)}\,c^2$ is the stress given by the acceleration $H\,c$, which is equivalent to a potential $H\,c\,r$. (Note that in the integral energy is given by acceleration, then kinetic energy $p^2/2m$; thus the factor 1/2.) Therefore:

$$\frac{M_{se(R)}}{M_{X(R)}} = \frac{3}{8} = 0.375\,, \qquad (12)$$

which agrees with the ratio of DM to DE given by the PM:

$$\frac{\Omega_C}{\Omega_{DE}} = \frac{0.2589}{0.6911} = 0.3746\,, \qquad (13)$$

and, since M_{se} is stress, identification is trivial; X is dark energy which creates stress interpreted as dark matter. Now we solve the system of equations and coincidences:

$$\rho_D = 2\pi^2\,\rho_V = \frac{2\pi^2}{2\pi^2+1}\,\rho_T = \frac{11}{8}\,\rho_{DE} = \frac{11}{3}\,\rho_C\,. \qquad (14)$$

It leaves no freedom or randomness in cosmological energies. In GR theory, those energy densities give four distinct effects:

- ρ_{DE} provides with a *decreasing* repelling force at the origin of expansion and then of the flat metric.
- ρ_C is stress due to the same repelling force; in the EFE stress comes in the stress-energy tensor, like mass, and then this result agrees with the ΛCDM model.
- ρ_V lies at the 4-sphere surface and non-homogeneity creates deviations to the flat metric.
- ρ_T is their sum and has critical density.

Each density finds its appropriate places in the EFE, and we can use M_T and R_U to replace G in the equations; we could compute $\Lambda = 8\pi\,G\,\rho_{DE}$ but we shall deduce it differently.

2.3 Λ and the CDM

In recent papers, [5–7] P. Marquet formally showed that a varying cosmological term restores in the EFE a conserved energy-momentum *true tensor* of matter and gravity with a massive source:

$$G^{\alpha\beta} = \frac{8\pi\,G}{c^4}\left[(T^{\alpha\beta})_{\text{matter}} + (t^{\alpha\beta})_{\text{gravity}}\right], \qquad (15)$$

Here $(t^{\alpha\beta})_{\text{gravity}}$ includes a background field tensor which persists in the absence of matter:

$$(t_\beta^{\ \alpha})_{background} = \frac{c^3}{8\pi\,G}\,\delta_\beta^{\ \alpha}(\Xi/2)\,, \qquad (16)$$

where $\Xi/2$ is the variation of cosmological constant Λ. As a result the de Sitter-Schwarzschild metric is slightly modified:

$$1 - \frac{R_s}{r} - \frac{\Lambda\,r^2}{3} \rightarrow 1 - \frac{R_s}{r} - \frac{\Lambda + \delta\Lambda}{3}\,r^2\,,$$

which we identify term to term with (11). But recall that the factor 1/3 in this metric is given by integration, it is then irrelevant for a correspondence with a derivative. We also introduce a parameter k to solve:

$$k\,\Lambda + k\,\delta\Lambda \leftrightarrow -1 + \frac{r}{R_U}\,, \qquad (17)$$

which means that since Λ is a constant, integration to RU is now possible and will give the flat metric like in (11); then:

$$-k\,\Lambda\int_0^{R_U} r^2 dr = 1 \rightarrow k\,\Lambda = \frac{1}{3\,R_U^3}\,. \qquad (18)$$

Then for any r we have $k\,\delta\Lambda(r) = -1/r^2$. Integrating the last term to the full solid angle (as stress), multiplying by 1/2 for kinetic energy and identifying with $H\,r/c$ gives:

$$\frac{1}{2}\int 4\pi\,k\,\delta\Lambda(r)\,r^2\,dr = \int 2\pi\,k\,dr = \frac{H\,r}{c}$$

$$\rightarrow k = \frac{H}{2\pi\,c} = \frac{1}{2\pi\,R_U}\,, \qquad (19)$$

where k is also the ratio entropy/energy on the right-hand side of (7). Here it links the expansion of R_U (∼ energy) to that of DE (∼ Λ) through $2\pi\,R_U$. Now we have completed the correspondence and using (18) and (19) we get:

$$\Lambda = \frac{2\pi\,c}{3\,H\,R_U^3} = \frac{2\pi}{3\,R_U^2} = 1.229\times 10^{-52}\ \text{m}^{-2}\,. \qquad (20)$$

The standard ΛCDM estimate is:

$$\Lambda \approx 1.19\times 10^{-52}\ \text{m}^{-2}\,, \qquad (21)$$

and then our reasoning on energy expansion is appropriate. But we found that the dark field has a unique source since

$\rho_{DE} \to \rho_{DM}$; then extending the source unicity to ρ_V explains the difference between (20) and (21) as the share of dark energy invested at the surface, its share of ρ_V. Picking Λ in (20) and following the ratios in (8) and (14):

$$\frac{\Lambda}{1 + \frac{1}{2\pi^2} \times \frac{8}{11}} = 1.185 \times 10^{-52}\,\mathrm{m}^{-2}\,, \tag{22}$$

which is well within precision of (21); here the complimentary $3/11$ of ρ_V comes from stress (12) in agreement with (8) where ρ_V is the surface.

3 The classical field

As shown in [1], using the Bohr hydrogen model (or inspecting the Dirac equation), we find the effects of $H\,c/2\pi$ when elementary particles mass increase linearly in time, and abusively computing with respect to a fixed frame:

$$\frac{da_0}{dt} = \frac{H\,c}{2\pi\,\nu}\,, \tag{23}$$

where a_0 is the Bohr radius and ν the electron pulsation ($E = h\,\nu$). In quantum theory, distances like a_0 are quantized as the inverse of mass, but in gravity the classical force is given by a product of masses, which doubles the effect. Then in the very weak gravitational field the acceleration $H\,c$ gives measurable effects in the form of anomalous acceleration; in circular orbit it will be:

$$a_{Hc} = \frac{H\,c}{2\,\pi} = 1.10 \times 10^{-10}\,\mathrm{m\,s}^{-2}\,, \tag{24}$$

like in (7) and (19). Then Newton's theory is no more the weak field limit of GR as it also needs $R_U \to \infty$. Now a_{Hc} is in range with Milgrom's modified Newton dynamics (MOND) limit acceleration [8, 9], which estimate is:

$$a_0 = 1.20\,(\pm 0.2) \times 10^{-10}\,\mathrm{m\,s}^{-2}\,. \tag{25}$$

Then we shall recover MOND in the weak field/circular orbit problem. In the modified Schwarzschild solution in (11), the term $H\,c$ denotes that the classical potential is permanently becoming steeper. Then a_{Hc} has specific direction; it just amplifies the local Newton acceleration. The simple sum gives:

$$A = \frac{G\,M}{r^2} + a_{Hc}\,. \tag{26}$$

Applying a force to an object in free fall gives reaction, so denoting A_N the Newton acceleration we can write:

$$A_N \left(1 + \frac{a}{A_N}\right) \Rightarrow -a\,, \tag{27}$$

where $-a$ corresponds to the effect of inertia, as a reaction to a non-gravitational acceleration a when A_N and a are parallel. *In GR this equation is given by the field transformation in weak accelerations.* Now denoting A_{eff} the effective acceleration in circular orbit we have $A_{eff} \Rightarrow 0$; meaning that it is A_{eff} that transforms the field, and not A_N. Then in order to link A_N, A_{Eff} and A_{Hc}, we must write:

$$A_N = \frac{f}{m} = A_{eff}\left(1 + \frac{a_{Hc}}{A_{eff}}\right)^{-1}\,, \tag{28}$$

where, since (27) defines the field transformation, the denominator of the right-hand side formally removes a_{Hc} from A_{eff} and then recovers the Newton force. *This equation is MOND simple interpolation function; needless to list the wide range of astrophysical data it fits.* It is then a formal approximation of the modified Schwarzschild solution in (11). QED.

4 The Hubble parameter and accelerated expansion

The parameters $\alpha = 2\pi^2 - 1$ and $\beta = 1$ in (9), which values are deduced reasoning on (10), show that the contribution of space expansion to the metric is trivial ($\beta = 1$), and the contribution of mass expansion is $1/2\pi^2$. Therefore the observable r, which depends on *massive* clocks and rulers, expands more than simple space expansion. Then we can approximate the metric state at distance r from the observer with:

$$d\tau(r)^2 \approx d\tau(0)^2 \times \left(\frac{2\pi^2}{2\pi^2 + \frac{R_U - r}{R_U}}\right)^2\,. \tag{29}$$

Therefore, measurements of the Hubble parameter from the CMB spectrum ($r \to R_U$) will give a value different from and larger than $H = 1/T$; we find:

$$H = \frac{1}{T} \to H^0_{CMB} = \frac{2\pi^2\,H}{2\pi^2 + 1} = 67.53\,\mathrm{km/s/Mpc}\,, \tag{30}$$

which agrees with the PM results:

$$H^0_{CMB} = 67.74 \pm 0.46\,\mathrm{km/s/Mpc}\,.$$

Eq. (29) gives other measurable effects:

- When measuring H^0 from baryon acoustic oscillations (BAO) for which T is also close to zero, the same discrepancy appears, $H^0_{BAO} \approx H^0_{CMB}$, as shown in [10].
- At the opposite, $H = 1/T = 71.1$ km/s/Mpc is compatible with most recent Hubble space telescope data [11] taken from SN1A (73.24 ± 1.73 km/s/Mpc, currently valid at $\sim 2 - 3\sigma$), for which $r \to 0$.
- A simple plot shows that the denominator of (29) permanently gives the illusion of accelerating expansion.

Last, the symmetry in (1) is:

$$\lambda\,R_U = const\,, \tag{31}$$

where λ is the Compton wavelength of any piece of energy. Taking the universe mass and $\lambda_T = h/M_T\,c$ yields:

$$\lambda_T\,\frac{T}{2} = l_p\,t_p\,,$$

where l_p and t_p are the non-reduced Planck length and time respectively. It gives immediate significance to those units as they define the symmetry of the field expansion versus condensation. It denotes an inversion between spaces and times which reads:

$$\frac{T}{t_p} = \frac{2\,l_p}{\lambda_T}\,, \tag{32}$$

and a similar equation also applies to any mass. Hence the energy scales corresponding to l_p and t_p are epoch-relative like clocks and rulers, and also other Planck units (M_p, P_p). It just means that the laws of nature are constant but that the scale at which they apply vary in time.

It makes a big difference when thinking of quantum gravity which is expected to solve the big bang problem, because (32) is a symmetry linking the expansions of space-time and energy in a non-linear manner. To show this, from (32) and since energies increase, we find that at any given epoch:

$$R_U = c\,T_0 \int t_p/t\,, \tag{33}$$

where the quantum of time t_p replaces dt, and T_0 is a constant. Integration gives a logarithm which implies that the universe radius as observed from loopback time at any epoch, but assuming energy conservation, starts with inflation.

5 Conclusion

Overall, we found 9 strong correlations (*) giving distinct numerical results agreeing with unexplained experimental data in several domains of cosmology and astrophysics. We also find inflation for which a quantitative fit is out of reach, and the illusion of accelerating expansion. All come from a single assumption, a limited development, and classical solutions of the Einstein field equations.

The correlations above are totally irrelevant in GR, and also in QFT, but nature agrees at all scales. Hence the answer to the title is positive, and then GR and QFT miss the most important point which is that the expansion of space-time is identical to the expansion of energy. That is to say that space-time and energy are the same phenomenon. Importantly, all correlations are geometrical and all calculus use as input only one parameter, namely the universe age T, and natural constants G and c; then the next theory uses geometry and has no free parameters.

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*With (1), (8), (12–13), (19), (20), (23), (24–25), (28), and (30).

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