THE GCDM MODEL: A PRIMER

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Abstract: This is a presentation of the gas-cold-dark-matter model of Universal development designed for a younger audience. It uses simple language and has elementary development of gas thermodynamic principles appropriate for undergraduates and the general public. The essay also explores the origin of the Hubble tension in more detail than originally provided.

PART 1: INTRODUCTION

This essay is an adjunct to a preprint, https://vixra.org/abs/2211.0057. While all are welcome to read, it's intended primarily for seventeen-to-twenty-one-year-old physics students who are currently taking an introductory cosmology course. The essay's remedial sections give a proper development of the GCDM model's central thesis for this younger audience.

If you're taking introductory cosmology, your course lecturer will present a mathematical model, known as the "ΛCDM" model. The ΛCDM model is mostly accurate, which is why it's so popular. It matches the astronomers' observations for much of the Universe's history. The ΛCDM model is, however, inconsistent with both the first and second laws of thermodynamics, which leads to tensions. Here's the reason:

Entropic gain is an unrecognized fifth force of Nature, and ΛCDM actively excludes it.

Entropic gain has been known since the nineteenth century. Its definition as a fifth force is consistent with, indeed required by, long-established principles of gas behavior. Consider the question: Which of the four forces of Nature keeps a balloon inflated? Proper recognition of gain as a fifth force solves this problem, and resolves two tensions:

1) The source of a repulsive field, presently expressed as "dark energy" Λ. Where does this energy come from? When gas thermodynamic laws are properly applied, Λ is best described as an artifact of the ΛCDM model resulting from deliberate exclusion of entropic gain. There is no Λ. That energy does not exist. The repulsive field is plasma kinetic energy. Its density is a miniscule fraction of Λ's purported value, and its ultimate source is nuclear fusion from stars.
2) The Hubble tension: This arises in part because ΛCDM's estimate of the Hubble parameter at the time of last scattering (H_{1089}) is too low, and in part because ΛCDM's ratio H_{1089}/H_0 is too low. Entropic neglect causes both of these.

The model described herein relies on entropy from the outset. It's called the GCDM model, an acronym for gas-cold-dark-matter. It utilizes the differential entropic energy gain of gaseous subatomic particles as the sole repulsive force underlying the Universe's reduction in density over time. Today, this entropic force has thermal (47%) and suprathermal (53%) components.

The difference between ΛCDM and GCDM is fairly easy to picture in a Newtonian Universe. The ΛCDM model treats the Universe like a bunch of rocks all hurtling away from each other. Their mutual gravitational attraction isn't enough to pull them back together. They slow down, but still keep getting further and further apart. The GCDM model treats the Universe as an infinitely massive gas. It has some rocks, we live on one of them. But mostly it's a gas. The Universe has no boundary, so the gas is freely expanding. Free expansion has the same repulsive force which keeps a balloon inflated: Pressure. The attractive force of gravity from all kinds of mass is nowhere near enough to offset the gas pressure.

THE HUBBLE PARAMETER

You may know about the Hubble parameter *H*:

$$H = \frac{v_r}{r}$$

This parameter, named after the astronomer Edwin Hubble, is the recession speed of a distant star, how fast it was moving away from us, divided by how far away it was back then. The Hubble parameter is the central quantity from which much of cosmology is derived. It's mostly found star-by-star through observation. The further the star, the faster it's moving away. This method of finding *H* is called the distance ladder method.

If you pop a balloon in outer space, once its atoms stop colliding with each other, their Hubble parameter is simple:

$$\frac{v_r}{r} = 1/t$$

The hotter the atom, the faster it moves away from its source. When you yell "bring the heat" to a baseball pitcher, it's quite accurate from a physics viewpoint.

The Universe is more complicated than a popped balloon. Mainly because we have to worry about gravity. But it's not that difficult to describe with math. There was a time when the Universe was easy to describe, and that's where we go now.

PART 2: THE GCDM THERMAL MODEL

We start long ago at the "time of last scattering", or simply "last scatter". This is the earliest time at which photons could travel far enough for us to see them. We see these photons today as the cosmic microwave background, or CMB. The CMB tells us that at last scatter, the entire Universe was exactly the same everywhere: a homogenous and isotropic gas consisting of neutral hydrogen and helium atoms. No free electrons to scatter the light. We will call this a "warm" Universe, as its estimated temperature of 2971 K wasn't hot enough to ionize the atoms. You or I would be burnt to a crisp, but we're not there. The collective kinetic energy of all these atoms is the thermal energy of the gas. Most of us see gases as a collection of elastically colliding atoms or molecules, so they repel each other, which is what keeps a balloon inflated. Helium atoms always collide elastically. Hydrogen atoms also collide elastically, and diatomic hydrogen doesn't form from these collisions without some sort of catalyst. Collisions between hydrogen and helium produce helium hydride, which has such a weak bond that we can also treat these collisions as elastic when warm. At very low gas density, the thermal behavior of atoms approaches an ideal limit, and the density of this gas was so low that it can easily be treated as an ideal gas. Normally with mixtures of gases one looks at their partial pressures, but we will instead treat this gas as a single species with a mean atomic weight (*Ж*). Atomic collisions back then were common enough to support the propagation of acoustic pressure waves, what most of us think of as sound. These acoustic waves eventually died off in much of the Universe. The atoms left behind in this vast void of emptiness between the galaxies still behave like a gas today. They may not be colliding anymore, but their kinetic energy remains. And it's a lot of kinetic energy.

The Universe at last scatter had a very important quality which we can take advantage of to simplify our calculations: It had an absolutely uniform density. There was no gravitational anisotropy whatsoever. No stars, no rocks, no large regions of increased gas density. Acoustic density variance was very small. Under these isodense and warm conditions, general relativity can be simplified to Newtonian rules in Euclidean space. All the atoms were moving at nonrelativistic speeds. These atoms' instant kinetic tensors are simply expressed as Newtonian momentum. Any four noncoplanar atoms in this Universe are well described by the instant Cartesian coordinate system which defines Euclidean space. These four atoms could be a centimeter apart, or ten billion light-years apart. Their instant coordinates can all be assigned to a single perfect cubic grid, extending to infinity in all directions. At last scatter, this grid's comoving coordinates slowly expanded, but remained Euclidean for perhaps a year or more, which is long enough to apply differential analysis to the gas's behavior. The progress of time in the last-scatter Universe was constant throughout its volume and elapsing at about the same rate as it is today in the intergalactic medium or IGM, that vast void of gas which resides between the network of stars and galaxies called the "cosmic web". For any one atom that has managed to remain in the IGM, its clock back then and its clock right now differ by less than a year in a million. Something like that. Time and space can be effectively separated from each other under these conditions of low and uniform atomic density: Time is linear, space is xyz, just like in the olden days before general relativity came along. The atoms didn't stay that way. The tiny acoustic pressure waves detectable at last scatter began to overlap within a colder and colder Universe, creating permanent regions of high gas density whose formation was abetted by the cold. Within these regions of higher density, acoustic resonance gave occasional antinodes that were dense enough to cause gravitational collapse into stars. Treatment of Universal mass using all of general relativity becomes necessary after that, and we will accept without reservation the consistency of myriad observations of the behavior of energy in all its forms with the predictions of general relativity. That does not negate the instant Euclidian approximation at last scatter. Furthermore, we can treat the intergalactic medium today as Euclidean. My understanding is that most physicists regard the Universe as mathematically "flat". Well, a flat instant Universe is Euclidean *ad infinitum*, and about 90% of the Universe's volume is the IGM.

Getting back to last scatter: We had a Universe composed of a uniform gas which was getting less dense over time. Locally, the gas was expanding. This is a situation well suited for application of certain gas laws which have been used by engineers for a century. There are no mysteries in the engineering community about the behavior of gases. We are going to apply those laws now. Full details of this treatment are in my paper.

Here are the basics. We start with a sphere of gas having the same exact size around each and every atom in the Universe, and we increment the sphere radius by a very small relative value, $\frac{\Delta r_i}{r} = 10^{-9}$ or one-billionth of its starting radius: $r_2 = 1.000000001\ r_1$. This gas is monatomic, so its thermal energy U_i and internal pressure P are simply related:

$$U_i = \frac{3}{2}PV = \frac{3}{2}nRT$$

The ideal gas law is also expressed here: $PV = nRT$.

These spheres of gas lose thermal energy as they expand. They get colder:

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

Some of the lost energy is taken up by gravity. That depends on how big the sphere is:

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

Note that the M' term in the above equation is the total mass, not just the gas's mass.

The difference between the energy released by thermal loss and the energy taken up by gravity is the radial kinetic energy E_k of the expanded sphere:

$$E_k = U_r - \Delta U_i = \left(\frac{3}{2}\right)P_1V_1\left(\left(\frac{V_2}{V_1}\right)^{-\frac{2}{3}} - 1\right) - \frac{3GM'^2}{5}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

This sort of energy can be seen in an exploding firework's beautiful visual trace.

We use a small increment of 10^{-9}. If we shrink the increment further it approaches zero, and the E_k of a sphere becomes its instant entropic energy gain:

$$E_k = d(TS)$$

This applies to an ideal monatomic gas whose density remains uniform as it expands.

The radial kinetic energy E_k of the sphere gives its entropic pressure $P_{V'}$, much like the pressure inside a balloon:

$$P_{V'} = \frac{E_k}{dV} = \frac{d(TS)}{dV}$$

When $dV = 0$, $P_{V'} = P$, just like in a balloon. The pressure's only entropic if the sphere is expanding.

These expanding spheres at last scatter can be any size, but there's one sphere which is special: The adiabatic sphere. In an adiabatic sphere, $E_k = 0$, and all of its differential thermal loss is taken up by gravity. We will call the radius of an adiabatic sphere its endpoint r_e. I can't derive an analytical expression for the endpoint, so it's found by convergence of r around $E_k = 0$. If we plug in the numbers, we find that at last scatter, the endpoint was 9.691 x 10^{16} meters, about twenty light-years in diameter. It's very big. Energy is conserved within any one adiabatic sphere, so it's conserved within all of them, and the first law of thermodynamics is obeyed. The adiabatic sphere also obeys the second law of thermodynamics: Entropy is always increasing, $dS > 0$. Engineers hold the second law as inviolate. To them, entropic change can never be equal to zero.

To find out how fast the adiabatic sphere is expanding, we need to determine the rate of expansion of the lesser spheres it contains. Let's go back to our differential expression of E_k. The radial kinetic energy also tells us how fast the mass M in that sphere is expanding. We call this the increment radial velocity v_s':

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

When we talk about an expanding sphere this way, what we mean is that each and every atom in the sphere is moving away from the central atom at exactly the same speed, no matter how far away from the center it is. That's how this model works. The radial velocity we calculate is a function not just of the radius but also of the size of the increment. It's not a true differential expression. We can get around this problem by keeping the increment fixed at 10^{-9} as we adjust the radius. When the sphere's radius falls below three one-thousandths of the endpoint, loss to gravity disappears, and the increment radial velocity stays the same: v'_{s_0}. We can then deduce the fastest rate at which any instant sphere will expand. We call this the initial radial velocity v_i:

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

As these instant spheres get larger, gravity takes a bigger and bigger bite out of the released energy from thermal loss, right up to the endpoint. We can get a good estimate of how fast each of these spheres are expanding, termed v_s, by using a ratio of increment radial velocities:

$$v_s = \frac{v'_s}{v'_{s_0}} v_i$$

When you add up all of these individual spherical shells' differential radial velocities, you get the integral radial velocity of the adiabatic sphere, termed v, which is how fast it expands while conserving energy:

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

Where $r_c = 0.003 r_e$. These points can be plotted, giving a curve. All such curves, without exception, give the same integral value of v/v_i, independently of density, temperature, or molecular weight:

$$v = 0.79210 v_i = K v_i$$

Since the instant Universe at last scatter was fully Euclidean, we can construct a line of adiabatic spheres, connected at their tangent points. Anywhere along this line, for any two atoms separated by a distance r, their recession rate v_r is given by:

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

Dividing through by r gives the fundamental equation:

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

This is the GCDM thermal model, or just the "thermal model". What came as a big surprise to me is that its predictions are independent of both temperature and molecular weight of the gas. You can raise the temperature, you can lower the temperature, it doesn't matter. You get the same H_G regardless. This is also true for molecular weight. There is only one independent variable in this model: The rest density of ordinary matter, known in the trade as baryons. The thermal model is exclusively dependent on baryon density. Physicists call ordinary matter "baryonic" because almost all atomic mass is found in the protons and neutrons of the nucleus, and these two particles are both baryons. The atom also contains bound electrons, which are a different type of particle called a lepton. The momenta of these bound electrons may have been insignificant at last scatter, but today they're mostly free electrons, are highly energetic, and they pack a big punch. Electron kinetic energy is the source of "dark energy", as we will see.

My paper says something else about an adiabatic sphere: Of the energy released by its expansion, only one-third is taken up by gravity in an "isoentropic" manner. Exactly two-thirds is entropic, radial kinetic energy. These adiabatic spheres' entropy is always increasing and they never stop expanding, which means the Universe never stops expanding, provided that its baryon mass remains mostly gaseous and far away from the galaxies. That, indeed, appears to be the case.

PART 3: PREDICTIONS AT LAST SCATTER. ΛCDM vs. THERMAL MODELS

I'm now going to introduce the "minimum flat-Universe ΛCDM model", the most empirically accurate model to date:

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

This equation connects today's reference value H_0, called the "Hubble constant", with the corresponding Hubble parameters at earlier times when the Universe was more dense. Again, we have an exclusive relationship between density and the Hubble parameter, just as we do in the thermal model. The difference is, ΛCDM treats all the baryons as if they were accreted, like rocks hurtling away from each other, in a vacuum. No gas. Gas is treated as a "dust", which would be a small rock.

Our two models share a common density that co-moves with H:

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

In GCDM, the total mass density $\rho_{M'}$ is used. In ΛCDM, the total energy density $\epsilon_{M'}$ is used. This is usually called the "critical energy density" ϵ_{crit}. Your lecturer will give you a full historical picture of the relation between critical density and Universal curvature. In a Newtonian Universe made of rocks, the critical density is that precise value where their kinetic energy approaches zero at infinite time. If $\rho > \rho_{crit}$, the rocks stop expanding, reverse course, and collapse. If $\rho < \rho_{crit}$, the rocks keep moving apart forever at a steady speed. The ΛCDM ρ_{crit} and thermal $\rho_{M'}$ are, however, not the same. In ΛCDM, ρ_{crit} includes Λ energy, and $\rho_{crit} = \rho_{M'}$. In GCDM, there's no such thing as Λ, and $\rho_{M'}$ treats this energy as nonexistent.

The "Ω" terms in the ΛCDM model are fractions. They always add up to one, giving the total. Their relative proportions change over time. The absolute densities of each of these kinds of energy, however, grow and grow the farther back you go, so the Hubble parameter does too. Lambda (Λ) is the outlier. If it was real it would be a "scalar" field, which means that its density doesn't change with time or space. It disappears from the total when you go back far enough. The Λ energy is repulsive, which translates into negative mass density. Yes, it does.

In GCDM, Ω_Λ doesn't exist, and stellar movement attributed to it instead arises from nonthermal entropic energy gain, or "suprathermal" energy. We'll get to that. The remaining Ω terms are retained by GCDM and used to get the total mass M'.

Both models rely on calculated H values of observed stars. The star's observed distance r is estimated from its luminosity, how bright it is to us. It's not easy to calculate r. Some would say this is less of a science and more of an art. The best estimates of r have been found by an army of astronomers who wait for a certain type of rare supernova to appear somewhere and then race against time to capture its highly consistent emission profile, and fingers crossed, brightest emission.

We also need to find the star's recession rate v_r, how fast it was moving away. This is found from the cosmic redshift z:

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

We know a lot about light emission and absorption from atoms in the laboratory and these are found from those same atoms in starlight. If the star is moving towards or away from us the wavelengths of emitted and absorbed light are shifted. The star's radial velocity v_r is calculated from the shift in emission wavelength using Einstein's special relativity equations.

The cosmic redshift gives the scale factor "a":

$$a = \frac{1}{(z+1)} = \frac{1}{z'}$$

The scale factor expresses how dense the Universe was at the time the star's light was emitted. This relation between the cosmic redshift of any one star and its scale factor at the time of emission is imperfect because of local gravitational effects, known as peculiar motion, which is quite pronounced for stars which are close to us. Many redshift values have to be measured in order to rule out the effects of peculiar motion. When combined with the imprecise luminosity estimates, the resulting plot of H vs. a gives a lot of point scatter, but you can still get a distance-ladder line from the plot. In 1998, two groups of astronomers reported that this line is actually a curve, and used Λ to account for the curvature.

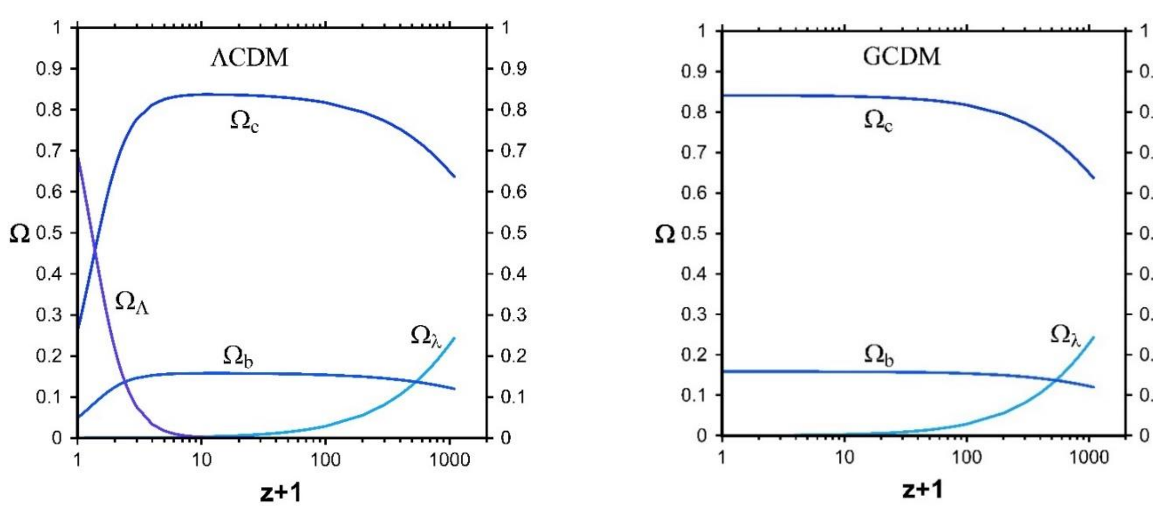
At the time of last scattering there were no stars, and other methods must be employed to get the scale factor. I use a popular value, 1/1090. People like it but it's still under debate. We can get the Universe's temperature at last scatter by starting with the CMB's Boltzmann value (2.726K) and dividing by the scale factor.

For ordinary matter, its mean rest density varies as the inverse cube of the scale factor. Today, the scale factor is one. Back when the scale factor was ½, ordinary matter was eight times as dense; when the scale factor was 1/3, it was twenty-seven times as dense, and so forth. At last scatter, it was 1/1090, so ordinary matter was about 1.3 billion times as dense as it is today. This is still a very high vacuum by terrestrial standards: About 1 x 10^{-16} atmospheres for our gas at 2971K. Stars lose mass through nuclear fusion so this is also an imperfect relationship.

There's another kind of mass, known as cold dark matter. It's the "CDM" in "lambda-CDM". As of 2023, very little is known about cold dark matter. Your lecturer will tell you what we do know. What is generally believed is that cold dark matter also has an inverse-cube relation to the scale factor and is always about 5 ¼ times as dense as ordinary matter. That is, in the Universe as a whole. Cold dark matter doesn't appear to exert any effects locally. There's no trace of this matter in our solar system. We won't dwell on this mystery. For now, cold dark matter has a constant density relative to ordinary matter, and that's all we need to know to use both of the models.

There's yet another kind of mass: Relativistic mass from photons in the cosmic microwave background. This density varies as the inverse fourth power of the scale factor. Photons may not have any rest mass, but their energy has mass equivalence within general relativity, and the density of the CMB was uniform throughout the Universe then and now. We can include this gravitational effect in our instant Euclidean approximation. Photon mass equivalence is trivially small today, but at last scatter photons comprised almost a quarter of the Universe's total mass.

For those of you interested in neutrinos, their equivalent mass is herein treated as fully nonrelativistic and thrown in with the CDM mass. This may, or may not, introduce error at higher *z* values. I happen to believe that cold dark matter is all neutrinos anyway. Neutrinos are leptons too, and I think the quark-gluon plasma is more accurately a quark-gluon-lepton plasma, but that's just my superstition about how leptons form, and the Gibbs free energy of each kind of particle during inflation.



Since the Ω fractions are central to ΛCDM, it's helpful to look at how they change over time. Looking at the above figures, we can see that for $z > 9$, they are identical. Relativistic mass in both models rises from zero at $z = 9$ to 24% at $z = 1089$ and the other mass terms drop proportionately. In the ΛCDM figure, for $z < 9$, the putative Λ proportion grows and becomes predominant when $z < 0.307$. The Ω fractions are attractive, except Ω_Λ which is repulsive. They still all add up to one. While these fractions are useful, Ω_Λ renders them inaccurate for $z < 9$.

THE HUBBLE TENSION

We now compare the thermal and ΛCDM models at last scatter. Since the Hubble parameter is used to get the total density, we must choose a value of today's Hubble parameter H_0 from a menu of estimates. Then we extrapolate today's total density backwards in time to get the total density at last scatter, and use that density to calculate H_{1089} from the two different models. Most H_0 values derive from distance-ladder measurements of stars. There is another method which relies on the cosmic microwave background. It uses the tiny variances in the CMB's Boltzmann temperature to get an H value at last scatter. This H estimate includes baryon acoustic oscillation, a contribution from sonic effects. The last-scatter H is then extrapolated *forward* in time using ΛCDM to give H_0. If accurate, this method should give an estimate of H_0 fairly close to the distance ladder estimates. But it doesn't. They're far apart. The distance ladder gives H_0 values around 74 units. Last-scatter extrapolation gives an H_0 of around 68 units. These values differ too much to be reconciled, and this discrepancy is known as the Hubble tension. There's a lot of speculation about the origin of this Hubble tension, much of which preserves ΛCDM as a proper method of extrapolation from last scatter to today. I think ΛCDM is inaccurate to begin with. The inaccuracy is quite pronounced at last scatter, and is the source of the Hubble tension. This is illustrated with some H values shown in the table below.

All of these calculations start with H_0 and are extrapolated backward in time to find H_{1089}. The top two rows in the table give the Hubble parameters with all energy included. The rows below that show what happens when we remove energy.

On the far-left column of the table are estimates of the present-day Hubble parameter, given in the units used by astronomers. The upper number, 67.70 units, is a CMB-derived estimate of H_0 from a published paper, "Planck 2018", which is where I derived all my Ω's. The top row of the table recalculates its last-scatter H_Λ. The result is 5.045×10^{-14} sec^{-1} which presumably re-expresses the authors' starting point; I couldn't find it anywhere in their paper. The lower number in each set of rows, 74.40 units, is one of many distance-ladder estimates.

The second column converts units into inverse seconds, which gives the proportionate increase in adiabatic sphere radius, per second. The next two columns give the Hubble parameters at last scatter for each model. The final three columns give H/H ratios for the four different input sets.

THE EFFECT OF RELATIVISTIC (CMB) ENERGY ON THE HUBBLE PARAMETER						
$z = 0$		$z = 1089$				
H_0	H_0	H_G	H_Λ	H_G/H_0	H_Λ/H_0	H_G/H_Λ
(km/sec/Mpc)	(sec^{-1})	(sec^{-1})	(sec^{-1})			
BOTH GCDM AND ΛCDM CONTAIN CMB ENERGY (Einstein's Universe)						
67.70	2.194 x 10^{-18}	6.319 x 10^{-14}	5.045 x 10^{-14}	28,805	22,995	1.253
74.40	2.411 x 10^{-18}	6.945 x 10^{-14}	5.544 x 10^{-14}	28,805	22,995	1.253
GCDM DOES NOT CONTAIN CMB ENERGY, ΛCDM DOES						
67.70	2.194 x 10^{-18}	4.784 x 10^{-14}	5.045 x 10^{-14}	21,807	22,995	0.948
74.40	2.411 x 10^{-18}	5.257 x 10^{-14}	5.544 x 10^{-14}	21,807	22,995	0.948
NEITHER GCDM NOR ΛCDM CONTAIN CMB ENERGY (Newton's Universe)						
67.70	2.194 x 10^{-18}	4.784 x 10^{-14}	4.389 x 10^{-14}	21,807	20,008	1.090
74.40	2.411 x 10^{-18}	5.257 x 10^{-14}	4.824 x 10^{-14}	21,807	20,008	1.090
NEITHER ΛCDM NOR GCDM CONTAIN CMB ENERGY, AND GCDM'S GAS DENSITY IS REDUCED BY 15.8%: $\rho_g = 0.8418\ \rho_b$						
67.70	2.194 x 10^{-18}	4.389 x 10^{-14}	4.389 x 10^{-14}	20,008	20,008	1.000
74.40	2.411 x 10^{-18}	4.824 x 10^{-14}	4.824 x 10^{-14}	20,008	20,008	1.000

The first thing we notice is that the ratio H_{1089}/H_0 is constant for each pair of H_0's. It's always the same within any of the eight pairs shown in the table. Other H_0's give the same result. The accuracy of this H_{1089}/H_0 ratio depends on the accuracy of the model, and the accuracy of H_{1089} depends on both H_0 and the model. I believe the distance-ladder H_0 and the thermal model, in Einstein's Universe, gives the best result: $H_{1089} = 6.945 \times 10^{-14}$ sec^{-1}, or 2.143 million units.

The far-right column of the table is what we want to focus on. This column gives the relative values of the models at last scatter. When CMB energy is included in both models, GCDM gives a value that is 125% of ΛCDM. When we remove CMB energy from GCDM, its value drops to 95%. This is because relativistic mass shrinks the adiabatic sphere, increases its baryon density, and increases H. When this mass is removed from the sphere, it gets larger and its baryon density drops, which reduces H. Density and entropy are covariant in a freely expanding gas, so an adiabatic sphere's increase in density gives an increase in its entropic pressure. This pressure is presently neglected by acoustic oscillation calculations. I'm hardly an expert on the subject, but I don't need to be. Here's an excerpt from Wikipedia:

"Without the photo-baryon pressure driving the system outwards, the only remaining force on the baryons was gravitational." (https://en.wikipedia.org/wiki/Baryon_acoustic_oscillations)

This is simply not true. A fifth force of Nature, entropic gain, is neglected. Gaseous baryons comprise this force. They create the force. They are the force-carrying particles. The differential entropic energy gain of the baryons is the sole driver of expansion at last scatter.

Baryon acoustic oscillation is only a small part of the CMB picture. When it's excluded from the Planck 2018 calculations, H_0 moves to 67.32 units, not a very large drop. Maybe inclusion of entropic force bolsters acoustic resonance enough to bring H_{1089} up to 2.14 million units, maybe not. I can't comment intelligently about that, or about how H_{1089} is derived from thermal variance in the CMB's Boltzmann curve. There's also the ratio H_{1089}/H_0 to consider. The only thing I can say with confidence is the thermal and ΛCDM models give very different results at last scatter, and that some of this variance arises from entropic neglect. I believe that all of the variance, and the Hubble tension, can be attributed to ΛCDM's theoretical inaccuracy.

Since the Universe at last scatter was Euclidean, if we get rid of relativistic energy altogether we can create a fully Newtonian Universe which is actually quite instructive. In a Newtonian Universe, without radiation or dark energy, the ΛCDM model becomes a simplified version of what is known as the Friedmann equation, derived by Alexander Friedmann a century ago:

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

This "simple Friedmann" equation describes the behavior of rocks in a vacuum, all hurtling away from each other at their comoving critical density. It can be expressed using the inverse scale factor z':

$$H = H_0\sqrt{\left(\Omega_b z'^3 + \Omega_c z'^3\right)}$$

The GCDM thermal model can also be expressed with z':

$$H = \frac{K}{r_{e_{1090}}}\text{ɱ}'\sqrt{\frac{3RT'}{\text{Ж}}\frac{(z')^3}{1090}\rho'_{z'}}$$

This derivation and the meaning of its symbols is given in my paper. It looks complicated but there's only two independent variables: the inverse scale factor z', and a term $\rho'_{z'}$, which is the fraction of baryons that are gravitationally unbound and still behave like a freely expanding gas. This $\rho'_{z'}$ term is called the mass partition. The mass partition removes the accreted mass, its kinetic energy, and its proportion of CDM mass from the thermal model. The term (1-$\rho'_{z'}$) is the accretion parameter, which is the fraction of Universal mass that is gravitationally bound: Stars, planets, black holes, bound gases, etc. These accreted baryons act like rocks and comprise the cosmic web of galaxies with all of its gravity-bound behavior.

When we assign a constant value to the mass partition, $\rho'_{z'}$ = 0.8418, we find that for the entire range of z = 0 to 1089, the thermal and simple Friedmann models give identical results:

$$\frac{\frac{K}{r_{e_{1090}}}\text{ɱ}'\sqrt{\frac{3RT'(z')^3}{\text{Ж}\ \ 1090}\rho'_{z'}}}{H_0\sqrt{\left(\Omega_b z'^3 + \Omega_c z'^3\right)}} = 1.000 \text{ for all } z = 0 \text{ to } 1089$$

In other words, expanding rocks which are forever slowing to an eventual halt behave exactly a freely expanding gas forever pushing itself apart. The only thing the CMB does is increase the push, and that only happens way back near last scatter. The "rocks", of course, are stars. In today's intergalactic medium, entropic pressure makes its gas expand, separating the tendrils of the cosmic web. About 90% of our Universe's present volume is occupied by this expanding gas, which contains 84% of all baryon mass. After around $z = 9$ or so, acoustic resonance in the intergalactic medium came to an end and accretion into the cosmic web stabilized at 16% of the total. This 84/16 proportion has remained about the same ever since, so our Universe will keep getting less and less dense forever.

Before $z = 9$, gas accretion into the cosmic web was incomplete, so if we can find any starlight from those earlier times and manage to calculate the Hubble parameter of that light, we can estimate the progress of accretion (1-$\rho'_{z'}$):

$$\rho'_{z'} = H^2 \frac{\left(r_{e_{1090}}\right)^2}{K^2(\text{ŋ}')^2} \frac{\text{Ж}}{3RT'} \frac{1090}{(z'_2)^3}$$

This depends on an accurate value of H_0 which is still a big debate. What we can do is use the CMB value of H_0, 67.70 units, and watch how the observed H/H_A values deviate upwards as we go back in time from $z = 9 \rightarrow 50$ or so. The upper limit of this H/H_A deviance is the last-scatter value of 1.25, shown at the top right-hand corner of the table. We'll never see that because there weren't any stars at last scatter, just gas. These measurements haven't been made yet, because there's only one telescope that can see back that far: The James Webb telescope. It was launched late in 2021 and as of this writing, only a few redshifts for $z > 9$ have been measured. I don't know of any Hubble parameters to date which have been calculated from these galaxies' luminosity estimates. We'll just have to wait.

The accretion parameter doesn't fully address the interplay between gas and rock. Can cosmic thermal behavior be easily parsed into Friedmann-like and gas-like components while accretion is still ongoing? I'm not so sure about that.

PART 4: SUPRATHERMAL ENERGY

What about dark energy? The thermal model alone can't account for observed stellar movement in more recent times. There has to be kinetic energy that does not behave thermally. Such energy does exist, in a well-known form, and comprises slightly more than half of all the kinetic energy in the intergalactic medium today. It comes from free electrons whose energy range far exceeds the thermal profile of the baryons: Suprathermal energy. The IGM today is a fully ionized plasma, which has both thermal and suprathermal components. Suprathermal energy doesn't drop thermally as the adiabatic sphere expands. Its loss arises from collisions with thermal electrons and low-energy photons, and from cosmic wavelength increase, similar to the cosmic microwave background's behavior in an expanding Universe.

The thermal model is modified to include suprathermal energy in the numerator:

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

Which gives the suprathermal model:

$$H = K \frac{v_i}{r_e} \sqrt{\left(1 + \frac{U_{\beta_s}}{U_b}\right)}$$

The U_{β_s} term is suprathermal energy, and the U_b term is the thermal energy of the baryons alone: atomic nuclei which have been stripped of their electrons. The thermal component of free electrons' kinetic energy affects v_i and r_e equally and has no effect on H. The suprathermal model's r_e and v_i are thus baryonic only and almost exactly the same as before. Their values and the constant K are left unchanged from the thermal model. I kept them thermal mostly because it just seemed like the right thing to do, but also to reduce the number of independent variables down to just the scale factor. Keeping the endpoint and K thermal is a big "if". Maybe one of you younger readers out there can provide some insight about this.

I conducted a point-by-point convergence of the ratio U_{β_s}/U_b to match it up with the ΛCDM model's predictions. The ratio U_{β_s}/U_b is temperature-independent, just like H_G. Full details are in my paper. Here's the resulting equation:

$$H = H_{G_0} a^{-\left(\frac{3}{2}\right)} \sqrt{1 + 2.2397 a^3}$$

The term H_{G_0} is a thermal constant derived from H_0, and the number 2.2397 is the ratio $U_{ß_s}/U_b$ today at $z = 0$. This equation matches ΛCDM perfectly out to $z = 2$ and is still very good out to $z = 4$. At $z = 5$, this model begins to deviate from ΛCDM's predictions.

The suprathermal model gives a "pumped Universe" scenario. In a pumped Universe, the intergalactic medium is continually fed with suprathermal energy. This energy persists and accumulates. Most of it comes from electrons which in turn derive their energy from photons produced by nuclear fusion within the cosmic web of galaxies. These photons collide with electrons, which is called Compton scattering, and impart kinetic energy to them. Much of that particle energy is well above the baryons' thermal range given by the Boltzmann curve. The Universe isn't just getting hotter. Its kinetic energy is increasing above and beyond simple thermal heat. This gives a tremendous amount of added entropic force. We should be able to connect suprathermal energy generation with the small number of known sources which are capable of producing the kind of high-energy photons required to generate these suprathermal electrons from neutral atoms. Maybe additional scattering of free electrons by the lower-energy photons emitted by all stars today gives net addition enough to account for the "dark energy" effect. I don't have those answers. What I do have is a model which adheres to both laws of thermodynamics. The same cannot be said about ΛCDM, and the next part of the essay shows how this came about.

PART 5: THE SPECIOUS ASSUMPTIONS OF ΛCDM

Two specious assumptions underpin ΛCDM: isoentropy and energy conflation. Isoentropy underpins the Friedmann equation, and conflation underpins the fluid equation. Both of these equations neglect entropic gain. The Friedmann equation pretends it doesn't exist. The fluid equation actively excludes entropy and has to conflate thermal and total energies to compensate. These two equations, plus a third, give the ΛCDM model.

THE FRIEDMANN EQUATION

We've already discussed the Friedmann equation. I show it here in semi-Newtonian form:

$$H = \sqrt{\frac{8\pi G\rho_{M'}}{3}}$$

The Friedmann equation overlooks the fact that most Universal baryon mass is gaseous. Instead of the thermal model's perpetual entropic pressure, we have ΛCDM's bunch of rocks at a "miraculous" critical density. Both give the same result, but the thermal model also gives a fraction of accreted mass. The Friedmann equation can't account for accretion because it treats baryon mass as 100% accreted in the first place.

Friedmann employed Einstein's field equation which makes no provision for entropic gain. Einstein invented the Λ force to offset gravity, as the Universe was thought to be static at the time, and he had to do something to prevent its collapse. Both Friedmann's and Einstein's entropic omissions were benign. It just didn't occur to either author to include entropy.

THE FLUID EQUATION

The fluid equation is a different story. It actively excludes entropic gain. We rearrange the fluid equation's derivation from the textbook treatments and start with the Gibbs equation:

$$d(U_i) = dE = TdS - PdV$$

Which is a form of the first law of thermodynamics appropriate for gases. It accurately predicts thermal change of sealed or "bound" gases precisely.

An unbound gas's behavior is similar if the gas remains uniformly dense:

$$dE = d(TS) - d(PV)$$

For a bound gas over time we get:

$$\frac{dE}{dt} = T\frac{dS}{dt} - P\frac{dV}{dt}$$

When applied to the entire Universe, we must use a broader definition of the first law which includes mass equivalence $E = Mc^2$. Nuclear fusion. We redefine E as total energy:

$$dE/dt = 0$$

Total Universal energy never changes. That's what the first law really says. Our cosmic dE term now includes rest mass, so we have to rename the old E back to its original U_i:

$$dE = d(Mc^2) - d(U_i) - d(PV) + d(TS) = 0$$

Rest mass M doesn't change at last scatter so this is the same equation we used for the thermal model. We know that $d(TS) = E_k$ or radial kinetic energy, and you may have figured out that $d(PV) = U_r$ or loss to gravity. Photon energy from the CMB isn't included here and my paper discusses relativistic energy change in more detail. It's unimportant for now.

The fluid equation's development continues with another bound equation:

$$dQ = TdS$$

This relates thermal change from heat flow, dQ, with the entropy change dS in a vessel. If dQ = 0 the vessel is well insulated, or adiabatic. No vessel is perfect. There's always some heat flow in or out of the vessel. The Universe is perfect. There's no heat flow in or out of the Universe.

In a bound vessel which is adiabatic, $dQ = 0$, so we get $dS = 0$. We call this isoentropic. When a bound gas expands isoentropically, it loses thermal energy reversibly to some sort of external storage. A good example is a bouncing rock atop a piston. Ideally, the rock bounces up and down forever as the piston's gas cools and warms reversibly. In reality, the rock stops bouncing as thermal energy flows out of the system to its (colder) surroundings. The system may lose heat, but its surroundings gain the heat. That's the first law. For both system and surroundings combined, entropy always increases: $dS/dt > 0$. That's the second law. In the Universe as a whole, the system and surroundings are one and the same thing, so $dS/dt > 0$ always.

The fluid equation sets Universal $dS = 0$ despite the second law. Baryon mass is treated either as a "perfect fluid" or as a lesser "dust" which is inconsistent with its actual existence as a gas having entropic pressure. Entropic gain is denied its role as a fifth force of Nature, and all energy change is isoentropic. The Gibbs equation now looks like this:

$$PdV/dt = -dE/dt$$

Which describes gas in an adiabatic vessel. The term $-dE/dt = -d(U_i)/dt$ describes its rate of thermal loss. Setting $dS = 0$ means that all the loss is reversibly stored, and in the Universe as a whole, there's only one place I know to store it: work against gravity. I've shown in [my paper]() that only a third of this thermal loss is stored that way. When the "vessel" is the Universe, the rest of it would be *leaving the Universe*. That lost thermal energy isn't going anywhere. It's become entropic. The gas's differential entropic gain is pushing everything apart, and its integral entropic gain gives reduced gas density over time.

Having looked through the literature, I can tell that there's folks out there who are aware of the second-law inconsistency, and insert caveats into their papers. They may also be aware of the resulting first-law inconsistency. My best guess about all this is that nobody could figure out how to properly include entropy, so they got rid of it in order to justify the fluid equation's development. This entropic excision was widely accepted and remains so to this day. After all, Einstein didn't use entropy. Friedmann didn't use entropy. Why should the fluid equation be any different? Many people, however, are well aware of the second law's true meaning. They must be deeply troubled by the fluid equation's isoentropy and possibly by the resulting problem with the first law. Those who don't understand any of this, or chose to ignore it, are busy with workarounds. There's about two thousand peer-reviewed papers that attempt to treat entropy through some sort of modification of ΛCDM while leaving one of its core problems, the fluid equation, untouched.

Cosmologists' questionable interpretation of the Gibbs equation has another consequence. Eliminating entropy eliminates entropic pressure, so its effects on stellar movement have to be accounted for some other way. The fluid equation does this by conflating the thermal and total E terms. Internal energy gets redefined. It isn't thermal energy anymore, it's total energy. The Gibbs equation now treats total energy as a thermal variable. Well, total energy isn't thermally variable. The first law says it's constant. Conflation of the E terms can thus appear to create an enormous amount of what is fictitious repulsive energy from what is actually a much smaller amount of entropic gain. This is exactly what happens when stellar data is interpreted.

Further development of the fluid equation is in all the texts. The result is the same for both Einsteinian and Newtonian versions, which differ only by c^2. The Newtonian expression of the fluid equation is:

$$\frac{d\rho}{dt} + 3H(\rho + "P"/c^2) = \frac{d\rho}{dt} + 3H\rho_{M'} = 0$$

Where ρ is rest mass density and $\rho_{M'}$ is total mass density. The term "P/c^2" is the mass density of energy not at rest. The energy density term "P" is labelled as "pressure":

$$"P" = w_b\epsilon_b + w_\lambda\epsilon_\lambda + w_\Lambda\epsilon_\Lambda \approx 2U_i/3V + \tfrac{1}{3}\epsilon_\lambda - \epsilon_\Lambda$$

This definition of "pressure P" is known as the equation of state. It's the third leg of ΛCDM and is detailed in [my paper](). The equation of state inverts the meaning of pressure. Positive "pressure" is gravitationally attractive in the equation of state. Most of us think of positive pressure as repulsive, like in a balloon. Not here. Repulsive energy density is now called "negative pressure".

Your lecturers will tell you how they interpret the terms which comprise "*P*". The way I see it, entropic pressure $P_{V'}$ as such is completely gone. About half (53%) of its repulsive energy U_i is conflated and shows up as -ϵ_Λ. This gives a "*P*" which is >99% composed of -ϵ_Λ. The other "*P*" terms are negligible compared to -ϵ_Λ when $z < 5$. Divide by c^2 and they disappear. Rest density's fraction gets pushed down too. ΛCDM's interpretation of stellar movement gives a +ϵ_Λ that would be 69% of total $\epsilon_{M'}$ today if Λ was real. But it's fictitious. It doesn't exist. Which is a pretty good explanation for why its source is such a mystery. The simple Friedmann model may not properly express entropic gain, but it can at least be made coincident with purely thermal behavior. That leaves suprathermal energy alone which Λ overexpresses.

The Friedmann equation is differentiated and combined with the fluid equation to give an acceleration equation which is integrated to give *H(a)* or *H(t)*. Lookback times are found this way. We won't go into that. What's important here is the Friedmann equation uses total energy density to give *H* as a function of its constituents:

$$H = \sqrt{\frac{8\pi G}{3c^2}\left(\epsilon_b + \epsilon_c + \epsilon_{U_i} + \epsilon_\lambda - \epsilon_\Lambda\right)}$$

Which can be seen as:

$$H = \sqrt{\frac{8\pi G}{3}\left(\rho_b + \rho_c + \rho_\lambda - \rho\left(\epsilon_{U_i}\right)\right)}$$

Where $\rho\left(\epsilon_{U_i}\right)$ is the mass density of kinetic energy. But this still uses fictitious negative mass. Baryon mass loss due to nuclear fusion, from last scatter to today, can be reasonably estimated at 2%. If that's kinetic energy now, then its density isn't even close to Ω_Λ's 69% even if you add in the primordial pressure. Does cold dark matter somehow proportionately become kinetic energy? Maybe. You would still only get about 15% of the total that way. But I digress. Total energy isn't the primary metric we should be looking at to begin with. Kinetic energy is. Most of the Universe's kinetic energy resides in a vast unbound plasma whose large-scale repulsive behavior is governed by a fifth force of Nature. This force can't be derived from the other four. It pushes apart distant galaxies, and keeps a balloon inflated. The repulsive nature of gas pressure was quantified a long time ago. All I did was recognize that the Universe is mostly an unbound gas.

PART 6: CONCLUSION

The GCDM model is simple at its heart. The thermal model has two codependent terms from a single variable, mean gas density. The suprathermal model adds a term derived from photon flux. This can be found from observation of stars, and there's a lot known about stellar photon flux. But the suprathermal electrons produced by this flux may not persist indefinitely. They could lose energy and become thermal, and that process must be accounted for. I'm no expert in Compton scattering or electron-electron collisions, but I read a book or two and have nagging unscientific doubts about whether these are properly estimated. There's also plenty of local entropic effects near galaxies to worry about. Gas engineers perform this sort of calculation all the time. Cosmologists and engineers may benefit from collaboration. For now, if you believe what the engineers have to say about the laws of thermodynamics, the ΛCDM model has to go. It's had its day, and we need to move on.