'Un-Darkening' the Cosmos: New laws of physics for an expanding universe

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Do **dark matter** and **dark energy** really exist? Or are the equations from which we infer their existence simply wrong?

"We know how much dark energy there is because we know how it affects the universe's expansion.

Other than that, it is a complete mystery. ...It turns out that roughly **68% of the universe is dark energy. Dark matter makes up about 27%**.

The rest - everything on Earth, everything ever observed with all of our instruments, all normal matter - adds up to less than 5% of the universe.

Come to think of it, maybe it shouldn't be called "normal" matter at all, since it is such a small fraction of the universe."

(www.science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy)

We've been fooled by our **weird world** before.

- Phlogiston
- Ether versus apparent constancy of the speed of light (Michelson-Morley experiment)
- Blackbody radiation (the Rayleigh-Jeans) experiment

- In every case the 'fixes' (chemistry and thermodynamics, special relativity and quantum mechanics) meant throwing away old equations and inventing new ones.
- Sometimes these reduced to our old ideas in some limit, but not always.
- This presentation suggests we have been fooled again.

  Whenever 68% of something inferred from our equations is missing (or even 27%) we should strongly suspect our equations are wrong!

An example of how we could have been fooled.

- If time were logarithmic, then these two derivatives would have been indistinguishable by any measurement we can make in our present era:

$$\frac{d}{d \ln t} = t \frac{d}{dt} \approx t_p \frac{d}{dt} \tag{1}$$

  where t the absolute time since the beginning and $t_p - t < 500$ years and the age of the universe is so large (about 14 billion years)..
- The reason of course is that:

$$\ln t - \ln t_p = \ln[(1 - (t - t_p)/t_p] \approx (t - t_p)/t_p \tag{2}$$

- For the same reason any change in a length scale parameter for the universe, say $\delta(t)$, would have simply not been measurable since $\delta(t_p) \approx \delta(t)$.
- The same argument applies to any non-linear time, even exponential.

Even the astronomers conclusions about the data are suspect

- The work the astronomers have done is truly spectacular. That they can get data of such high quality at all is truly remarkable.
- **BUT** most deductions are based on *models and earthly physics* about how the universe works. If the model or physics is wrong or not quite right at large scales, so are the deductions.
- For example. if radiation is propagating through a linearly expanding universe with logarithmic time, the red-shifted frequency is:

$$\omega = \frac{d\phi}{dt} = \frac{\omega^*}{t} - \vec{k}^* \cdot [\vec{\eta} - \vec{\eta}_{osc}] \left[\frac{1}{\delta} \frac{d\delta}{dt} \right] \tag{3}$$

  Note the extra term, ω^*/t, which if not included would lead to the conclusion that the universe expansion rate is increasing with t even if it is not (George 2016 J. Cosmology).

General Relativity and Einstein's Field Equations

:

$$\left\{R\mu\nu - \frac{1}{2}R\ g_{\mu\nu}\right\} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{4}$$

- $G_{\mu\nu} = R_{\mu\nu} - (1/2)Rg_{\mu\nu}$ is called the Einstein Tensor
- $R_{\mu\nu} = R^{\alpha}_{\mu\alpha\nu}$ is the Ricci tensor which is the trace of the Riemann curvature tensor, $R^{\alpha}_{\mu\beta\nu}$.
- $R = g^{\mu\nu}R_{\mu\nu}$ is the curvature scalar and $g^{\mu\nu}$ is the metric tensor.
- $T_{\mu\nu}$ is the energy-momentum tensor.
- Λ is Einstein's **cosmological constant** which was **arbitrarily** added to the equations.
- The left-hand-side tells how space-time is curved by the distribution of energy and matter on the right-hand side.

The Weakest Link is to Newton's Second Law and Gauss' Gravitational Law

- Einstein set things up this way. He wanted to reproduce these 'known' results under 'earthlike ordinary' conditions.
- So his field equations are really as 4-dimensional generalization of **Gauss' gravitational law**; i.e.,

$$\nabla^2 \Phi = 4\pi G \rho(\vec{x}) \tag{5}$$

  where Φ is the gravitational potential field and $\rho(\vec{x})$ is the mass density distribution.
- These of course reproduce Newton's Gravitational Law exactly, but introduce the idea of a *gravitational acceleration field* that exists everywhere even if the mass is concentrated – hence the term **field equations**.
- We argue instead that **universal laws should be written in universal coordinates**, and our earthly laws deduced as approximations to them. Clearly either our old G or ρ must depend on δ or t.

Einstein Field Equation

$$\left\{ R\mu\nu - \frac{1}{2} R \; g_{\mu\nu} \right\} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{6}$$

- So to use these we just need to pick a metric (like the Minkowski metric $ds^2 = -c^2 dt^2 + dx^2 + dx^2 + dy^2$. for the left-hand side, and start differentiating and computing Christoffel symbols.
- R_{tt} will always be like the acceleration term in Newton's Law (i.e., like $\partial^2 \vec{x} / \partial t^2$)
- And the T_{tt} on the right-hand side will just be the 'mass' density distribution, but computed using the rest mass $m = E/c^2$.
- If $\Lambda = 0$, space is flat — as all our observations to-date suggest.
- BUT if $\Lambda = 0$ there can be no dark energy. So we invent 'vacuum energy' and stick that into E to make our equations balance. Do vacuums have energy – enough for the missing 68%? Many think so. But it has never been seen.

The FLRW solutions for homogeneous isotropic space

- The usual metric satisfying these conditions was first used by Friedman about 100 years ago:

$$-c^2 \mathrm{d}\tau^2 = -c^2 \mathrm{d}t^2 + a(t)^2 \mathrm{d}\boldsymbol{\Sigma}^2 \tag{7}$$

  where $\boldsymbol{\Sigma}$ ranges over a 3-dimensional space of uniform curvature.

- $\mathrm{d}\boldsymbol{\Sigma}$ does not depend on t all of the time dependence is in the function $a(t)$, known as the "scale factor"

$$\mathrm{d}\boldsymbol{\Sigma}^2 = \frac{\mathrm{d}r^2}{1 - kr^2} + r^2 \mathrm{d}\boldsymbol{\Omega}^2, \tag{8}$$

$$\mathrm{d}\boldsymbol{\Omega}^2 = \mathrm{d}\theta^2 + \sin^2\theta \, \mathrm{d}\phi^2. \tag{9}$$

  k is a constant representing the curvature of the space.

- For most of cosmology (more than a billion years), the Newtonian equations give same result. Only need GR when the mass is very concentrated (eg. black hole) or massless (eg. photon) and traveling very close to a massive body (eg star).

The Ricci Tensor in Reduced-Circumference Polar Coordinates

In more general FLRW space using spherical coordinates the surviving components of the Ricci tensor are (Wiki):

$$
\begin{aligned}
R_{tt} &= -3\frac{\ddot{a}}{a}, && (10)\\
R_{rr} &= \frac{c^{-2}(a(t)\ddot{a}(t) + 2\dot{a}^2(t)) + 2k}{1 - kr^2} && (11)\\
R_{\theta\theta} &= r^2(c^{-2}(a(t)\ddot{a}(t) + 2\dot{a}^2(t)) + 2k) && (12)\\
R_{\phi\phi} &= r^2(c^{-2}(a(t)\ddot{a}(t) + 2\dot{a}^2(t)) + 2k)\sin^2(\theta) && (13)
\end{aligned}
$$

and the Ricci scalar is

$$R = 6\left(\frac{\ddot{a}(t)}{c^2 a(t)} + \frac{\dot{a}^2(t)}{c^2 a^2(t)} + \frac{k}{a^2(t)}\right). \qquad (14)$$

The Friedmann (or FLRW)) equations

When the energy-momentum tensor is similarly assumed to be isotropic and homogeneous. The resulting equations with the standard big bang cosmological model including the current Λ-Cold-Dark Matter model are (Wiki)

$$\dot{\rho} = -3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) \tag{15}$$

$$\frac{\ddot{a}}{a} = \frac{4\pi G}{3}(\rho + \frac{3p}{c^2}) + \frac{\Lambda c^2}{3} \tag{16}$$

- ρ is the energy (or effective mass density) which is for matter just E/c^2 per unit volume.
- These generally solved for $a(t)$, the expansion rate of the universe.
- They assume time is measured in linear increments.
- And that gravity is Gauss/Newton.

Einstein's 'Greatest Mistake'

- Einstein (like Newton) believed the universe to be static. So without the constant Λ which he **arbitrarily added**, a static universe meant that the equation reduced to:

$$\frac{\ddot{a}}{a} = 0 = \frac{4\pi G}{3}(\rho + \frac{3p}{c^2}) \tag{17}$$

  and there was no gravity.
- So only by adding the cosmological constant term $\Lambda c^2/3$, could he keep things balanced. But even this turned out to be unstable.
- His '*mistake*' (according to him) was not recognizing that his equations were telling him the universe was not static. So LeMaitre gets the credit for that. And the Big Bang idea.
- The results of Hubble made clear that $a(t)$ was indeed increasing.
- But even so, the model with $\Lambda = 0$ does not really predict very well any epoch we have been able to measure. And for sure it cannot grow exponentially as many currently believe.

Let's try an alternative approach where we write the laws of physics first in expanding space AND TIME!

- For our new gravitational acceleration potential we will write:

$$\nabla_\eta{}^2\Phi^* = 4\pi G^* \rho^*(\eta) \tag{18}$$

  where $\eta = r/\delta(t)$, r and $\delta(t)$ represents the time dependent length scale of the universe (to be determined or specified by measurement) and G^* is true universal gravitational constant.
- For all times within our earthly environment, $\delta(t)$ is indistinguishable from a constant.
- We get our previous law if $G^*\rho^* = G\rho/\delta^2$ where G is what we previously believed to be the universal gravitational constant and ρ is what we previously believed to be inertial mass density.

Proposal: A New Metric

- We propose that the appropriate metric for a homogeneous isotropic expanding universe is:

$$ds^2 = \frac{-c^2dt^2 + dr^2 + r^2(d\theta^2 - sin^2\theta d\phi^2}{\delta(t)^2}) \tag{19}$$

- An obvious candidate would be an exponentially growing universe for which $\delta(t) = A\ \exp(\beta\ t)$ which implies a constant value of the Hubble parameter:

$$H(t) = \frac{1}{\delta}\frac{d\delta}{dt} = constant \tag{20}$$

- Another option consistent with recent observations might be a linearly expanding universe for which $\delta(t) = K\ t$ which implies $H(t) = 1/t$.
- BUT in principle $\delta(t)$ (or $d\delta/dt$) could be whatever the astronomers tell us it is *using consistent models to evaluate their data*.

A metric for homogeneous isotropic linearly expanding space

- Let's for the sake of this presentation restrict ourselves to a linearly growing universe, say $\delta = Kt$.
- Then we can rewrite our metric as:

$$ds^2_{lin} = -\left[\frac{c^2}{K^2}\right](d\ln\tau)^2 + d\eta^2 + \eta^2(d\theta^2 - sin^2\theta d\phi^2) \quad (21)$$

  where $\tau = \ln t/t_o$ and t_o simply sets the units of linear time.
- t of course is the linearly measured time since the beginning of time – or at least a virtual origin accounting for a change of physics very close to the Big Bang.
- Note that since $K = d\delta/dt$ is constant, the dimensionless speed of light c/K is itself constant.

What is absolute time? Or LOGARITHMIC TIME? Or EXPONENTIAL TIME?

- Let's DEFINE **absolute time**, say t, to be the time measured in linear increments since the beginning of time – the Big Bang if you will.
- Note that a Big Bang does not imply the universe must be expanding. It could have been a BIG BANG in an infinite universe. But this really doesn't matter to us. We just pick an arbitrary place whence begins our current epoch.
- And we DEFINE **logarithmic time**, say τ as the log of absolute time normalized by some arbitrary time scale. I.e.

$$\tau_{ln} = \ln(t/t_o) \tag{22}$$

  where t_o is the arbitrary time scale.
- We could simllarly define an exponential time as:

$$\tau_{exp} = \exp(t/t_o) \tag{23}$$

How could we not have noticed that time might not be linear?

- Mechanics is all about time differences.
- Logarithmic time satisfies this, since if the difference in two times is δt, then the difference in logarithmic time is:

$$\delta\tau_{ln} = \ln(t+\delta t)/t_o - \ln(t/to) \quad (24)$$
$$= \frac{\delta t}{t} + \left[\frac{\delta t}{t}\right]^2 + \cdots \quad (25)$$

- But t until now is about 13.8 billion years — 13.8×10^9!!!! And we have been doing mechanics for only about 500 years. So to see the leading error term could at most be 3.6×10^{-8}!
- Even if time varied exponentially, we wouldn't have noticed since

$$\delta\tau_{exp} = \exp(t+\delta t)/t_o - \exp(t/to) \quad (26)$$
$$= \exp t/t_o \left\{ \frac{\delta t}{t} + \frac{1}{2}\left[\frac{\delta t}{t}\right]^2 + \cdots \right\} \quad (27)$$

Logarithmic velocity and accelerations in an expanding universe

- For an expanding spatial coordinate system, any displacement, say $\vec{\eta} = \vec{x}/\delta(t)$, the logarithmic velocity would be given by:

$$\vec{V} \equiv \frac{d\vec{\eta}}{d\tau} \tag{28}$$

$$= \frac{t}{\delta}\vec{v} - \left[\frac{t\dot{\delta}}{\delta}\right]\eta \tag{29}$$

  where $\vec{v} = d\vec{x}/dt$ is the linear time non-expanding velocity.
- If $\delta = Kt$, then the linear non-expanding velocity seen by us is:

$$\vec{v} = \frac{\delta}{t}\vec{V} + \dot{\delta}\ \vec{\eta} \tag{30}$$

- In any distant galaxy for any velocity at rest in it, $\vec{V} = 0$, so it is perceived by any other galaxy at distance $|\vec{\eta}|$ to be moving at $\vec{v} = \dot{\delta}\ \vec{\eta}$. Thus if $\dot{\delta} > 0$ it is perceived as moving away

Could we have been able to tell whether the universe is expanding?

- Certainly not by measuring distances, since any distance or length scale, say $\delta(t)$, is also changing very slowly.
- But by measuring redshifts of radiation we can tell the universe is expanding. So we can measure $\dot{\delta}/\delta$.
- We indeed observe Hubble's 'law'

$$v_{galaxy} = H(t)\ d_{galaxy} = \frac{\dot{\delta}}{\delta}\ d_{galaxy} \tag{31}$$

  where $H(t) = \dot{\delta}/\delta$ is the Hubble parameter.
- If $H(t) =$ constant $\delta(t)$ is exponential. If $\dot{\delta} = constant$, the universe grows linearly.
- Unfortunately the amount of the redshift we measure depends on what we assume about $\delta(t)$ and t itself.

How does this work for Maxwell's equations?

- Maxwell's equations (in Gaussian units) are given by (Wiki) as: $\partial E_j/\partial x_j = 0$, $\partial B_j/\partial x_j = 0$ and

$$\epsilon_{ijk}\frac{\partial B_k}{\partial x_j} = -\frac{1}{c}\frac{\partial E_i}{\partial t} \tag{32}$$

$$\epsilon ijk\frac{\partial E_k}{\partial x_j} = \frac{1}{c}\frac{\partial B_i}{\partial t} \tag{33}$$

  where c is the speed of light and assumed to be constant and universal.

- Rewriting these in an expanding coordinate system $\eta_i \equiv x_i/\delta(t)$ yields immediately: $\partial \hat{E}_j/\partial \eta_j = 0$, $\partial \hat{B}_j/\partial \eta_j = 0$ and

$$\epsilon_{ijk}\frac{\partial \hat{B}_k}{\partial \eta_j} = -\frac{\delta}{c}\frac{\partial \hat{E}_i}{\partial t} \tag{34}$$

$$\epsilon ijk\frac{\partial \hat{E}_k}{\partial \eta_j} = \frac{\delta}{c}\frac{\partial \hat{B}_i}{\partial t} \tag{35}$$

Maxwell's Equations with Linear Expansion Rate and Logarithmi Time

- In the special case where δ is linearly dependent on absolute time, t, we can write $\delta = Kt$ where K is the expansion rate of the universe. Using this we can absorb the t directly into the equations with time-derivative as follows:

$$\epsilon_{ijk} \frac{\partial \hat{B}'_k}{\partial \eta_j} = -\left[\frac{1}{\tilde{c}}\right] \frac{\partial \hat{E}_i}{\partial \tau} \quad (36)$$

$$\epsilon ijk \frac{\partial \hat{E}_k}{\partial \eta_j} = \left[\frac{1}{\tilde{c}}\right] \frac{\partial \hat{B}_i}{\partial \tau} \quad (37)$$

  where we have defined the cosmic time, $\tau = \ln t/t_o$ and we have defined the non-dimensional speed of light as: $\tilde{c} = c/K$.
- There is nothing special here about logarithmic time and linearly expanding space. Almost any $\delta(t)$ would work.
- So the astronomers rule! BUT only if they use integrated theory and data to interpret their results.

Redshifts are different as well.

- Let's consider what happens if an oscillator operates in expanding space, $\vec{\eta} = (\vec{x} - \vec{x}_{osc})/\delta(t)$, and with logarithmic time, $\tau = \ln(t - t_{osc})/t_o$. Its location is at fixed $\vec{\eta}_{osc}$ and i begins at time t_{osc}.
- The phase at any time and location would be given by:

$$\phi = \vec{\kappa}_* \cdot (\vec{\eta} - \vec{\eta}_{osc}) - \omega_*(\tau - \tau_{osc}). \tag{38}$$

  where $\vec{k}^* = \nabla_{\vec{\eta}}\phi$ and $\omega^* = -d\phi/d\tau$ are the dimensionless wavenumber vector and frequency in our spatially scaled and logarithmic time space.
- The important question for us on earth is: **what do we see in our linear time, linear space coordinates as it reaches us?**

- The answer can again be found from our earthly definitions of 'frequency', 'wavenumber' and 'phase velocity' as $\omega = -d\phi/dt$, $\vec{k} = \nabla_{\vec{x}}\phi$, and $c = \omega/|\vec{k}|$.
- It follows immediately that:

$$\omega = \frac{d\phi}{dt} = \frac{\omega^*}{t} - \vec{k}^* \cdot [\vec{\eta} - \vec{\eta}_{osc}] \left[\frac{1}{\delta}\frac{d\delta}{dt}\right] \tag{39}$$

$$\vec{k} = \nabla_{\vec{x}}\phi = \frac{\vec{k}^*}{\delta(t)} \tag{40}$$

- Equation 40 clearly implies a wavenumber red-shift for all non-negative expansion rates. And for frequency, equation 39 implies that the farther away, the greater the shift.

Thus the redshift has TWO component – one from the velocity, another from the time change. Using only one would lead to a conclusion that the expansion rate is increasing more than it is.

The acceleration in an expanding universe with logarithmic time

- And the logarithmic acceleration, $\vec{A}$, by:

$$\vec{A} = \frac{d\vec{V}}{d\tau} = \frac{d^2\vec{\eta}}{d\tau^2} \tag{41}$$

$$= \left[\frac{t}{K}\right] \vec{a} \tag{42}$$

where $\vec{a}$ is the linear time acceleration.

- Interestingly this simply relation is ONLY true if $\delta = Kt$. A different choice of $\delta(t)$ yields more complicated expression, but leading term still dominates.

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- So the conclusion is if time were indeed logarithmic, then our replacement for Newton's Second Law should be:

$$\begin{aligned} \vec{f} &= m^* \frac{dV_p}{d\tau} && (43) \\ &= m^* \frac{t^2}{\delta} \left\{ \frac{d^2 \vec{x}_p}{dt^2} \right\} && (44) \\ &= [m^* \frac{t}{K}]\ \vec{a}_p && (45) \end{aligned}$$

- Thus for all times not close to the very beginning of time, what we thought was the mass, m, is really:

$$m = m^* \frac{t}{K} \quad (46)$$

- Clearly the farther back we travel in time for our observations, the more important the departures from the classical Newton's or Kepler's laws become.

Summary of what have deduced for a linearly growing universe

- True Mass, M^* is constant and is related to what we thought was mass by $M^* = MK/t$ or $M = M^* t/K$.
- So the farther we look back in time, the more mass appears to be missing.
- Now we know how to write the Gauss/Newton Gravitational Potential Law. It is just $4\pi G^* M^*/\tilde{R}$ where $\tilde{R} = R/\delta(t)$ and G^* is related out old gravitational 'constant', G, by $G = G^* K^{-4}$.
- Velocities are given by $\vec{V} = \vec{v}/K - \vec{\eta}$.
- And accelerations by $\vec{A} = (t/K)\ \vec{a}$

A new cosmology

- The Friedman-type equation can be written in using our new laws as:

$$\frac{d^2\tilde{R}}{d\tau^2} = \frac{dV_r}{d\tau} = \frac{G^*M^*}{\tilde{R}^2} \tag{47}$$

where M^* is the mass inside radius $\tilde{R}$.

- Note: We assume here M^* to be constant, although this could be relaxed if necessary to include the possibility it is not (e.g. radiation, etc.).
- Note that we can turn this into a proper balance by multiplying both sides by a test mass, say m^*; i.e.

$$m^*\frac{d^2\tilde{R}}{d\tau^2} = \frac{dV_r}{d\tau} = \frac{G^*M^*m*}{\tilde{R}^2} \tag{48}$$

New Energy and Implications for cosmology

- Multiplication by $V_r = d\tilde{R}/d\tau$ and rearranging yields immediately:

$$\frac{d}{d\tau}\left\{\frac{1}{2}m^* V_r^2 - \frac{G^* M^* m^*}{\tilde{R}}\right\} = 0 \tag{49}$$

- Or integrating we find the new energy balance to be:

$$\left\{\frac{1}{2}m^* V_r^2 - \frac{G^* M^* m^*}{\tilde{R}}\right\} = E^* \tag{50}$$

- Note that $E^* = 0$ is an acceptable solution, since the expansion rate of the universe is already included. New potential energy and new kinetic energy simply balance each other. If $M^* \propto \tilde{R}^3$ then $V_r \propto \tilde{R}$ as hypothesized.
- This works because the expansion rate of the universe need not be determined from the equations, but in fact determines them.

So what happened to the need for Dark Energy?

- We need to transform our new energy conservation law back to ordinary space-time variables to see why we had a problem with missing energy sources.
- What is conserved (in linear space time variables) is:

$$\left\{\frac{1}{2}mv_r^2 - \frac{GMm}{R}\right\} = \left[\frac{t}{K}\right] E^* = E \tag{51}$$

- Thus it appears that the energy need to balance the equations needs to increase linearly with time.
- So of course we needed a mysterious source to provide it – the dark energy.
- But now we don't. We have eliminated Einstein's dilemma by refining our physical laws.
- This is similar to Special Relativity where the curious constancy of the speed of light redefined the equations in ordinary space-time.

Summary of This Presentation

We have reversed our usual approach of making cosmological equations and equations of general relativity reduce to Newtonian.

- First: It is proposed that time is determined by gravity just as is space. And that the expansion of space and time are linked so that the increments of time are non-equally spaced.
- Second: It is proposed that the gravitational and electromagnetic laws should be expressed in the natural expanding four-dimensional coordinates of the universe.
- Third: The laws we previously believed to exist are only approximations valid over the limited time of our observation (a few hundred years) and over relatively small distances (a few hundred light years).
- Fourth: Our concepts of mass and energy need to be redefined – **a direct consequence of which is that the need for dark energy is eliminated; and perhaps dark matter as well**.