The GCDM Model of Universal Density Reduction

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Abstract: The Universe at last scattering is treated as an unbound gas. The internal kinetic energy of the gas effectively constitutes a scalar energy field. The gas's adiabatic expansion creates a repulsive force: Entropic pressure. Gas kinetic energy is converted into entropic energy gain (63%) and isoentropic work against gravity (37%) at a constant 63:37 ratio. A three-term expression of the gas's Hubble parameter is derived and found to be exclusively dependent on its mass density. At last scattering, this model gives a Hubble constant that is 125% of the value found from the ΛCDM model. After partition of Universal mass into the cosmic web of galaxies and the intergalactic medium (IGM), expansion came mostly from the IGM, presently comprising about 85% of total Universal mass and 90% of its volume. The onset of star formation within the cosmic web increased the IGM's kinetic energy through the action of starlight, giving free electrons as an additional repository. Many of these free electrons are suprathermal. Suprathermal energy from both electrons and protons comprises about half of the IGM's total kinetic energy, persists indefinitely, and is expressed in the ΛCDM model as "dark energy" Λ. Entropic pressure derives from thermodynamic laws not found within general relativity.

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INTRODUCTION

Astronomers measure what we can see, but only a small amount of Universal mass is capable of producing light. About 85% of baryons, the mass from which stars form, lie in the intergalactic medium, or IGM. The IGM comprises about 90% of Universal volume. Although largely invisible, I believe its preponderance in both mass and volume gives the IGM a front and central role in Universal expansion.

Just after last scattering,[2] the entire Universe was an ideal gas. It had a low and uniform density, and was made of elastically colliding atoms. Its internal pressure, being unbound, had a time gradient which caused it to become less dense. Today, most of the universe is the IGM. It's much less dense than it was, but mostly retains its primordial composition, still behaves like a gas, and is ionized. The IGM is the engine of Universal expansion, ever driven by its temporal pressure gradient. The model using the IGM's behavior is called the "GCDM" model, for gas-cold-dark-matter. The main concepts of the GCDM model are as follows:

1) The first and second laws of thermodynamics are combined with gas laws and Newton's laws to produce a balanced energy budget which includes *entropic energy gain*.
2) A sphere of gas is modeled around every atom. Gas expansion works against gravity. The excess is *radial kinetic energy*, outward from the center. The instant radial kinetic energy is the differential entropic energy gain.
3) Density reduction in what is now the IGM released energy which was 63% entropic.
4) The cosmic web of galaxies supplies the IGM with photons which are absorbed and converted to kinetic energy.
5) Free electrons in the IGM are the principal reservoir of its kinetic energy, and of these, suprathermal electrons are the primary source of "dark energy".

Nearly all of the Universe today is IGM plasma, which can be treated as a monatomic gas. Its density reduction can be locally viewed as adiabatic, unbound gas expansion. As the gas expands, it loses internal kinetic energy. Kinetic energy in the IGM is comprised of *thermal* energy which obeys the gas laws, and *suprathermal* energy which doesn't. Their combined energies expend into isoentropic work and entropic energy gain. Work is performed against the change in gravitational potential energy as the Universe gets less dense. The IGM has a very low density, and loss to gravity in a thermal Universe is only 37% of total loss. The majority is entropic energy gain. This gain creates a physical force, *entropic pressure* E_k', which has been historically neglected in accepted treatments of Universal development. A minor portion of this neglect can be traced back to the physicist Albert Einstein. His theory of general relativity comprises much of cosmology today and isn't so much isoentropically derived as it is anentropic altogether. There is no provision for entropy within general relativity. The issue of cosmic entropic increase has been considered unsolveable for more than a hundred years, but not for lack of trying. Literature treatments of cosmic entropy are numerous and often describe an intrinsic force field as a property of empty space. Many of them derive from one original paper (Verlinde 2011).[3] Other than Verlinde, few appear to be extensively cited. Purely isoentropic treatment of the Universe and its constituent domains remains as a cornerstone premise in the literature and the classroom, evolving into an *ad hoc* term in the ΛCDM model: Ω_Λ. The Ω_Λ term embodies a widely-accepted belief in the existence of a time-invariant, repulsive scalar "dark energy field", commonly referred to using the Greek letter Λ. Einstein invented Λ, but soon thereafter had a well-documented change of heart (O'Raifeartaigh 2018). Einstein may have felt intuitively that Λ was wrong, but there's no extant evidence to suggest that he quantified his position. This paper supports Einstein's misgivings. There is a Λ-type

[2] The time of last scattering is that moment when free electrons entirely disappeared from the Universe and could no longer couple with, or scatter, light from what is now the cosmic microwave background. This time is also called "recombination". Semantics aside, recombination was a longer process than last scattering. The latter term is more precise.
[3] Verlinde's paper defines an end state for an endless Universe, which is convenient for the practicing cosmologist.

field, unbound kinetic energy, but it's only scalar in three dimensions. It isn't constant with time as Einstein initially proposed.

Most of the differential kinetic energy loss in the IGM partitions to E_k', and of this, suprathermal E_k' is the cause of Λ. There's also thermal E_k' which doesn't contribute to Λ. Entropic pressure E_k' behaves much like a scalar field in the Universe as a whole, but is found locally as tensors if accreted mass is present. The *in toto* E_k' value at scale stems from unaccreted atoms, and isn't intrinsic to empty space like e.g. the Higgs field (Higgs 1966).

I earlier described the temporal reduction in Universal density with gas laws used by the engineering community (Johnson 2021)[4]. These laws are thermodynamic in nature. When applied to unbound conditions at scale, E_k' results. General relativity can't be used to derive E_k'. General relativity is better seen as a constraint to how E_k' unfolds. Simpler Newtonian laws are adequate for this purpose, and less obfuscatory.

The idea that the Universe's density drop over time can be accurately described without entropic gain is deeply entrenched within the community of cosmologists. If I had to guess, it's probably because they saw no way to include entropy, so they decided it was unimportant and got rid of it. In the present paper I show how to include entropy increase as entropic energy gain, what then happens, and how neglect of this gain led to reintroduction of Λ.

Events at scale

We often refer to events at scale, which today means any comoving sphere of mass/energy with an observed radius >100 megaparsecs (Mpc) or about three hundred million light-years (ly), the distance at which the Universe becomes homogenous and isotropic when viewed through a telescope. The term "comoving" means the sphere is expanding and defines a reference frame for the items in the sphere as they separate. The contained mass/energy in a comoving sphere is constant. Mass may fuse and release energy, but the total is always the same. The 100 Mpc distance represents a huge increase of volume compared to our everyday life, but for the entire Universe, it's just the opposite: A huge decrease, from infinite to finite. A 100 Mpc comoving sphere, being both homogenous and isotropic, is the smallest effective proxy for the properties of today's Universe as a whole.

The *proper distance* of a star at the sphere's surface is how far away it is today, after all the time its light took to get to us. A cube of proper distance has a *proper volume*. Proper distance and volume are used for expressions herein.

ADIABATIC FREE EXPANSION: THE CORE PREMISE OF THE GCDM MODEL

Reversible and Free Expansion in a Classic Engineering Setting

In a classic setting, an amount of gas is held in a *sealed* vessel, which means the gas is trapped inside a physical *boundary*: The walls of the vessel. The boundary of a sealed gas can change, like in a piston. All bound gases are sealed. However, not all boundaries are seals. There's imaginary boundaries, which don't really exist. They're used for constant amounts of gas. An unsealed gas is unbound, despite any imaginary boundary we may apply. The math terms, bound and boundary, are common to textbooks over the range of disciplines we use in this paper, so we'll describe gas behavior in sealed vessels this way.

There are two kinds of gas expansion: reversible and free. Reversible expansion is isoentropic by definition: $\Delta S = 0$, where S is the entropy of the gas (kg-m^2/s^2-K or J/K). A classic, perfectly reversible expansion must also be adiabatic, which means there is no heat transferred into or out of the vessel. When a bound gas expands both adiabatically and isoentropically, its pressure P (kg/m-s^2), internal kinetic energy U_i (J), and temperature T (K) decrease. Energy $-\Delta U_i$ is lost, leaves the vessel, and converted into work $\Delta(PV)$ as the boundary moves. This PV work from e.g. a piston can be stored and reused.

[4] A earlier draft of the present paper is also available online (Johnson 2022).

An adiabatic bound gas can also undergo free, Joule expansion, which is entropic ($\Delta S > 0$). No work is performed. As the bound volume V (m^3) increases, U_i does not decrease and only P drops. Adiabatic, freely expanding bound gases do convert energy, it's just not through loss of U_i. It's referred to as *entropic energy TS* and its *gain TdS*, or more generally *d(TS)*, measures the bound gas's reduced ability to convert U_i into a storable form. Inside an adiabatic bound vessel, the total energy [$U_i - PdV + TdS$] of a freely expanding gas remains constant. For any bound gas, its density ρ is a primary metric for how much of its U_i can be harnessed.

The Two Laws of Thermodynamics

The first and second laws of thermodynamics are held inviolate, by engineers at least, and can be expressed at scale. The first law of thermodynamics, in its broadest definition, says that energy is neither created nor destroyed:

$$dE/dt = 0 \tag{1}$$

Where E is the sum of mass and energy in an at-scale sphere. We note here that the terms E and dE do double duty in this paper. They have the meaning given by (1) in our discussion of the fluid and acceleration equations (21)-(23). They also refer to adiabatic thermal loss from work: $E = -\Delta U_i$, and when isoentropic, $dE = -PdV$. There is conflation of these two meanings in derivation of the fluid equation.

The second law of thermodynamics is more subtle in meaning than the first law, and has had several descriptions over the years. The broadest of these says that entropy at scale is always increasing over time:

$$dS/dt > 0 \tag{2}$$

This links time and entropy. If one assumes an isoentropic process then (2) requires that no time shall elapse. Equation (2) can't be compared directly to (1) because they have different units of measurement. To make direct comparison possible, I will restate (2) in terms of energy:

$$d(TS)/dt > 0 \tag{3}$$

Note that (3) only applies to an unbound *system*. "System" usually means e.g. a bound vessel's contents. In this paper it also refers to constant amounts of gas that aren't bound. It's possible to have $d(TS)/dV < 0$ and $d(S)/dV > 0$ in a bound system if heat transfer to or from its surroundings is neglected. However, for both the system and surroundings combined, (3) is always true. At scale, the system *is* the surroundings. There is no scenario at scale where the entropy of the system is increasing and its entropic energy isn't. The converse applies: If $d(TS)/dV > 0$ at scale then $d(S)/dV > 0$ as well.

Free Expansion in a Classic Setting

We conduct three different "thought experiments" in which gravity is unimportant. These will help us better understand the nature of free expansion within the GCDM model, where gravity plays a central role.

Bound, Equilibrium Free Expansion

Take a spherical helium balloon, of radius r_1 = 10 cm, at a temperature T = 300K and pressure P = 1 atmosphere, and place it in the center of a perfectly rigid, insulated, spherical vacuum chamber of radius r_2 = 50 cm. Gravitational effects are infinitesimal. The insulation and rigidity of the chamber means any gas expansion from r_1 to r_2 will be adiabatic. The gas in the balloon is monatomic, and its internal kinetic energy U_i is 100% thermal. For a monatomic gas, this is given by:

$$U_i = \frac{3}{2}nRT = \frac{3MRT}{2Ж} \tag{4}$$

Where *R* is the gas constant (8.314 J/mole-K), *Ж* is the atomic weight of the gas (kg/mole), *n* is the number of moles of gas, and *M* is the *thermodynamic mass* of the gas (kg). Other forms of mass are important at scale and discussed later. The thermal energy U_i in the balloon is defined as the *instant* sum of its atoms' individual kinetic energies:

$$U_i = \sum_{r=0}^{r_2} \sum_{\theta=0}^{\pi} \sum_{\varphi=0}^{2\pi} \left\{ \frac{1}{2} m \left[(\boldsymbol{v} sin\{\theta'\})^2 + (\boldsymbol{v} cos\{\theta'\})^2 \right] \right\} \tag{5}$$

"Instant" means time stands still. The tensor $\boldsymbol{v}$ is the atom's instant kinetic energy, *m* is the mass of the helium atom (6.6 x 10^{-27} kg), *r* is the distance from the center, θ is the conic angle of latitude, φ is the angle of longitude, and θ' is the conic angle of $\boldsymbol{v}$'s deviance from radial. These are shown in two dimensions in figure 1. If you spin figure 1 around its polar axis you get φ; this is omitted in the graphic for simplicity. The void between r_1 and r_2 makes no contribution to U_i as long as the balloon is intact. The balloon is an *idle* sphere, having a constant radius r_1.

We pop the balloon. The thermal energy U_i is temporarily and partly transformed into *radial kinetic energy* E_k:

$$E_k = \sum_{r=0}^{r_2} \sum_{\theta=0}^{\pi} \sum_{\varphi=0}^{2\pi} \sum_{\theta'=0}^{\pi/2} \left\{ \frac{1}{2} m [(\boldsymbol{v} cos[\theta'])^2] \right\} - \sum_{r=0}^{r_2} \sum_{\theta=0}^{\pi} \sum_{\varphi=0}^{2\pi} \sum_{\theta'=\pi/2}^{\pi} \left\{ \frac{1}{2} m [(\boldsymbol{v} cos[\theta'])^2] \right\} \tag{6}$$

Which is the scalar difference in energy between the outward and inward radial components of the atoms' tensors. Implementation of (6) isn't as sequential as (5). We have to determine if the atom is moving in or out before assigning it. Another definition for U_i can now be given:

$$U_i = \sum_{r=0}^{r_2} \sum_{\theta=0}^{\pi} \sum_{\varphi=0}^{2\pi} \frac{1}{2} m \left[(\boldsymbol{v} sin\{\theta'\})^2 \right] + 2 \sum_{r=0}^{r_2} \sum_{\theta=0}^{\pi} \sum_{\varphi=0}^{2\pi} \sum_{\theta'=\pi/2}^{\pi} \left\{ \frac{1}{2} m \left[(\boldsymbol{v} cos[\theta'])^2 \right] \right\} \tag{7}$$

For an idle sphere, the inward and outward radial scalars of $\boldsymbol{v}$ in (6) are equal, so we can just double the inward scalar and replace the radial term in (5). This gives (7), which yields the same result as (5) for an idle sphere but can also be used to get U_i for an expanding sphere. Note that that (6) and (7) always have precise instant values.

The *total kinetic energy* U_k in the sphere is:

$$U_k = U_i + E_k \tag{8}$$

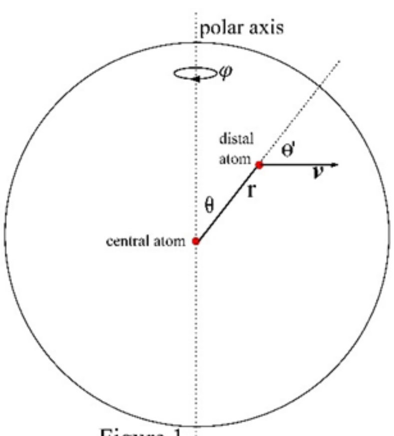

Figure 1.

When idle, $U_k = U_i$. When expanding, U_k stays the same and E_k diminishes U_i. The instant E_k given by (6) is the differential entropic energy gain:

$$E_k = d(TS) \tag{9}$$

Equation (9) is the single most important concept of this entire paper. It links kinetic and entropic energies. Entropic energy gain can be expressed with (9) through kinetic energy calculations without resort to direct calculation of entropy. All conclusions herein arise from (9)'s basic premise: Unbound kinetic energy and entropic energy are two facets of the same phenomenon, the second law of thermodynamics (2)-(3).

In the special condition of uniform comoving density ρ, E_k is given as:

$$E_k = E_k' dV \tag{10}$$

Where E_k' is the entropic pressure:

$$E_k' = \frac{d(TS)}{dV} \tag{11}$$

At last scatter, the Universe's ρ was uniform throughout its volume, so (10) and (11) apply. In the present bound example, uniform ρ only occurs at the instant the balloon is popped, giving $E_k' = P$. Since ρ is not uniform after the balloon is popped, (10) and (11) don't describe the later behavior of the atoms in this example. However, (8) and (9) remain accurate, and since loss to gravity is negligible, $E_k = -d(U_i)$ for the one-meter sphere as a whole during expansion. It lasts for maybe a second; the exact amount of time is unimportant. During the initial phase of expansion, U_i drops to a minimum value U_i' and E_k reaches its maximum. The atoms quickly bounce off the wall and E_k drops. When equilibrium is reestablished, $E_k \rightarrow 0$, the terms of (6) again cancel, and $U_i = U_k$ is unchanged for the enlarged idle sphere. The entropic energy gain E_S from volume increase is:

$$E_S = T(S_2 - S_1) = nRTln\left(\frac{V_2}{V_1}\right) \tag{12}$$

Bound, Nonequilibrium Free Expansion

Take that same balloon, put it in the center of a large vacuum chamber ($r_2 = 10^8$ m) and pop it. A helium atom at T = 300K has a root mean square speed v_{rms} = 1368 m/s. Those atoms will take about 20 hours to reach the wall of the chamber if their tensor of movement is perfectly radial. As they expand, they stop colliding with each other at any meaningful rate. After that happens, we can say that atomic movement is in a nonequilibrant "unbound free expansion" regime which is best considered at a time period when the atoms have stopped colliding, but haven't hit the wall yet. During the regime, almost all of the kinetic energy is radial: $U_i \approx 0$ and $U_k \approx E_k$. The radial component of each outward atom's speed, or *radial velocity* v_r, is proportional to its distance from the center:

$$v_r/r \ = \ H \ = \ 1/t \tag{13}$$

Where t is the elapsed time. The atomic Hubble parameter H is simply expressed by (13). Once the atoms stop colliding, E_k remains unchanged until they start to hit the wall. Eventually the atoms bounce off the wall, the regime slowly comes to an end, thermal equilibrium is reestablished, and U_i rises back to its starting value. A classic Joule expansion has a similar U_i profile: Helium gas at 300K is allowed to pass unimpeded through a connecting tube from a small pressurized chamber into a much larger vacuum chamber. The gas cools while it passes through the tube as U_i partitions into E_k, which in the tube is linear kinetic energy, not radial. The thermal energy U_i, when applied to the gas inside the tube, is well defined since the instant temperature is constant along short lengths of the tube and can be measured in situ.[5] The enlarged vessel's boundary again eventually yields thermal equilibrium, with U_i unchanged from its starting value.[6]

Unbound, Nonequilibrium Free Expansion

What if there's no boundary? There's no equilibrium to be reached, so for a freely expanding gas, more and more of U_i is permanently converted to gain as time passes. One can approach Universal conditions by looking only at the comoving central core of a large popped sphere with $r_{inner} = 10^{-6}\ r_{outer}$, or some similar small fraction of the total. That inner sphere would be nearly homogenous ($d\rho/dr \approx 0$), and as such, has a uniform instant value of U_i which obeys (10) and (11). The H value of the inner sphere's surface would be more complex than (13) and perhaps similar to the Universe at its cosmic redshift z = 1089,[7] the time of last scattering. That is, if the universe happens to be 100% helium, and denser. With proper parameters and a computer, this sort of treatment could be accurate at scales large enough to include gravity. I'm not suggesting that the Universe has finite mass, only that it can be so modeled.

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5 For turbulent flow. This description is adequate for our purposes. Fluid mechanics is a complex subject, outside the scope of the paper.

6 The Joule-Thompson effect for helium is negligible at this temperature.

7 The cosmic redshift z is given by (35). The term z also means the z axis of an xyz grid but the different contexts should be clear.

GCDM VERSUS ΛCDM: COMPARISON

Einsteinian Energy vs. Newtonian Mass; Euclidean Space at Scale.

The behavior of common mass in e.g. a rock closely follows the laws of gravity and motion discovered by Isaac Newton. Einstein's laws of general relativity, a refinement of Newton's laws, considers Newtonian mass as a form of energy through the well-known equation $E = mc^2$, a special case of:

$$E_m^2 = m^2c^4 + (m'v')^2c^2 \tag{14}$$

Where E_m is the total or *Einsteinian* energy of the mass. The *rest mass m* is when it stands still relative to its neighbors, and is exactly Newtonian. This *m* could mean a helium atom as before, or a larger mass. The term *c* is the speed of light (3 x 10^8 m/s), and *m'* is the *relativistic mass*, an increase *m'/m* at a relative speed *v'*.[8] When $v' << c$, (14) simplifies to:

$$E_m = mc^2 + \frac{1}{2}mv'^2 \tag{15}$$

The ΛCDM model discards $\frac{1}{2}mv'^2$ as insignificant (22). The GCDM model discards mc^2 as unchanged between successive thermodynamic states (45). The Einsteinian energy of rest mass plays only a supporting role in the GCDM model, as a source of kinetic energy in the IGM arising from nuclear fusion in the cosmic web.

Newtonian laws operate in *Euclidean* or *flat* spacetime, a continuous array of infinitely large three-dimensional instant Cartesian grids *x,y,z* over linear time *t*. General relativity combines space and time into a single curved non-Euclidean description. All measurements to date support its conclusions, which led to the question of Universal curvature beyond scale. This does not preclude the idea that at scale, the Universe is well approximated by flat space and linear time if $v' << c$. This author is hardly an expert in general relativity, but will attempt to show why Newtonian laws in Euclidean space are adequate.

We consider two isolated massive objects with $v' << c$. Every point in spacetime around these objects has a set of ten gravity tensors and ten momentum tensors in a four-dimensional normalized coordinate system *x, y, z*, and *t*. All the tensors must be used to accurately describe the relative movement of the two masses. When the objects are far away from each other, the gravitational tensors of the system approach two isolated sets, and their relative movement can be fairly described with Newtonian momentum in Euclidean space. Exactly what "far away" means depends on the masses in question, and the distance between them.

We consider two isolated helium atoms. The distance beyond which Newtonian and Euclidian space becomes an accurate description is very low: maybe a micron, depending on the level of rigor one chooses to pursue. At last scattering, the mean distance between atoms was more than a millimeter, so Newtonian laws in Euclidean space give a good description of their relative movement.

We consider a large assembly of atoms, like a gas. If the atoms are evenly dispersed, the gravitational stress tensors in *x,y,z* between any two atoms remain at zero as density increases. There's no lateral stress even at very high densities. This means that the instant volume occupied by the gas is Euclidean. In the Universe at scale, we make the approximation that the instant IGM is uniformly dense. This works well, as we will see later. Practically, the instant Euclidean approximation is accurate for any two atoms if they both lie in the same gravitationally unbound region of the Universe.

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[8] $m' = m\left(1 - v'^2/c^2\right)^{-\frac{1}{2}}$

Time stress is a different story. There's always some *t* stress in an unbound assembly of atoms, and there's two tensors: gravitational and entropic. The gravity tensor changes monotonically with ρ. In Newtonian physics, attractive gravity stress in a model sphere can be expressed as $dU/d\rho$, where U is the gravitational potential energy (33). We assume Newton's G stays constant. A variable G gives Einstein's time curvature. If G increases with time, so do the gravity tensors.

Repulsive entropic stress $d(TS)/d\rho$ has a different density dependence than U. At low ρ, $d(TS)/d\rho$ is dominant over $dU/d\rho$. At higher ρ, $dU/d\rho$ can wrest control, resulting in collapse into accreted bodies. This paper only considers low-density conditions in the IGM, where $d(TS)/d\rho$ rules.

Universal curvature is presently considered by astronomers be "very small" (Planck 2020). The present paper goes farther in that direction with two axioms:

1) *The instant Universe is exactly flat for all time after inflation.*
2) *Newton's constant G is invariant with time.*

These axioms consider the debate about Universal curvature as settled in favor of absolute flatness. This may be controversial, along with the neglect of non-Euclidean curvature near e.g. galaxies. At scale these bodies of accreted matter are only local perturbations in a much more voluminous and massive flat landscape. All available evidence suggests that the Universe has no curvature.

GCDM

The GCDM model unifies U_i with H. Its energy budget is expressed with rest mass, unlike the ΛCDM model, which turns rest mass into energy. At last scattering, the Universe was homogenous and isotropic at scales eight or more orders of magnitude below 100 Mpc, as evenly dispersed atoms. These atoms collided elastically. They repelled each other on contact and their aggregate kinetic energy was repulsive, like any other gas. Gravitational anisotropy in x,y,z was locally significant only on a micron scale if even that. There was significant relativistic mass present from what is now the cosmic microwave background (CMB), but its effects were uniform and didn't affect the Euclidean nature of that instant spacetime. Newtonian laws combined with gas laws can provide an accurate description of baryon movement at scale back then. The arising thermal model is then slightly modified to include suprathermal energy which better describes the more recent Universe. General effects arising from density variance are only marginally relevant in the instant IGM today. It remains flat, with minor changes inside and proximity to accreted mass at its edges. Special effects, however, are more important. They are just detectable in the model at around $z = 10$ and became prominent after $z = 0.308$. The model indicates that today, particles moving at near-relativistic speeds comprise about half of the kinetic energy in the IGM.

ΛCDM

The ΛCDM model combines three formulas to describe H and its change over time dH/dt:

1) The Friedmann equation which gives a relation between H and Einsteinian density ϵ.
2) The fluid equation which describes comoving ϵ vs. V.
3) The equation of state which divides ϵ into three different constituents.

The ΛCDM model is a benchmark, giving the most accurate empirical fit to date. It converges with the GCDM model at $z = 0$. The ΛCDM's "dark energy" term Ω_Λ is restated in the GCDM model as $\Omega_{ß_s}$ (90). Unlike Ω_Λ whose source Λ is baffling, $\Omega_{ß_s}$ has a known origin: suprathermal electron and baryon kinetic energies in the IGM. The models have different theoretical foundations and their predictions diverge. Dissection of their foundations clarifies their differences. Two texts, Ryden (2017) and Liddle (2015), were consulted for this dissection.

The Friedmann Equation

We start with the Friedmann equation (16), given in both its Einsteinian and Newtonian forms. The debate over the curvature of the Universe is largely settled now, and most of us believe it to be flat at scale and above in both time and space. The Friedmann equation can then be simply expressed:

$$H^2 = \frac{8\pi G\epsilon}{3c^2} \approx \frac{8\pi G\rho}{3} \tag{16}$$

Where $H = v_r/r$ is the time-dependent Hubble parameter, G is Newton's constant, 6.6743 x 10^{-11} $m^3/kg\text{-}s^2$, ρ is the comoving rest mass density (kg/m^3) and ϵ is the comoving Einsteinian energy density (J/m^3). For mass at rest, $\epsilon = \rho c^2$. The Newtonian expression of (16) doesn't include mass equivalence from CMB energy, hence the "≈". Equation (16) describes what happens when a sphere of rocks are all hurtling away from each other as the sphere expands. The rocks lose E_k as they work against their mutual gravitational attraction. Both models share a calculated value, the *critical density*, given by (17):

$$\epsilon_{crit} = \frac{3H^2c^2}{8\pi G} = \rho_{crit}c^2 \tag{17}$$

The GCDM model uses $\rho(z) = \rho_{crit}$ which does include CMB energy. It's a resultant value of the comoving equilibrium arising from perpetual dominance of gas gain over total work in the IGM at scale. The ΛCDM model uses $\epsilon(z) = \epsilon_{crit}$. It's a Euclidean fulcrum between positively curved spacetime, where the hurtling rocks slow down too much and end up collapsing, vs. negatively curved spacetime, where the rocks possess $E_k >> 0$ forever.[9] At the fulcrum, the rocks' E_k is exactly spent by work, and $E_k \rightarrow 0$ asymptotically at infinite time.

The term ϵ is almost completely comprised by rest mass. Skipping ahead a bit, we use (36) to arrive at ϵ. At last scatter, when $z = 1089$, relativistic mass from the CMB was important: about 24% of ϵ. However, by $z = 10$, it was only 0.3%. That was more than eleven billion years ago. Today at $z = 0$, the GCDM model gives CMB energy as only 0.03% of ϵ. Mass density ρ is thus a 99.7-99.97% accurate estimate of ϵ/c^2 for most of the Universe's history. Equation (16) can be practically expressed for this time period with Newtonian ρ. Furthermore, the Universe is 85% gas by weight. The reader should be able to comprehend how it can thus be locally seen as mostly an unbound gas with repulsive U_i, expanding in flat space. In the GCDM model, $H \equiv E_k$ is fed by U_i via (44). The Friedmann equation (16) makes no provision for entropic pressure arising from differential gas expansion; it's incomplete, so it's inaccurate. The resultant deviance of (16)'s predictions from observation gave credence to Einstein's time-invariant Λ as an added term: a plug-in, preexisting solution.

Another way to look at the limitation of the Friedmann equation (16) is that it only considers outward radial motion of accreted bodies in its model sphere. The off-radial or *peculiar motion* isn't included. Unaccreted atoms also have peculiar motion which comprises their internal kinetic energy U_i. Atomic peculiar motion, like that of accreted matter, is untreated by (16).

The Fluid and Acceleration Equations

If all the energy in the Universe was bodies of accreted mass, its expansion could be fairly described with (16) and (17). However, as Einstein pointed out, CMB light has energy which also imparts mass density. CMB energy density drops off faster than that of accreted mass. To reconcile these differing rates of density drop, the fluid equation (21) was devised. Its derivation starts with (18), the engineer's preferred expression of the first law of thermodynamics. This is not the same as (1). Engineers work with bound systems, and (18) describes the behavior of gas in e.g. a vessel:

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[9] These curved Universes continue to underpin current cosmology, for example calculation of the value of H at last scatter from the CMB. The debate about a flat Universe is far from over.

$$dE = TdS - PdV \tag{18}$$

Where dE is the differential change of thermal energy U_i inside the vessel. Also in this vessel,

$$dQ = TdS \tag{19}$$

Where dQ is the differential heat flow (J) to or from the vessel. A restriction is placed on (19), $dQ = 0$. So far, so good: The system is adiabatic,[10] like the Universe. If $dQ = 0$ in (19), then $dS = 0$ as well. This precept is used to set dS in (18) to 0. However, a vessel is required for heat to flow in (19). A vessel isn't required for (18), but if dS in (18) is differentiated over time, a term TdS/dt arises which at scale cannot be set to zero since that is inconsistent with (2). This issue isn't taken seriously enough in current theory. It's instead skirted by removal of TdS prior to differentiation. The outcome is:

$$-PdV/dt = dE/dt \tag{20}$$

From (1), dE/dt should at scale be zero. Neglect of (2) leads to inconsistency with (1). Equation (20) is nonetheless used to derive the fluid equation (21):

$$\frac{d\epsilon}{dt} + 3H(\epsilon + P) = 0 \tag{21}$$

By excising entropic gain, (21) inverts P into a gravity term. Pressure becomes a proxy for mass density ρ, or ϵ if you prefer. Gas "pressure" is now attractive, and trivially small.

The Newtonian expression of (21) is:

$$\frac{d\rho}{dt} + 3H(\rho + P/c^2) = 0 \tag{22}$$

Equation (22) better shows why gas pressure is thought to be insignificant. The kinetic energy of any one atom is, from (15), dwarfed by its rest mass term. The fluid equation, however, isn't accurate. It has a problem in its derivation: Application of a bound expression (18) to unbound conditions. The results aren't good:

1) Inconsistency with both the first and second laws of thermodynamics (1) and (2).
2) Gas pressure P is inverted from repulsive to attractive.
3) Gas thermal energy U_i is excised as trivial.
4) CMB entropic energy gain is unaccounted. This will be discussed shortly and isn't especially important. It doesn't affect H after last scatter and is only needed to balance the energy budget (45).

The Friedmann equation (16) is differentiated and combined with (21) to give the acceleration equation:

$$\frac{dH}{dt} = -\left[\frac{4\pi G}{c^2}(\epsilon + P)\right] \tag{23}$$

In (23), the expression dH/dt is governed only by G and energy (mass) density ($\epsilon + P$). Entropic pressure E'_k, which comprises part of P, is insignificant and even if significant would be an attractive term.

The acceleration equation (23) is inaccurate. It derives from the fluid equation (21) which is inconsistent with both laws of thermodynamics (1) and (2). These laws cannot be simply ignored. The attempt by the fluid equation to adhere to general relativity as the sole source of Universal behavior improperly conflates E between bound (18) and unbound (1) systems. Setting $dS = 0$ in (19) is conditionally allowed in a perfectly adiabatic bound system.

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[10] A truly adiabatic vessel has yet to be devised. High-field magnet users aren't happy; they have to settle for the best they can get.

However, transfer of $dS = 0$ from (19) to (18) is inconsistent with (2) at scale. This results in (20) which is again conditionally allowed when bound, but inconsistent with (1) at scale, so (20) is inaccurate. Equation (20)'s inaccuracy is then incorporated into (21), followed by (23).

The Jeans resonance model of star formation (Owen and Villumsen 1997) is relevant to our discussion here. At last scatter, both (23) and the Jeans model operated concurrently within any given volume. The Jeans model treats *P* as repulsive, an offset against gravitational collapse. The acceleration equation (23) treats *P* as attractive and is inconsistent with the Jeans model. The GCDM model treats *P* as repulsive, which is consistent with the Jeans model's treatment of *P*.

The Equation of State

The ΛCDM equation of state describes the relation between pressure *P* and density ϵ. It treats *P* as attractive, and has three terms: baryonic[11], relativistic, and Λ:

$$P = w_b\epsilon_b + w_{rel}\epsilon_{rel} + w_\Lambda\epsilon_\Lambda \tag{24}$$

The ϵ terms are the Einsteinian energy densities of baryons (ϵ_b), photons (ϵ_{rel}), and Λ (ϵ_Λ). The *w* terms are dimensionless numbers: $w_b << 1$, $w_{rel} = 1/3$, and $w_\Lambda = -1$. Equation (24) is combined with (23) to complete the ΛCDM model (36).

Baryonic Mass

The mass of baryonic, everyday matter is nonrelativistic, which means it moves much slower than light: $v' << c$. Its Einsteinian energy content is given by (15). Baryons comprise stars, cars, and helium balloons. Baryonic mass is considered attractive in the ΛCDM model. This might disturb a vendor watching his balloons implode. It's repulsive in the GCDM model; the balloon vendor feels better. At last scatter, baryon mass was 100% elastically colliding atoms, i.e. a repulsive atomic gas: Helium and monatomic hydrogen.[12] Presently, the repulsive : attractive ratio of baryon mass in the Universe is about 5:1.

The ΛCDM term $w_b\epsilon_b$ is expressed as:

$$w_b\epsilon_b \approx \left(\frac{kT}{\mu c^2}\right)\epsilon_b \approx \left(\frac{kT}{\mu c^2}\right)(\rho_b c^2) = \frac{kT\rho_b}{\mu} \tag{25}$$

Where μ is the mean atomic mass (kg), ρ_b is the mean baryon density (kg/m^3), and *k* is Boltzmann's constant, 1.38 x 10^{-23} (m^{2}kg)/(s^{2}K). Without ado, (25) gives 1.088 x 10^{-11} Pa at $z = 1089$, the same value obtained from the GCDM model's equation of state (31). They are, for slow neutral atoms, equivalent expressions. Equation (25), however, treats baryon rest mass as part of the internal energy density ϵ. The baryons in the IGM are considered a perfect fluid or "dust" with almost all of ϵ contained in their rest mass. Thermal energy U_i is relegated to the status of a rounding error (shown in (25) as ≈), and $-\Delta U_i = E$ is unaddressed. In the GCDM model, *E* is the source of repulsion, and the Einsteinian energy density of rest mass is irrelevant (45).

[11] Cosmologists include electrons when they refer to baryonic matter.

[12] This does discount any formation of helium hydride HeH, a highly unstable diatomic species. He-H collisions were effectively 100% elastic for the temperature and density found at last scattering. Monatomic hydrogen scatters elastically even though it's thermodynamically unstable with respect to its diatomic form. A catalyst is required for H_2 formation, for example, an aggregate mass, or a lithium atom.

Relativistic Mass; Entropy of a Photon

Relativistic mass, expressed as $w_{rel}\epsilon_{rel}$ in the ΛCDM model, is attractive in both models and arises from photon and neutrino energy (37)-(38).[13] We digress briefly into photon energy. An expanding sphere of CMB light has an r^{-4} dependence of energy density (Ryden 2017). Volume increases as r^3, so there appears to be a $1/r$ loss of CMB energy upon expansion. During the "dark age" from last scattering until reionization began (Miralda-Escude 2003; Natatajan and Yoshida 2014), there was no coupling of the CMB with free electrons or stripped protons because there weren't any. There was no mechanism through which that lost energy could perform work. It vanished and the energy budget became unbalanced. We get inconsistency with (1). I see no escape from this conundrum except to apply (3): CMB light yields entropic energy gain $E_{S_{\Delta\lambda}}$ through wavelength stretch Δλ. Any one CMB photon's wavelength increases with time and their combined lost energy is the entropic gain at scale:

$$E_{S_{\Delta\lambda}} = E_{CMB_1} - E_{CMB_2} = \sum_{\lambda_1 \approx 0}^{\infty} n_\lambda hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) \tag{26}$$

where E_{CMB_1} and E_{CMB_2} are the before and after CMB energies, h is Planck's constant (6.6 x 10^{-34} J/Hz), λ_1 and λ_2 are the before and after wavelengths of the stretched photon (m), and n_λ is the number of photons at a wavelength λ_1. The distribution n_λ vs. λ for any z in the dark age is given by the Boltzmann curve at last scatter, $T = 2971$K. The ratio λ_2/λ_1 between two CMB states is akin to the *scale factor a* (34).

The above analysis of the CMB gives an individual photon's entropy S_λ as equal to Planck's constant:[14]

$$S_\lambda = h \tag{27}$$

Its entropic energy E_{S_λ} is the photon energy:

$$E_{S_\lambda} = h\mathfrak{f} = \frac{hc}{\lambda} \tag{28}$$

Where ƒ is the frequency of the photon (Hz). Entropy is expressed as J/Hz rather than the more conventional J/K.

Photon energy is 100% entropic. This makes sense, given that entropic energy gain is linked to E_k (9), hence volume increase (12). The rate of volume increase of radial light dV_λ/dt in an unbound model sphere is:

$$\frac{dV_\lambda}{dt} = \frac{4\pi c^3}{3} \tag{29}$$

which far outpaces other kinetic energy in the sphere.

Current treatment of CMB energy is isoentropic, also begins with (18), and concludes that radiation expands more slowly than baryonic matter (Liddle 2015). A balanced budget may give a different result, if $E_{S_{\Delta\lambda}}$ is included in an *ab initio* derivation. In the observable Universe, $E_{S_{\Delta\lambda}}$ may affect E_k and H at $z \approx 1089$, as free electrons were still present at $z > 1089$, and photons were more strongly coupled to baryon movement.

Electrons are wavelike so their entropic energy is also a function of wavelength (28).

[13] Neutrinos are believed to have been relativistic at last scattering but became nonrelativistic in the dark age. This affects their temporal mass density dependence, which is untreated in the present paper.
[14] An alternate treatment of photon entropy is given by Kirwan (Kirwan 2003).

Dark Energy

The remaining term, $w_\Lambda \epsilon_\Lambda$, describes repulsion. In the ΛCDM model, Einstein's time-invariant Λ is used to account for the behavior of distant stars (Perlmutter et al. 1999). The term w_Λ = -1 arises because (23) treats P as attractive, so $w_\Lambda \epsilon_\Lambda$ has to have negative pressure. In the GCDM model the behavior described by $w_\Lambda \epsilon_\Lambda$ arises from suprathermal electrons, whose pressure P is repulsive. These electrons do create a scalar field, but unlike Λ its value changes with time. A time-invariant Λ field has a constant ϵ. This creates more and more energy at comoving scale, which is inconsistent with (1). If (1) is obeyed, Λ must change with time.[15]

CONSTRUCTION OF THE GCDM MODEL

Parameters

The GCDM model follows a balanced energy budget. Energy is conserved through inclusion of E_k and E_{λ_S} in the budget. We construct the model with a finite element method using the radius r of a sphere as the finite variable. A spreadsheet is used for the calculations. This is less satisfactory than an analytic derivation, but it does give solace in that the equilibrium expressions (30), (31), (49), and (50) are exact, as they describe changes in U_i which has a precise instant value (7). It is only in the partition of $-\Delta U_i$ between gain (44) and work (43) where error accrues. We must find a time period when the Universe was 100% gaseous and as homogenous as possible. That happened at z = 1089, the time of last scattering. Baryonic matter was all unaccreted atoms. We use the BBN estimate for baryons (Weinberg, 1988) as a mixture of about 75% hydrogen (H_1) : 25% helium (He) by weight, giving a mean atomic weight Ж = 1.24 x 10^{-3} kg/mol. Hydrogen was monatomic and nonrecombinant to diatomic form, absent catalysis through aggregation. The isotropy in the CMB appears to indicate that the Universe at z = 1089 had a constant density, only minimally perturbed by the observed nascent Jeans resonance wiggles in the power spectra (Planck 2020). There is a metric not fully understood by this author, η_{slip}, found from the wiggles. It describes the accord between Einsteinian and Newtonian physics in a presumptively homogenous and isotropic Universe, and may be conversely used to estimate variation in mass density. At z = 1089, if η_{slip} = 1, then there was no variance, and this atomic Universe would have been homogenous and isotropic. The value of η_{slip} was found to be 1.004 ± 0.007. How exactly this translates to spatial density variation is unclear to me, but the text in Planck proclaims agreement between Einstein's and Newton's models for the presumed uniform gravitational potential. We proceed as follows: There was no accreted matter at z = 1089, and gas density variations from e.g. Jeans resonance were either averaged out or insignificant relative to the volumes used in the GCDM model, on the order of a sphere with $r \approx 10^{17}$ meters, or $V \approx 140$ cubic parsecs. The wiggles tell us the atoms were dense enough to support the Jeans resonance, which is sonic pressure transmission vs. gravitational free fall. Since these atoms could transmit sound, they behaved like a gas back then so we can safely assume they had all the same properties we associate with gases today. The baryon density $\rho_{b(z=1089)}$ was $(\Omega_b \rho_{crit})(1+z)^3 = 5.46 \times 10^{-19}$ kg/m^3. This is very low and we can say the gas behaved ideally in a thermodynamic sense. The critical density ρ_{crit} and the Ω values are given in Table 1 and are derived from table 6 of Planck. The CMB had decoupled right around then so the baryon temperature T at z = 1089 will be set to the extrapolated value $(T_{CMB,\, z=0})(1 + z)$ = (2.726K)(1090) = 2971K.

Table 1. Values at z = 0.

H_0.	2.1938 x 10^{-18} sec^{-1}
ρ_{crit}.	8.6075 x 10^{-27} kg/m^3
baryons Ω_b.	0.04898
cold dark matter Ω_c.	0.26014
relativistic energy Ω_{rad}.	0.000091
dark energy Ω_Λ.	0.6908
T_{CMB}.	2.6720 K

Notes. H_0 and the Ω values were calculated from table 6 of (Planck Collaboration, 2020), except for Ω_Λ, which is 1-($\Omega_b - \Omega_c + \Omega_{rad}$). The critical density $\rho_{crit} = 3H_0^2/8\pi G$.

[15] This author is firmly wedded to x,y,z, and t. There's no room here for extra dimensions as a Λ source.

The Dark Model at *z* = 1089

The *dark model*, described immediately below, is constructed using equilibrium monatomic gas thermodynamic expressions, found in many introductory engineering textbooks and Wikipedia. Its *z* range, 1089→10, includes the entire "dark age" of the universe, hence the name. Its expression (58) is valid at *z* = 1089 as there was no high-energy light to perturb the model.

The *light model*, discussed later, has a range *z* = 10→0. Equation (58) is still used but one of its terms is adjusted to include suprathermal energy from cosmic and *ß* rays. The *ß* energy dominates and comes from impact of light upon electrons. One additional adjustment is made, to ρ_{crit}. This is constant (61), and precise in result.

Adiabatic Energy Release

Consider a comoving sphere of initial radius r_1 around a single atom of H_1, at 2971K and $\rho = 5.46 \times 10^{-19}$ kg/m^3. There are similar spheres around all the other atoms. Nonequilibrium conditions besides expansion, e.g. turbulence, Jeans resonance, etc. will be set aside so that the underlying transformation of conserved energy is clearly described. There are two competing forces acting on the sphere: Repulsive entropic push, and attractive gravity pull. We are using a finite element method, so we define an *increment*: $\frac{(r_2-r_1)}{r_1} = \frac{\Delta r_i}{r}$, which must be kept below 10^{-4} for most purposes to minimize the partition error. I will use 10^{-9}, as low as the spreadsheet will tolerate. When the gas in the sphere expands, it must do so adiabatically, and there's no void outside the sphere into which free expansion can occur. Under classic bound conditions, the comoving sphere would then have to lose U_i through work. We postulate that those rules apply in a cosmic setting as well. For monatomic gases this is:

$$U_{i_1} - U_{i_2} = -\Delta U_i = E = U_{i_1}\left(\left(\frac{V_2}{V_1}\right)^{-\frac{2}{3}} - 1\right) = \frac{3}{2}P_1V_1\left(\left(\frac{V_2}{V_1}\right)^{-\frac{2}{3}} - 1\right) \tag{30}$$

Where the numeric subscripts refer to the before and after U_i and V values. Volumes V_1 and V_2 are readily found ($4\pi r^3/3$). The starting pressure P_1 is found from the equation of state for ideal gases:

$$P = \frac{\rho RT}{Ж} = \frac{MRT}{ЖV} = \frac{3MRT}{4Ж\pi r^3} \tag{31}$$

If work against gravity is negligible, there is no alternative to free expansion within the sphere that I can find, so the released energy E from (30) is 100% entropic E_k. From (11), the finite differential E_k gives the entropic energy gain E_S:

$$E_S = E_k = \int_{V_1}^{V_2} E_k' = \int_{V_1}^{V_2} \frac{d(TS)}{dV} = \int_{V_1}^{V_2}\left(T\frac{dS}{dV} + S\frac{dT}{dV}\right) \approx (S_2 - S_1)\left(T_2 + \frac{1}{2}(T_1 - T_2)\right) \tag{32}$$

Where the subscripts refer to the before and after values on a T-S diagram. Volume increase is strictly local to the sphere. At scale, it all just gets less dense.

An exception to the low-increment rule is that any size increment gives zero error in the calculation of $-\Delta U_i$. You can get the temperature at any dark redshift just from the increment. This is discussed later (62)-(63).

Gravitational Attraction

The sphere has to get quite large before gravity begins to play any kind of role. To find out just how large, we now look at the gravitational potential energy U of the sphere:

$$U = \frac{-3GM'^2}{5r} \tag{33}$$

The potential energy U must take into account the *total mass* M', not just the thermodynamic mass M of the baryons. In addition to baryon mass there's cold dark matter (CDM) which is about five times as abundant as baryon mass. Its only interaction with baryons, electrons, or light, is through gravity. CDM does move relative to accreted baryons like stars, but all that occurs within the cosmic web, and at scale, does not affect H. A consistent description of CDM's composition and origin remains to be found (Bertone and Hooper 2018). There's widespread belief that CDM's mass density evolution over time is inverse third-order in r, like baryons. We use this convention. Due to $\eta_{slip} \approx 1$, its density at $z = 1089$ can be kept constant with respect to baryon density. Both follow $1/r^3$, as expressed by the scale factor a:

$$a = \frac{r}{r_0} = \frac{1}{(1+z)} \tag{34}$$

where r_0 is the comoving radius of a sphere today, and z is the cosmic redshift used throughout this paper:

$$z = \frac{\lambda_{ob} - \lambda_{em}}{\lambda_{em}} \tag{35}$$

Where λ_{ob} is the observed wavelength of light of known laboratory value, λ_{em}. There's also relativistic mass from the CMB, whose comoving density follows $1/r^4$. This is addressed by the minimum flat-universe ΛCDM model:

$$H_\Lambda^2(a) = H_0^2[\Omega_\lambda a^{-4} + \Omega_b a^{-3} + \Omega_c a^{-3} + \Omega_\Lambda] \tag{36}$$

Where H_Λ is the ΛCDM Hubble parameter, H_0 is today's Hubble constant ($z = 0$), and the Ω values are energy density ratios at $z = 0$. These are listed in Table 1. The Ω values are dimensionless and always add up to one at any given z. They share a common denominator ϵ_{crit}, and have identical values when expressed as mass density ratios using the common denominator ρ_{crit}. To get the relative density, and therefore mass M' for a given volume, we divide them by each other; the denominators cancel. This gives an *Einsteinian density multiplier* η_E:

$$\eta_E = \frac{\Omega_\lambda a^{-4} + \Omega_b a^{-3} + \Omega_c a^{-3}}{\Omega_b a^{-3}} \tag{37}$$

which we use to get the total Einstein mass:

$$M'_E = M\eta_E = M\left(\frac{\Omega_\lambda a^{-4} + \Omega_b a^{-3} + \Omega_c a^{-3}}{\Omega_b a^{-3}}\right) \tag{38}$$

In an Einsteinian Universe, $M'_E = 6.313M$ at $z = 0$ and increases to $M'_E = 8.336M$ at $z = 1089$. The reader may be curious as to why Ω_Λ wasn't included in the calculation of M'_E. It's a repulsive energy term generated by the ΛCDM model and unrelated to the gravitational effect of mass.

In a Newtonian Universe, the mass equivalent of Ω_{rel} doesn't exist. This gives a *Newtonian density multiplier* η_N:

$$\eta_N = \frac{\Omega_b a^{-3} + \Omega_c a^{-3}}{\Omega_b a^{-3}} \tag{39}$$

which we use to get the total Newton mass:

$$M'_N = M\eta_N = M\left(\frac{\Omega_b a^{-3} + \Omega_c a^{-3}}{\Omega_b a^{-3}}\right) \tag{40}$$

Which is $M'_N = 6.3111M$ for all z.

Throughout this paper, we assume that the ΛCDM model is an empirically perfect description of H vs. z. Neither η_N nor η_E matches H_Λ at $z = 1089$. The Einstein mass M'_E overshoots and the Newton mass M'_N undershoots. I will add a third multiplier, the *J density multiplier* $\mathfrak{m}_J$, whose relativistic contribution Ω_{rel} is treated as an inverse *j* power:

$$\mathfrak{m}_J = \frac{\Omega_\lambda a^{-j} + \Omega_b a^{-3} + \Omega_c a^{-3}}{\Omega_b a^{-3}} \tag{41}$$

giving the total *J* mass:

$$M'_J = M\mathfrak{m}_J = M\left(\frac{\Omega_\lambda a^{-j} + \Omega_b a^{-3} + \Omega_c a^{-3}}{\Omega_b a^{-3}}\right) \tag{42}$$

Unlike $\mathfrak{m}_E$ and $\mathfrak{m}_N$ which derive from known theory, $\mathfrak{m}_J$ is ad hoc. We proceed using a single term M' which may be any of M'_E, M'_N, or M'_J, depending on context. The energy lost to gravity upon expansion of the sphere is:

$$U_r = U_1 - U_2 = \frac{-3GM'^2}{5}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \tag{43}$$

Where U_1 and U_2 are the before and after gravitational potential energies, respectively.

We've seen that atoms can freely expand without colliding. Less obvious to the engineer reader is the fact that they can also perform work against gravity without colliding. How is this possible? Well, the Friedmann equation (16) does the same thing, but with stars instead of atoms. Any volume of space containing evenly dispersed atoms, however dilute, has a uniform gravitational potential energy at scale. This is expressed within general relativity as an attractive stress tensor having net value only in time (*t*) and not space (*x,y,z*). When the atoms all move away from the central atom of a comoving sphere, they are climbing out of a gravity well caused by the reduced density resulting from their movement, and E_k diminishes accordingly. It is this loss of radial kinetic energy to gravity, not *PV* work, which is responsible for the "isoentropic" portion of $-\Delta U_i$.

Energy Release and Gravity Combined: The Adiabatic Sphere

Combining (30) and (43) gives a finite differential E_k value which includes loss to gravity:

$$E_k = E + U_r = \left(\frac{3}{2}\right) P_1 V_1 \left(\left(\frac{V_2}{V_1}\right)^{-\frac{2}{3}} - 1\right) - \frac{3GM'^2}{5}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \tag{44}$$

An expression of conserved Einsteinian energy upon expansion is given by (45):

$$E_1 - E_2 = \begin{bmatrix} \left(M_b c^2 + M_e c^2 + M_c c^2 + E_{CMB_1} + U_{i_1} + U_1\right) - \\ \left(M_b c^2 + M_e c^2 + M_c c^2 + E_{CMB_2} + E_{S_{\Delta\lambda}} + U_{i_2} + U_2 + E_k\right) \end{bmatrix} = E + U_r - E_k = 0 \tag{45}$$

Where E_1 and E_2 are the total Einsteinian energies of the before and after sphere. The CMB gain $E_{S_{\Delta\lambda}}$ is decoupled from E_k at $z < 1089$ and separately expressed. Energy for nonrelativistic mass is given by (15). This is accurate: Relativistic mass increase $[(m'/m) - 1)]$ for an atom of H_1 at 2971K is only around 10^{-9}. Furthermore, the baryon rest mass M_b, electron mass M_e, and CDM mass M_c are unchanged so their rest mass energies Mc^2 cancel. It is only their Newtonian mass which is relevant for (44).

At any instant, as the radius *r* increases isotemporally, the mass density ρ remains constant and the subsumed mass in the sphere increases as r^3. The loss and gain terms in (44) shift toward loss. When *r* reaches the *adiabatic radius* or *endpoint* r_e, they cancel, giving an *adiabatic sphere*: $E_k = 0$. The adiabatic sphere is a principal construct of the GCDM model. Energy is conserved within any one such sphere, indeed all of them, as they expand over time. The comoving imaginary boundary of a sphere with $r = r_e$ is the *adiabatic surface*. This isn't adiabatic in the classical sense. Energy can flow freely in both directions across the boundary, but any such net transfer between many spheres would always be zero. The term "adiabatic" is apt and so repurposed. In today's Universe, the adiabatic surface around a central atom isn't always spherical due to anisotropic stress from accreted baryons, e.g. stars. This happens near the cosmic web. Density variation also occurs locally in the IGM. These are inconsequential at scale. The cosmic web's mass in this context is addressed later (60)-(61). At $z = 1089$, there's no anisotropy, let alone a web, so it's all spheres. The endpoint r_e is found from (44) by convergence of r around $-U_r/E = 1$. If we use the Einsteinian η_E, we get $r_e = 9.69 \times 10^{16}$ meters, about 20 ly in diameter. If we use the Newtonian η_N, a bigger

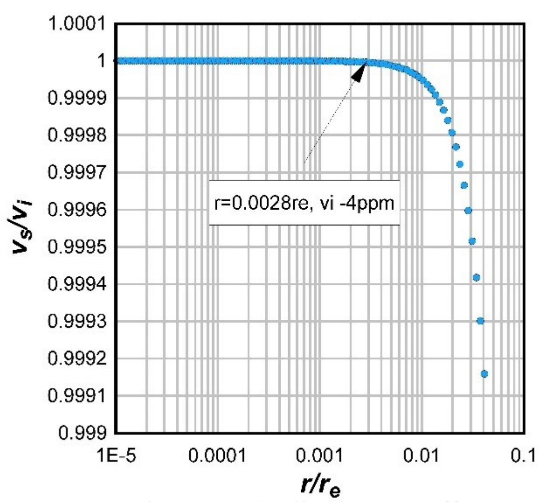

Figure 2. Small sphere cutoff

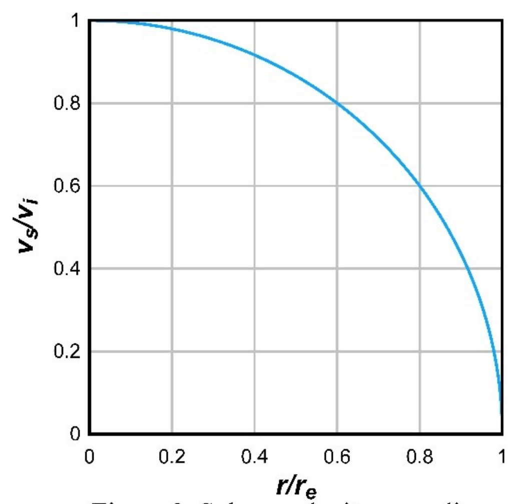

Figure 3. Sphere velocity vs. radius

sphere results: $r_e = 1.28 \times 10^{17}$ m. Either way we get an adiabatic sphere about 20 ly across.

For an adiabatic sphere, the postulate connecting classic to cosmic gas behavior in (30) is clearly seen. The thermal loss in the sphere just balances gravity, like a piston's expansion just holding up a weight. The postulate holds for lesser, *medium* spheres, as differential work and E_k combined.

Spheres larger than adiabatic result in gravitational contraction. Although quite interesting, treatment of these *large spheres* as a description of gravitational collapse lies outside the scope of the present paper.

The Expanding Adiabatic Sphere and GCDM Equation, $H_G = Kv_i/r_e$

One might suppose that because $E_k = 0$ at r_e, the adiabatic sphere isn't comoving: $d(r_e)/dt = v = 0$. That's not true. It is, just very slowly: $v > 0$.[16] The adiabatic sphere contains medium spheres: For $r < r_e$, $E_k > 0$. To find v, we have to figure out how fast these are expanding (46)-(55), and add up their combined radial speeds (56).

The finite differential E_k gives the *increment radial velocity* v_s':

$$v_s' = \sqrt{\frac{2E_k}{M}} \tag{46}$$

This is best visualized as each and every atom in the sphere moving away from the center at v_s'. The true picture is messier (6). Note that v_s' is increment-dependent: A larger $\frac{\Delta r_i}{r}$ gives more v_s'. This state of affairs can be sorted by following v_s' as a function of r. The *cutoff radius* $r_c = 0.003r_e$ is important. Below r_c, loss to gravity is negligible and all these *small spheres* have the same E_k/M value to within 5 ppm (Figure 2):

[16] There's another sphere, the *static sphere*, where $v = 0$ and $E_k < 0$. It's nonconservative.

$$\frac{E_k}{M} = \frac{E}{M} = \frac{dE}{dM} = \frac{dV}{dM}\frac{dE}{dV} = \left(\frac{RT}{ЖP}\right)\frac{dE}{dV} = \frac{RT}{Ж}\left(\frac{dE}{PdV}\right) = \frac{RT}{Ж} \tag{47}$$

For an adiabatic system with an imaginary boundary, $dE = -PdV$ at the instant isoentropic limit. The minus sign is omitted. Combining (46) and (47) gives the *initial radial velocity* v_i:

$$v_i = \sqrt{\frac{2E_k}{M}} = \sqrt{\frac{2E}{M}} = \sqrt{\frac{2RT}{Ж}} \tag{48}$$

We can compare this with E and see if energy is conserved (51). We expand a small sphere ($r = r_I = 1 \times 10^{12}$ m) by $\frac{\Delta r_i}{r} = 10^{-9}$, giving P_2 and T_2. The pressure drop of an adiabatically expanding bound monatomic gas is given by:

$$P_2 = P_1\left(\frac{V_2}{V_1}\right)^{-\frac{5}{3}} \tag{49}$$

And the temperature drop by:

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{2/5} \tag{50}$$

We examine the partition error:

$$\frac{\frac{1}{2}M\left[\left(v_{i_{(T_1)}}\right)^2 - \left(v_{i_{(T_2)}}\right)^2\right] - E}{E} \tag{51}$$

Development in (47) gets dV/dM from the ideal gas law (31) and not from the thermal energy (4). By use of (51) we find that v_i is better expressed by rearranging (4):

$$\frac{U_i}{M} = \frac{3RT}{2Ж} \tag{52}$$

Which gives:

$$v_i = \sqrt{\frac{2U_i}{M}} = \sqrt{\frac{3RT}{Ж}} = \sqrt{\frac{3(8.3145)(2971)}{(0.00123988)}} = 7731 \text{ m/s} \tag{53}$$

By use of (53) instead of (48), the partition error (51) is at its minimum (2×10^{-8}). Note that v_i is the fastest rate at which any sphere can expand. Small spheres are all expanding this fast, so an increment should not affect v_i. Again using (53), the partition error of v_i for our small sphere is:

$$\frac{\left(v_{i_{(T_2)}} + v_s'\right) - v_{i_{(T_1)}}}{v_{i_{(T_1)}}} = 4.5 \times 10^{-5} \tag{54}$$

Which is about as good as we are going to get with an increment, and sphere, this large. Now that we have a proper value of v_i, I propose that the radial velocity v_s of any one medium sphere is given as:

$$v_s = \frac{v_s'}{v_{s_0}'}v_i \tag{55}$$

Where v'_{s_0} is the constant value of v'_s at $r < r_c$. Equation (55) gives a zero value at the endpoint, and gives v_i at low r. My guess is v_s/v'_s remains constant. The radial velocity v of the adiabatic sphere is the sum of the radial speeds of the contained medium shells, plus the small core:

$$v = (v_i)\left(\frac{r_c}{r_e}\right) + \sum_{r_c}^{r_e}\left(\frac{r}{r_e}v_s\right) \tag{56}$$

At our chosen T, ρ, and Ж, for all $r < r_c$, v = 23.2 m/s. That leaves the remaining 99.7% of v to be found. Numerical integration of the sigma portion of (56) (Figure 3)[17] gives 6103 m/s. Adding 23.2 to this gives 6126 m/s, or 0.7925 v_i. If r_c/r_e is kept constant, the fraction K of v_i not lost to gravity shows little change with any of M', ρ, T, or Ж; K is constant to the 4th decimal place. About 63%, $(v/v_i)^2 = K^2$, of E is converted to entropic E_k. Only 37% is stored by gravity. The term K^2 is the *conversion ratio*. In the special case of atoms separated by $2r_e$, their adiabatic spheres are joined at a tangent point and they are moving apart at $2v$. A line of adiabatic spheres, connected at their tangent points, can be constructed in the instant Euclidean space. Anywhere along this line, for any two atoms separated by a distance r, their recession rate v_r is:

$$v_r = K\frac{r}{r_e}v_i \tag{57}$$

Rearrangement of (57) gives the fundamental equation:

$$H_G = K\frac{v_i}{r_e} \tag{58}$$

Where $H_G = v_r/r$ is the Hubble parameter of the GCDM model.

H_G vs. $H_Λ$ at z = 1089. Newtonian, Einsteinian, and J Mass

We compare H_G (58) with $H_Λ$ (36) at z = 1089, using the different density multipliers $ɱ_N$, $ɱ_E$ and $ɱ_J$. We start with the Newtonian $ɱ_N$ (39). Equation (58) gives H_G = 4.79 x 10^{-14}/s, or 21,817H_0. This is 0.949 or 95% of the $H_Λ$ value found from (36). When the Einsteinian $ɱ_E$ (37) is used, (58) gives H_G = 6.32 x 10^{-14} s^{-1}. This is 28,817H_0 or 125% of the $H_Λ$ value found from (36). We have an undershoot and an overshoot of $H_G/H_Λ$. If we use $ɱ_J$ we can get an exact match. We modify the exponent j in (41) to j = 3.745225, which gives $H_G = H_Λ$. The exponential dependence j is 4 in the Einsteinian model for all z, and turns out to be ≈ 3.75 in the J model at z = 1089. Whether or not this has any physical interpretation is left to the reader.

I believe that at z = 1089, H_{1089} = 28,800H_0 is accurate, j = 4, and the ΛCDM H_{1089} = 23,000H_0 is an underestimate.

Sole Dependence of the Dark Model on Mass Density

For any given M', deployment of (58) at varying T from 10K to 50,000K at z = 1089, or any other dark z value, gives the same H_G to five decimal places every time. The dark model is zero-order in temperature. It's also zero-order in Ж. A universe made of xenon atoms (0.131 Kg/mole) at the same ρ and T returns 100% of our primordial mix. The mass density ρ is the only remaining independent variable in the dark model. This fact is hidden inside of (58) and not obvious from cursory inspection.

[17]Numerical integration of (56) used 997-998 steps of linearly increasing r/r_e, beginning at r_c/r_e and ending at r/r_e = 0.999 or 1. The integrals were calculated with the plotting program, Dplot, giving third-order correlation > 0.9999 in all cases. Replacement of the integral constant with r_c/r_e = 0.003 gave the reported $K = v/v_i$, 0.7925. All measured curves gave 0.79245 ≤ K ≤ 0.79258. The step separation is many times larger than the incremental increase.

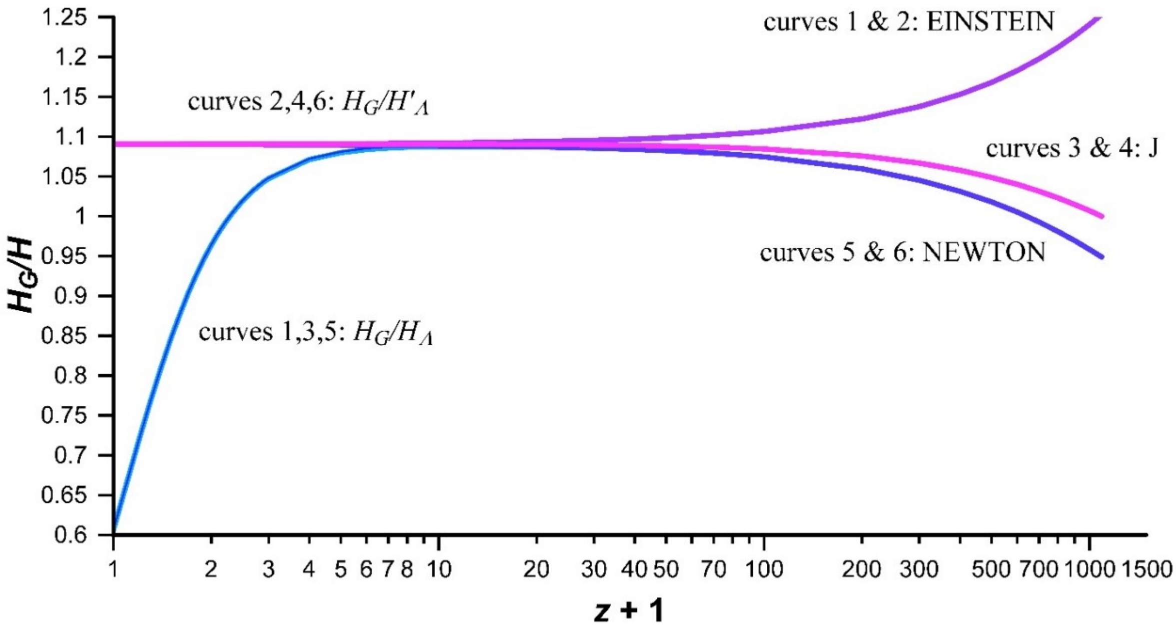

Figure 4. Hubble ratios at differing total mass

VARIANCE BETWEEN THE ΛCDM AND GCDM MODELS AT *Z* < 1089

Divergence between the models can be parsed into two ranges, associated with separate physical events.

1) The first event is the partitioning of mass into gravitationally bound and unbound domains, today known as the cosmic web of galaxies and the IGM respectively. This evolves over the range $z = 1089$ to 10.
2) The second event is the introduction of suprathermal energy. This is noticeable around $z = 5$, significant by $z = 3$, and dominant after $z = 0.3$. The v_i term in (58) is modified to fit the light model into the dark framework.

***z* = 1089 to 10: Partition of Mass and Repulsive Mass Density**

The differences between the models arising from the partition of mass into gravitationally bound and unbound domains evolves over the range $z = 1089$ to 10, and is unchanged from $z = 10$ to 0. "Dark energy" interferes with accurate visualization of this process at low z values. We remove the Ω_Λ term in (36), giving:

$$(H'_\Lambda)^2 = (H_0)^2[\Omega_{rad}a^{-4} + \Omega_b a^{-3} + \Omega_c a^{-3}] \quad (59)$$

Where H'_Λ is the ΛCDM H parameter, without dark energy. Both H_G (58) and H'_Λ (59) are purely density-dependent functions and we can look at their evolution without interference from extraneous repulsive effects. Figure 4 is a plot of H_G/H_Λ and H_G/H'_Λ vs. $(z + 1)$ using data derived from each of the three density multipliers $\mathfrak{m}_N$, $\mathfrak{m}_E$ and $\mathfrak{m}_J$. There's a total of six curves, but it looks like just two or three due to overlap. There are two separate ranges of overlap: $z > 10$, where $H_G/H_\Lambda = H_G/H'_\Lambda$ for each of the three $\mathfrak{m}$'s, giving three sets of two curves, and $z < 10$, where the six curves converge to two sets, each set having the same H_G/H_Λ or H_G/H'_Λ. Maximum convergence between all six curves occurs at $z = 10$, where the values are within 0.2% of each other.

We now focus on H_G/H'_Λ in the $z \leq 10$ range (Figure 5). Relativistic mass from the CMB had largely disappeared by then. The ratio H_G/H'_Λ converged to a constant value 1.09 and remains so all the way to $z = 0$. The transformation of H_G/H'_Λ from 1.09 to 1 is achieved through a single precise adjustment, to ρ_{crit}. We multiply ρ_{crit} by a best-fitting *mass partition ratio* ρ':

$$\rho' = \rho/\rho_{crit} = 0.840 \tag{60}$$

giving the *repulsive mass density* ρ:

$$\rho = \rho'\rho_{crit} = 0.84\,\rho_{crit} \tag{61}$$

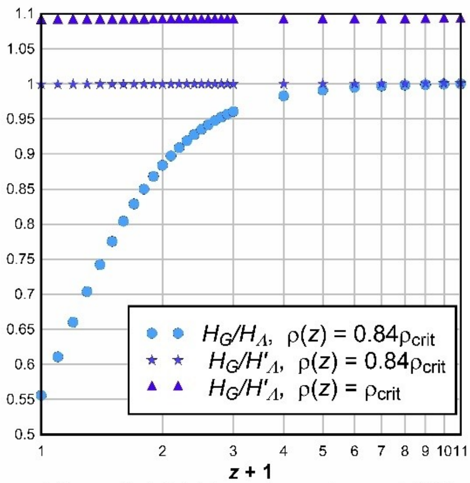

Figure 5. Hubble ratios at low redshift

The two models H_G and H'_Λ now give nearly identical results from z = 10 to 0 for any of the three M'. The substitution $\rho = 0.84\rho_{crit}$ is shown in Figure 5, using M'_E for total mass. It gives a result of -0.05% of the ΛCDM H'_Λ values at z = 0, increasing to +0.1% at z = 10. Its variance is positive with z. The J mass M'_J gives the most uniform variance, -0.045% ± 0.004%, not shown. The Newton mass M'_N gives negative variance, decreasing from -0.08% at z = 0 to -0.22% at z = 10, not shown.

There is a physical event which underlies $\rho_{crit} \rightarrow \rho$, namely the partition of mass into the cosmic web of galaxies and the IGM. The repulsive mass density ρ is defined as the IGM mass alone divided by the total volume, web included. There's a reason for this: It's the IGM that's fed by U_i. Web mass isn't repulsive like a gas and can be seen as having Friedmann behavior (16). Since $\rho = 0.84\rho_{crit}$, we can conclude there's five times as much mass in the IGM which separates the tendrils of the cosmic web as there is in the tendrils themselves. The IGM is estimated to occupy up to nine times as much volume as the web at z = 0. Any given tendril or node within the web isn't expanding as much as the IGM surrounding it. That is different from two tendrils separated by an intervening IGM volume; they are separating at a rate comparable to the IGM's rate of expansion. Density and distribution of mass within the cosmic web changes over time along with its structure, but any reduction in web density at $z \approx 0$ is far exceeded by the reduction in density of the IGM over the same time period. A scalar ρ' is an oversimplification of any local IGM variance which might better describe the development of partitioned domains, but ρ' gives an astonishingly good fit with H'_Λ at scale, and it tells us roughly when the mass partition into IGM and web was complete. Introduction of an *ad hoc* partition ratio does raise questions about its accuracy as a physical interpretation. For one thing, the cosmic web's mass isn't included in ρ'. The entropic energy gain arising from expansion of accreted matter in the web is treated as negligible this way, and if its rest mass doesn't change a constant partition ratio ρ' may result. I see no way at present to quantify the effect of accreted matter on entropic pressure except through ρ'. Other questions might arise, but the fit of ρ' with H'_Λ is good and we'll use these terms as dark baselines later.

Two new issues emerge.

Issue 1: How did ρ' evolve during what is now the dark age? Was it complete by z = 10, or was it earlier than that? An analytical dark expression (75) of H can be derived via (58) and used to estimate ρ', by examining very old stars.

The redshift z_2 can be obtained from any starting value z_1 by changing the increment $\frac{\Delta r_i}{r}$:

$$z_2 = \frac{z_1+1}{\frac{\Delta r_i}{r}+1} - 1 \tag{62}$$

The dark temperature change T_z can be found via (62) from (49) and (50). We let $z' = z + 1 = 1/a$. Given $T_{(z'=1090)}$ = 2971K, we find via spreadsheet that $T_{z'}$ is an exact function:[18]

$$T_{z'} = T'(z')^2 \tag{63}$$

Where T' = 0.002500631 is expressed as degrees K. At z = 60, T = 10K; at z = 10, T = 0.3K. The Universe was a very cold place just before stars appeared.[19]

The value of v_i in (58) is found by inserting (63) into (53):

$$v_i = \sqrt{\frac{3RT}{Ж}} = \sqrt{\frac{3RT'z'^2}{Ж}} \tag{64}$$

The value of r_e in (58) must now be adjusted for both T and ρ.

For the T adjustment, the dark radius change r_{e_2}/r_{e_1} vs. T at constant ρ and $Ж$ is found exactly:

$$r_{e_2} = r_{e_1}\sqrt{\frac{T_2}{T_1}} \tag{65}$$

We use (63) to get:

$$r_{e_2} = r_{e_1}\frac{z_2'}{z_1'} \tag{66}$$

For the ρ adjustment, the dark radius change r_{e_2}/r_{e_1} vs. ρ at constant T and $Ж$ is found exactly:

$$r_{e_2} = r_{e_1}\sqrt{\frac{\rho_1}{\rho_2}} \tag{67}$$

For nonrelativistic mass,

$$\frac{\rho_1}{\rho_2} = \frac{(z_1')^3}{(z_2')^3} \tag{68}$$

Combining (66), (67), and (68) gives:

$$r_{e_2} = r_{e_1}\sqrt{\frac{z_1'}{z_2'}} \tag{69}$$

Inserting (64) and (69) into the dark model (58) gives:

$$H = K\frac{v_{i_2}}{r_{e_2}} = \frac{K}{r_{e_2}}\sqrt{\frac{3RT_2}{Ж}} = \frac{K}{r_{e_2}}\sqrt{\frac{3RT'(z_2')^2}{Ж}} = \frac{K}{r_{e_1}}\sqrt{\frac{3RT'(z_2')^2}{Ж}\frac{z_2'}{z_1'}} = \frac{K}{r_{e_1}}\sqrt{\frac{3RT'}{Ж}\frac{(z_2')^3}{z_1'}} \tag{70}$$

We adjust for relativistic mass using:

[18] 170 points from z' = 1090 to 10.8; median z' = 320. Found: $T = 8 \times 10^{-9} + 9 \times 10^{-9}(z'/100) + 25.006312599(z'/100)^2$; correlation = 1; standard error 2×10^{-7}.

[19] Calculated temperatures ≤ 12K sidestep the issue of energy dissipation from exothermic diatomic hydrogen formation inside the "snowballs" that should form in this extreme cold through Van der Waals aggregation at a sonic antinode. These snowballs could get big enough to be gravitationally bound, acting as seeds for further accretion at higher temperatures. This unexplored hypothesis lies outside the scope of the present paper.

$$\left(\frac{\Omega_\lambda+\Omega_b+\Omega_c}{\Omega_b+\Omega_c}\right)_z = \left(1+\frac{\Omega_\lambda}{(\Omega_b+\Omega_c)}\right)_z = \Omega_z' \quad (71)$$

Where:

$$\Omega_\lambda = \Omega_{\lambda_0}(z')^4 \quad (72)$$

And:

$$\Omega_{(b,c)} = \Omega_{(b,c)_0}(z')^3 \quad (73)$$

A linear dependence on Ω_2'/Ω_1' is found:

$$H = K\frac{v_{i_2}}{r_{e_2}}\frac{\Omega_2'}{\Omega_1'} = \frac{K}{r_{e_1}}\frac{\Omega_2'}{\Omega_1'}\sqrt{\frac{3RT'}{Ж}\frac{(z_2')^3}{z_1'}} \quad (74)$$

When ρ' is set to 1, equation (74) matches the manually calculated values of H_G from (58) to within 0.0004% for all z = 1089 to 0. In this ideal case, one only needs to calculate r_e, T and z' at last scatter to get dark H values at lower z. However, mass accretion is untreated in (74) so a term ρ_z' must be inserted, from (67) as the square root:

$$H = K\frac{v_{i_2}}{r_{e_2}} = \frac{K}{r_{e_1}}\frac{\Omega_2'}{\Omega_1'}\sqrt{\frac{3RT'}{Ж}\frac{(z_2')^3}{z_1'}\rho_z'} \quad (75)$$

In (75), the constant ρ' = 0.84 for z < 10 is now a variable ρ_z' for z > 10. Rearrangement of (75) gives:

$$\rho_z' = H^2\frac{(r_{e_1})^2(\Omega_1')^2}{(K)^2(\Omega_2')^2}\frac{Ж}{3RT'}\frac{z_1'}{(z_2')^3} \quad (76)$$

To estimate ρ_z' from (76), stars or galaxies with a known emission profile are required, along with an estimate of their distance via their luminosity. These earliest stars' light energy won't perturb the dark model (figure 5). To the extent we get better at seeing them, use of (76) to estimate ρ_z' will allow us to better understand the progress of accretion in the dimly lit Universe.

Issue 2: How did the volume fraction of gravitationally bound mass evolve? It was 0% at last scatter and now it's about 10%. Is this simply connected to issue 1)?

The variance of H_G/H_Λ due to added repulsive energy remains, as shown by the circles in Figure 5.

z = 10 to 0: The Light Model and Suprathermal Energy

None of the above expressions come any closer to explaining the source of the repulsive "dark energy" term Ω_Λ in the ΛCDM model. I found a candidate for most of this: suprathermal electrons in the IGM, whose kinetic energy arises from photoionization and Compton scattering, reliant in turn on photon flux. There are partial flux estimates available (Yüksel et al. 2008; Wandermann and Piran, 2010) but the process of connecting these and other sources of suprathermal energy to produce a definitive light model is an undertaking of considerable magnitude. This paper is merely an introduction.

The dark model (58) has three terms: v_i, K, and r_e. If we want to express the light model within the dark framework, we need to increase v_i or K, decrease r_e, or some combination. We can express v_i (53) as a sum:

$$v_i = \sqrt{\frac{2U_i}{M}} = \sqrt{\frac{2(U_{i_t}+U_{i_s})}{M}} \tag{77}$$

where U_{i_t} and U_{i_s} are thermal and suprathermal kinetic energies in the adiabatic sphere. In the dark model, there's no U_{i_s}, so $U_{i_t} = U_i$ and (77) ≡ (53). In the light model, the total baryon kinetic energy is:

$$U_b = U_{b_t} + U_{b_s} \tag{78}$$

Where U_{b_t} is the dark value of U_b, and U_{b_s} is cosmic radiation. The total electron kinetic energy in the light model is:

$$U_ß = U_{ß_b} + U_{ß_t} + U_{ß_s} \tag{79}$$

Where $U_{ß_b}$ is the thermal energy of atomically bound electrons, ≤ $0.0005U_{b_t}$. The term $U_{ß_t}$ is the thermal energy of free electrons in equilibrium with U_b, and the term $U_{ß_s}$ is the suprathermal energy of the free electrons. Any one suprathermal particle's energy has a thermal component which fractionally decreases as the particle energy increases, and fractionally increases as the IGM gets hotter.

Inserting (78) and (79) into (77) gives:

$$v_i = \sqrt{\frac{2U_i}{M}} = \sqrt{\frac{2(U_{i_t}+U_{i_s})}{M}} = \sqrt{\frac{2\left[\left(U_{b_t}+U_{ß_b}+U_{ß_t}\right)+\left(U_{b_s}+U_{ß_s}\right)\right]}{M}} \tag{80}$$

We neglect U_{b_s} for now as its omission doesn't substantially affect the logic of the following expressions. Cosmic rays can be included in a more rigorous treatment later. This means $U_{b_t} = U_b$, so:

$$v_i = \sqrt{\frac{2U_i}{M}} = \sqrt{\frac{2\left(U_b+U_{ß_b}+U_{ß_t}+U_{ß_s}\right)}{M}} \tag{81}$$

We examine the thermal energies $U_{ß_b}$ (bound) and $U_{ß_t}$ (free). Thermal free electrons behave at very low densities as a monatomic gas. Treatment as such reduces the mean atomic weight *Ж* from its dark value. The dark model is independent of both *Ж* and *T* and dependent only on the mass density. The result of thermal ionization is thus an increase in both v_i and r_e without affecting *H* or *K*. If v_i is doubled, so is r_e, as is the case with pure hydrogen plasma which will serve as our example. In a thermal system with no ionized H_1:

$$U_i = U_b + U_{ß_b} = 1.0005U_b \tag{82}$$

so $U_i = U_b$ is reasonably accurate. When H_1 is 100% ionized at e.g. 4000K, the number of gas particles is doubled, the atomic weight halved, and the energy equipartitioned: $U_{ß_b} = 0$, $U_{ß_t} = U_b$, $U'_i = 2U_b$, and $Ж' = Ж/2$, where U'_i and $Ж'$ are the thermal energy and the mean atomic weight of the 100% ionized plasma respectively. Making these plasma substitutions into (81) and (53) with no $U_{ß_s}$ gives:

$$v_i = \sqrt{\frac{2U'_i}{M}} = \sqrt{\frac{2\left(U_b+U_{ß_t}\right)}{M}} = \sqrt{\frac{2(2U_b)}{M}} \approx \sqrt{\frac{4U_i}{M}} = \sqrt{\frac{6RT}{Ж'}} = \sqrt{\frac{6RT}{Ж/2}} = \sqrt{\frac{12RT}{Ж}} = 2\sqrt{\frac{3RT}{Ж}} \tag{83}$$

The added $U_{ß_t} = U_b$ gives twice the old value of v_i from (53); more generally, added $U_{ß_t}$ gives a linear increase in v_i and we can expect the same for r_e. This all means that for thermal plasmas, the dark model (58) is better expressed using the baryon kinetic energy alone:

$$H_G = K\frac{\left(\frac{(U_b+U_{ß_t})}{U_b}\right)v_i}{\left(\frac{(U_b+U_{ß_t})}{U_b}\right)r_e} = K\frac{v_i}{r_e} = K\frac{\sqrt{\frac{2U_b}{M}}}{r_e} \tag{84}$$

The denominator term associated with r_e in (84) is inserted to comply with the dark model's zero-order dependencies. Equation (84) gets more accurate with increasing ionization and is exact for completely stripped baryons. In (84), v_i remains close to (58): $U_b = 0.9995U_i$, so the effect of thermal ionization on H is at most a tiny reduction in its value.

We proceed by assuming that suprathermal energy $U_{ß_s}$ has no effect on either K or r_e. It may have some effect but we will say it doesn't. Kinetic energy may then be added to the adiabatic sphere without increasing its size. We keep r_e unchanged in (84) and modify v_i:

$$v_{i_{(b+\beta)}} = \sqrt{\frac{2(U_b+U_{ß_s})}{M}} = v_i\sqrt{\left(1+\frac{U_{ß_s}}{U_b}\right)} \tag{85}$$

Where v_i' is the initial radial velocity of the light adiabatic sphere, and $U_{ß_s}/U_b$ is the *suprathermal ratio*. This gives:

$$H_G = K\frac{v_{i_{(b+\beta)}}}{r_e} = K\frac{v_i\sqrt{\left(1+\frac{U_{ß_s}}{U_b}\right)}}{r_e} \tag{86}$$

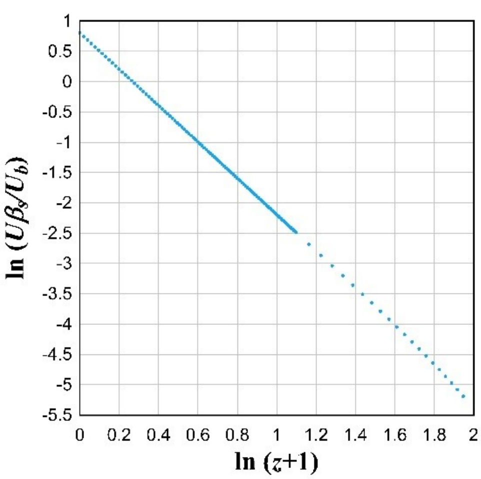

Figure 6. Suprathermal ratio vs. z'

Use of (84)-(85) to get (86) presupposes thermal plasma, a safe bet for a reionized Universe. We fit the light model to the ΛCDM model by manual convergence of $U_{ß_s}/U_b$ around $H_G/H_\Lambda = 1$ for each data point.[20] Since $\rho' = 0.84\rho_{crit}$ gives a best fit with H_Λ' over the range z = 0 to 10, we use ρ' and H_Λ' as dark baselines to calculate H_G/H_Λ. We use the same temperature, 4000K, for all calculations. The convergence of $U_{ß_s}/U_b$ around $H_G/H_\Lambda = 1$ for z = 2→0 is shown as a ln-ln plot in Figure 6. A line is found, giving (87):

$$\frac{U_{ß_s}}{U_b} = e^{\left(0.8048-2.998ln\left(z'\right)\right)} \approx \frac{2.236}{\left(z'\right)^3} \tag{87}$$

At z = 0, $U_{ß_s}/U_b = 2.237$ gives $H_G/H_\Lambda = 1$.[21] This is close to the ratio $\Omega_\Lambda/(\Omega_b+\Omega_c)$ in the ΛCDM model, 2.235, and a simple restatement of the source of "dark energy" repulsion. At higher z, $U_{ß_s}/U_b$ drops steadily to 0.0056 at z = 6. Deviance from linearity in the ln-ln plot occurs above z = 2; these are shown in figure 6 but not included in the regression. A negative $U_{ß_s}$ is found at z = 10. The crossover to $U_{ß_s}$dominance is found from (87) at z = 0.308.

[20] For the regression from z = 0 to 2, 101 data points were used with 3+ significant figures for all calculated $U_{ß_s}/U_b$. Found: y = 0.804791041595-2.99822613611x; Correlation 0.99999998; std. error 0.0001. The y intercept gives z = 0.3077.
[21] T = 4,000-50,000K gave the same results for all z.

Equation (87) derives from ΛCDM and accordingly shows the amount of Λ-like repulsive energy in an adiabatic sphere as proportional to its volume. Equation (87) is only found as empirically true and not *ab initio* proven, a significant leap of faith presently unaddressed.

From the same data, a ln-ln plot of r_e vs. z' gives (88x):[22]

$$r_e = r_0 e^{[0.00009-1.5006 ln(z')]} \approx r_0 (z')^{-\frac{3}{2}} \tag{88}$$

Where $r_0 = r_e$ at $z = 0$. From (86) - (88x) we arrive at an expression of H for $z = 0$ to 2:

$$H_G = H_0 z'^{\frac{3}{2}} \sqrt{1 + \frac{2.237}{z'^3}} \tag{89}$$

Equation (89x) gives 100.00%→99.92% of the ΛCDM value (36) for $z = 0$ to 2. The exponents in (87) - (89) are shown both exactly and rounded to the nearest fraction. The rounding excises CMB relativistic mass Ω'_z (71), resulting in -0.08% deviance of (89) from (36) at $z = 2$. Equation (89), like its dark progenitor (58), is temperature-independent and any constant T may be used to calculate the dark H_0 value.

Expression Connecting the Models

At $z = 0$, the ΛCDM and light GCDM models are connected by their Ω terms:

$$\Omega_{ß_s} = \frac{U_{ß_s}}{(U_b + U_{ß_s})} = \Omega_\Lambda = 0.6908 \tag{90}$$

Plasma kinetic energy in the IGM today is proposed as predominantly suprathermal, and (90) gives the same result as Table 1. If we include thermal electrons $U_{ß_t} = U_b$ in the denominator of (92), we get $\Omega_{ß_s} = 0.528$, still more than half of all kinetic energy in the IGM. The GCDM $\Omega_{ß_s}$ varies with time. The ΛCDM Ω_Λ is time-invariant. They give the same value only at $z = 0$.

Suprathermal Effects on r_e and K

Suprathermal electrons do not obey the gas laws (30), (31), (49), and (50) which underpin the dark model. The light model's $\Omega_{ß_s}$(92), however, fits well with ΛCDM's Ω_Λ at $z = 0$, leading us to conclude that suprathermal effects do not arise from highly relativistic particles. The dark model's r_e dependence follows (67). A sphere four times as dense has its r_e decrease by half, and so forth. Any large relativistic mass effect on r_e would be reflected in (86)-(87) giving deviance from the calculated Λ values. The conversion ratio K^2 may change with introduction of suprathermal energy. Again, however, (86)-(87) tend to indicate otherwise. Even if K and r_e do change, the light model still allows us to use known and conserved energy sources, in compliance with (1), to account for H.

CONCLUSION

This paper proposes a fundamental change in the way the Universe is viewed: As a thermodynamic system, first and foremost. Obedience to (1) and (2) is thus an essential prerequisite for an accurate model. The ΛCDM model excises (2) and the GCDM model includes it. At last scattering, gas expansion under the homogenous, unbound conditions then found yields an obedient quantitative description of Universal behavior. These two conditions

[22] Found: y = 0.0000746 - 1.50054923914x; correlation 0.99999999.

remain abundant today. The Universe contains a repulsive scalar field, kinetic energy, arising from both primeval and contemporary sources. Entropic pressure accounts for most of the field's differential energy loss. The field's scalar value changes with time, and has both thermal and suprathermal components. The suprathermal component causes "dark energy" Λ. Entropic pressure is undefined by general relativity and has independent existence. These two sets of rules operate concurrently within their mutual constraints. Energy other than rest mass *M* and gravity *U* is entropic at scale. Photons have no rest mass and photon energy is 100% entropic.

DATA AVAILABILITY

An .XLSX workbook containing the model and its output is available from the author on request.

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