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A Heuristic Model of the Evolving Universe Inspired by Hawking and Penrose

Eugene Terry Tatum

Abstract

A heuristic model of universal expansion is presented which uses, as its founding principle, Stephen Hawking's singularity theorem. All assumptions of this model are intrinsically linked to Hawking's theorem and its implications with respect to the time-symmetric properties of general relativity. This is believed to be the first mathematical model constructed in such a way, and it is remarkably accurate with respect to current astrophysical observations. This model's apparent superiority to standard inflationary cosmology is emphasized throughout, including its accurate derivations of the observed Hubble parameter value and CMB anisotropy. The model definition of cosmic entropy not only correlates the observed temperature anisotropy but also may have implications for resolving the cosmological constant problem and the mystery of dark energy. Moreover, the model has a temperature curve which is more favorable for the remarkably early formation of quasars and galaxies. Possible deep connections to Verlinde's "emergent gravity" theory are also discussed.

Keywords: flat space cosmology, cosmology theory, cosmic inflation, dark energy, cosmic flatness, CMB anisotropy, cosmic entropy, black holes, cosmic dawn, $R_h = ct$ model

1. Introduction and background

A heuristic mathematical model of the evolving universe, for the purpose of this chapter, is one which tracks its *global* parameters (Hubble parameter, radius, mass, energy, entropy, average temperature, temperature anisotropy, etc.) as a function of cosmic time. For it to be useful, such a model should be consistent with everything we currently observe about the universe as a global object and extend these parameters indefinitely into the past and future. In assembling such a model, it is particularly useful to start with a founding principle on which some or, preferably, all of the starting assumptions can be based. For this particular model, the founding principle is based upon the groundbreaking work of Roger Penrose [1] and Stephen Hawking [2, 3] concerning the similar theoretical nature of astrophysical and cosmological singularities. This founding principle is Hawking's singularity theorem.

Hawking's singularity theorem implies that our universe, following time-symmetric properties of general relativity, could be treated mathematically as if it were a cosmological black hole-like object moving *backward in time* (i.e., *expanding*

from a singularity state as opposed to *collapsing to* a singularity state). Unfortunately, although Hawking's theorem was rigorously logical, he never actually put together a predictive mathematical cosmological model based upon his theorem. *What is presented in this chapter is believed to be the first such model.*

This author was sufficiently intrigued by the potential implications of Hawking's singularity theorem that he teamed up with two Indian physicists (U.V.S. Seshavatharam and S. Lakshminarayana) in 2015 to publish the seminal papers [4–6] on this model. For reasons to be discussed below, this model is called “flat space cosmology” (FSC). The current five basic assumptions of FSC are presented below.

2. The five basic assumptions of flat space cosmology

1. The cosmic model is an ever-expanding sphere such that the cosmic horizon always translates at speed of light c with respect to its geometric center at all times t . The observer is operationally defined to be at this geometric center at all times t .
2. The cosmic radius R_t and total mass M_t follow the Schwarzschild formula $R_t \cong 2GM_t/c^2$ at all times t .
3. The cosmic Hubble parameter is defined by $H_t \cong c/R_t$ at all times t .
4. Incorporating our cosmological scaling adaptation of Hawking's black hole temperature formula, at any radius R_t , cosmic temperature T_t is inversely proportional to the geometric mean of cosmic total mass M_t and the Planck mass M_{pl} . R_{pl} is defined as twice the Planck length (i.e., as the Schwarzschild radius of the Planck mass black hole). With subscript t for any time stage of cosmic evolution and subscript pl for the Planck scale epoch and incorporating the Schwarzschild relationship between M_t and R_t ,

$$\begin{aligned}
 k_B T_t &\cong \frac{\hbar c^3}{8\pi G \sqrt{M_t M_{pl}}} \cong \frac{\hbar c}{4\pi \sqrt{R_t R_{pl}}} \\
 \left\{ \begin{array}{l} M_t \cong \left(\frac{\hbar c^3}{8\pi G k_B T_t} \right)^2 \frac{1}{M_{pl}} \quad (A) \\ R_t \cong \frac{1}{R_{pl}} \left(\frac{\hbar c}{4\pi k_B} \right)^2 \left(\frac{1}{T_t} \right)^2 \quad (B) \\ R_t T_t^2 \cong \frac{1}{R_{pl}} \left(\frac{\hbar c}{4\pi k_B} \right)^2 \quad (C) \\ t \cong \frac{R_t}{c} \quad (D) \end{array} \right\} \quad (1)
 \end{aligned}$$

5. Total cosmic entropy follows the Bekenstein-Hawking black hole entropy formula [7, 8]:

$$S_t \cong \frac{\pi R_t^2}{L_p^2} \quad (2)$$

The rationale for these basic assumptions is closely tied to Hawking's singularity theorem as it might pertain to a time-reversed Schwarzschild cosmological black

hole-like object. From the centrally located observer’s point of view, outwardly moving photons traveling along geodesics at the cosmic boundary (i.e., the fastest-moving “particles” of the expansion) are infinitely redshifted and thus define the observational event horizon. Therefore, as given in assumption 3, the truly *global* Hubble parameter value can always be defined as speed of light c divided by the ever-increasing Schwarzschild radius R_t . While the first equation of assumption 4 closely resembles Hawking’s black hole temperature formula, it is modified so that cosmological mass scales in Planck mass units. This is thought to be more appropriate for a scaling cosmological model, as opposed to the relatively static thermodynamics of an astrophysical (i.e., stellar) black hole.

As described in some detail in the seminal FSC papers, the first three assumptions allow for perpetual Friedmann’s critical density (i.e., perpetual global spatial flatness) of the expanding FSC cosmological model from its inception. It should be emphasized that these assumptions were not adopted for this particular purpose. However, this unexpected and fortuitous outcome is perhaps the most important feature of this model. By dividing the Schwarzschild mass (defined in terms of cosmic radius R_o) by the spherical volume and substituting c^2/R_o^2 with H_o^2 , Friedmann’s critical mass density $\rho_o = \frac{3H_o^2}{8\pi G}$ is achieved for any given moment of theoretical observation (hence the subscript “o”) in cosmic time. So, *perpetual Friedmann’s critical density and global spatial flatness from inception is a fundamental feature of the FSC model. Our model was named for this important feature.*

This perpetual spatial flatness feature, as well as the finite properties of light-speed expansion of the cosmic horizon, obviates the need for an inflationary solution to the cosmological “flatness problem” and the “horizon problem.” It also avoids the disturbing and incredible “infinite multiverse” implications inherent within inflationary cosmic models. The problems of the required new physics of the “inflaton” field, and of the “past-incomplete” nature [9] of inflationary models, are also avoided in the FSC model. Many of these differentiating features of FSC with respect to standard inflationary models were discussed at length in a recent FSC summary paper [10].

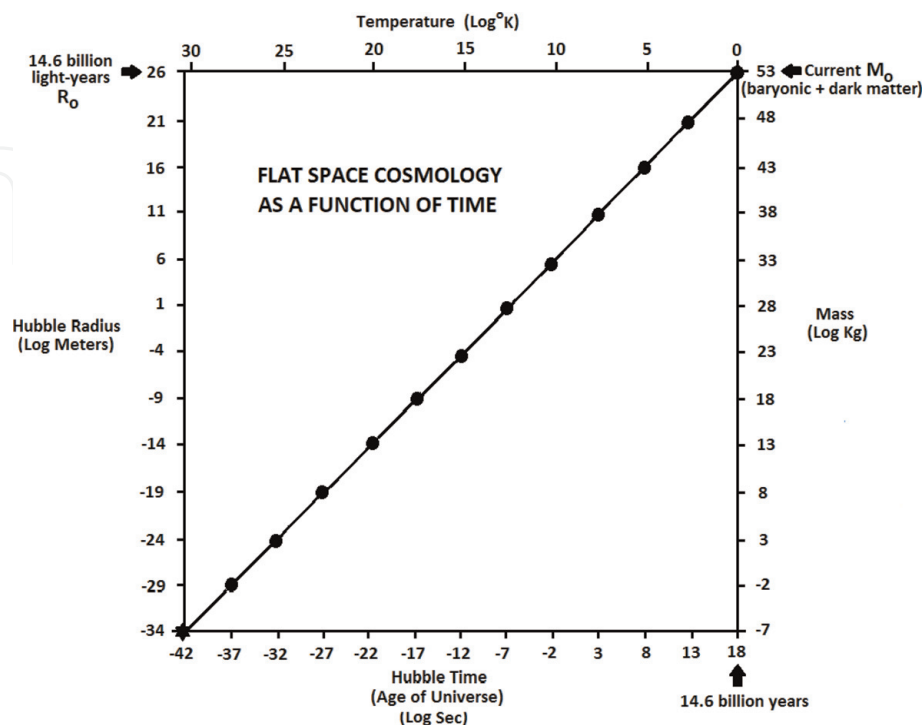


Figure 1.
Cosmic radius, temperature, and mass as a function of cosmic time.

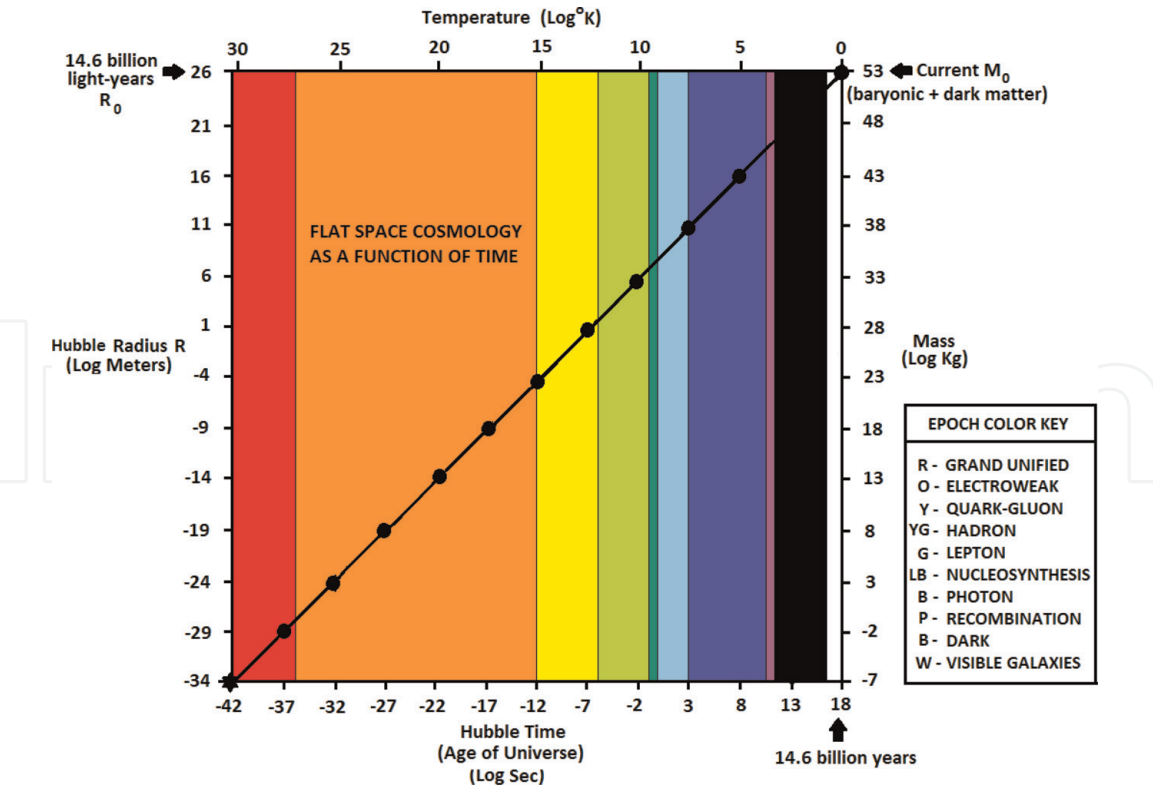


Figure 2.
Particle physics epochs as a function of cosmic time and temperature.

Based upon the relations proceeding from the top equation of assumption 4, and the model Hubble parameter definition of assumption 3, an FSC log graph can be presented in **Figure 1**.

A color-coded overlay of cosmic epochs evolving from the Planck scale epoch, as believed to be the case from particle physics experiments and quantum field theory, is presented in **Figure 2**.

In both figures, there is a tight correlation between cosmic temperature and time elapsed since the Planck scale epoch (not shown) at approximately the 10^{-43} s mark of cosmic expansion.

3. FSC correlations with astronomical observations

The following temperature-dependent cosmological parameters can be easily calculated in the FSC model. The only free parameter in any of these equations is the cosmic temperature. Furthermore, by incorporating the values of T_0 , \hbar , c , G , k_B , L_p , and π to as many decimal places as known, any of these FSC parameters can be shown to closely match astronomical observations:

$$R \cong \frac{\hbar^{3/2} c^{7/2}}{32\pi^2 k_B^2 T^2 G^{1/2}} \quad R_0 \cong \frac{\hbar^{3/2} c^{7/2}}{32\pi^2 k_B^2 T_0^2 G^{1/2}} \quad (3)$$

$$H \cong \frac{32\pi^2 k_B^2 T^2 G^{1/2}}{\hbar^{3/2} c^{5/2}} \quad H_0 \cong \frac{32\pi^2 k_B^2 T_0^2 G^{1/2}}{\hbar^{3/2} c^{5/2}} \quad (4)$$

$$t \cong \frac{\hbar^{3/2} c^{5/2}}{32\pi^2 k_B^2 T^2 G^{1/2}} \quad t_0 \cong \frac{\hbar^{3/2} c^{5/2}}{32\pi^2 k_B^2 T_0^2 G^{1/2}} \quad (5)$$

$$M \cong \frac{\hbar^{3/2} c^{11/2}}{64\pi^2 k_B^2 T^2 G^{3/2}} \quad M_0 \cong \frac{\hbar^{3/2} c^{11/2}}{64\pi^2 k_B^2 T_0^2 G^{3/2}} \quad (6)$$

$$Mc^2 \cong \frac{\hbar^{3/2} c^{15/2}}{64\pi^2 k_B^2 T^2 G^{3/2}} \quad M_0 c^2 \cong \frac{\hbar^{3/2} c^{15/2}}{64\pi^2 k_B^2 T_0^2 G^{3/2}} \quad (7)$$

Current parameters are calculated in the right-hand column. The currently observed cosmic temperature value $T_0 = 2.72548$ K. Accordingly, the theoretical current FSC Hubble parameter value at this temperature is.

$$H_0 = 2.167862848658891 \times 10^{-18} \text{ s}^{-1} (66.89325791854758 \text{ km.s}^{-1}.\text{Mpc}^{-1})$$

This derived theoretical global H_0 value fits the 2018 Planck Collaboration observational global H_0 value of $67.36 \pm 0.54 \text{ km.s}^{-1}.\text{Mpc}^{-1}$ (68% confidence interval for TT, TE, EE + lowE + lensing) [11] and the DES 2018 H_0 value of $67.77 \pm 1.30 \text{ km s}^{-1}.\text{Mpc}^{-1}$ (SN + BAO) [12]. Since the Planck observational value was obtained *partially* with the aid of extraordinarily precise observations of the CMB black body radiation spectrum, this may be as close as we can come in the foreseeable future to a truly *global* Hubble parameter measurement. And yet, the above theoretical H_0 calculation is based *solely* upon this one carefully measured free parameter: $T_0 = 2.72548$ K. This is a remarkable result!

Therefore, one should have great confidence that the following cosmological parameters incorporating the FSC-derived H_0 value are also highly accurate:

$$t_0 \cong \frac{1}{H_0} = 4.61283794 \times 10^{17} \text{ s} (14.61694684 \times 10^9 \text{ sidereal years})$$

(multiplying by 1 sidereal year per $3.155814954 \times 10^7 \text{ s}$)

This value is simply the reciprocal of the above-derived Hubble parameter value, as one would expect for the perpetually spatially flat FSC cosmic model in comparison with the standard inflationary model. For reasons not elaborated here, *any* inflationary model would be *expected* to calculate a slightly younger cosmic age. 13.8 billion years is now consensus for the standard inflationary model:

$$R_0 \cong \frac{c}{H_0} = 1.38289402 \times 10^{26} \text{ m} (14.617201 \times 10^9 \text{ light - years})$$

(multiplying by 1 Julian light-year per $9.4607304725808 \times 10^{15} \text{ m}$)

This current cosmic radius value correlates with current cosmic time by $R_0 = ct_0$. Therefore, FSC is a $R_h = ct$ cosmological model. Later discussion in this chapter will focus on the extremely good statistical fit between $R_h = ct$ models and the accumulated Type Ia supernovae light curve data purported to “prove” the existence of cosmic acceleration:

$$Vol_0 = \frac{4\pi}{3} \left(\frac{c}{H_0} \right)^3 = 1.10778456 \times 10^{79} \text{ m}^3$$

$$M_0 = \frac{c^3}{2GH_0} = 9.31126529 \times 10^{52} \text{ kg}$$

This total mass number can be compared very favorably to a rough estimate made from astronomical observations. The visible matter consists of roughly 100 billion galaxies averaging roughly 100 billion stars each, of average star mass equal to roughly $1.4 \times 10^{30} \text{ kg}$ (70% of solar mass), totaling to roughly $1.4 \times 10^{52} \text{ kg}$.

The 2015 Planck Collaboration report indicates a universal matter ratio of approximately 5.5 parts dark matter to 1 part visible (baryonic) matter. This brings the total estimated matter in the observable universe to approximately 9.1×10^{52} kg. A recent study [13] of average mass density of intergalactic dust gives a value of approximately 10^{-30} kg.m⁻³. Since this is approximately 1 part intergalactic dust to 1000 parts galactic and perigalactic matter, intergalactic dust does not appreciably modify the estimated total observational mass of matter given above. Accordingly, this observational estimate is remarkably close to the above FSC theoretical calculation of total cosmic mass attributed to positive energy (i.e., gravitationally attractive) matter.

According to the FSC Friedmann equations (referenced below), the positive matter mass-energy is equal in absolute magnitude, and opposite in sign, to the negative (dark) energy at all times. This is a 50/50 percentage ratio as opposed to the approximately 30/70 ratio implied by yet unproven, and supposedly dark energy-dominating, cosmic *acceleration*. However, without definitively proving cosmic acceleration, standard inflationary cosmology cannot claim this 30/70 ratio! (Please see the discussion and relevant references in the last two paragraphs of this section):

$$M_0 c^2 = \frac{c^5}{2GH_0} = 8.3685479 \times 10^{69} \text{ J}$$

$$\rho_0 = \frac{3H_0^2}{8\pi G} = 8.40530333 \times 10^{-27} \text{ kg.m}^{-3} \text{ (critical mass density)}$$

This closely approximates the observational cosmic mass density calculation of critical density:

$$\rho_0 c^2 = \frac{3H_0^2 c^2}{8\pi G} = 7.554309896 \times 10^{-10} \text{ J.m}^{-3} \text{ (critical mass – energy density)}$$

This closely approximates the observational cosmic mass-energy density and the observational vacuum energy density. They are equal in absolute magnitude, and opposite in sign, in FSC.

A recent paper [14] has integrated the FSC model into the Friedmann equations containing a Lambda Λ cosmological term. Thus, FSC has been shown to be a scalar dynamic Λ dark energy model of the w CDM type (wherein equation of state term w is always equal to -1.0). Furthermore, it is well-known that a sufficiently realistic $R_h = ct$ model, such as FSC, can fit within the tightest constraints of the Supernova Cosmology Project (SCP) data. The following open-source graph (**Figure 3**) from the SCP is offered as proof [15].

One can readily see (by the “flat” line intersection) that a realistic spatially flat universe model such as FSC is an excellent fit with all such SCP observations to date.

Currently, there is no certainty about the percentage of the critical density which is attributable to dark matter. Those with knowledge of the observational studies of the ratio of dark matter to visible matter realize the difficulty of determining a precise *co-moving* value for this ratio at the present time. Galactic and perigalactic distributions of dark matter can be surprisingly variable, as evidenced by the 29 March 2018 report in *Nature* [16] of a galaxy apparently completely lacking in dark matter! Although the 2015 Planck Collaboration consensus is a large-scale approximate ratio of 5.5 parts dark matter to 1 part visible matter, this can only be considered as a rough estimate of the actual *co-moving* ratio, particularly if this ratio varies significantly over cosmic time. A 9.2-to-1 actual ratio in approximately co-moving galaxies (i.e., those within about 100 million light-years of the Milky

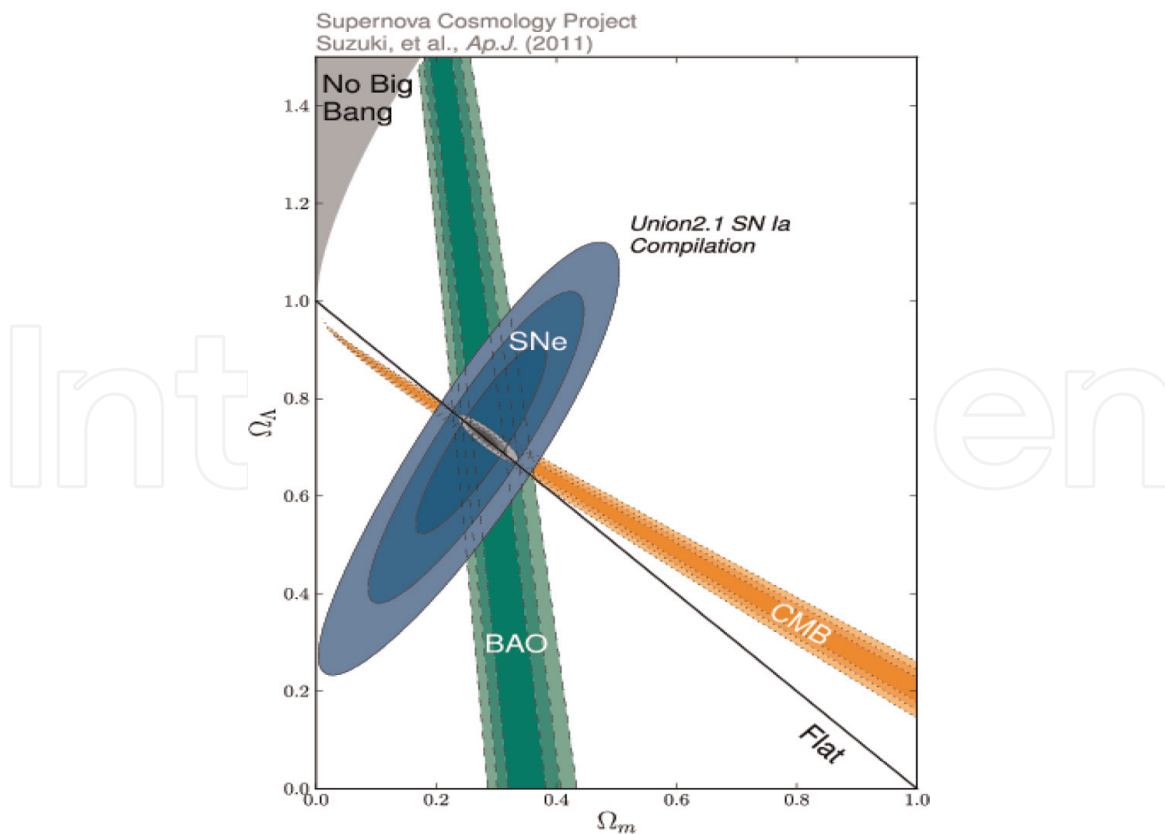


Figure 3.
 SCP supernovae, BAO, and CMB data.

Way galaxy) remains a possibility and would change the ratio of total matter mass-energy to dark energy to essentially unity (i.e., 50% matter mass-energy and 50% dark energy). Thus, the intersection zone of tightest constraints shown in **Figure 3** should then correlate with 0.5 Ω_m and 0.5 Ω_Λ . This is one of several important testable predictions discriminating the FSC model from the standard inflationary cosmology model. Precise measurements of approximately co-moving galaxies are in order, for comparison with the CMB observational Planck Collaboration result.

The question of dark energy density dominance over total matter energy density remains in doubt, at the present time, in the scientific literature. Several recent papers [17–21] have clearly shown that cosmic acceleration, as opposed to the cosmic coasting of $R_h = ct$ models, is not yet *proven*. These are not, of course, refutations of the existence of dark energy as it may be defined by general relativity. Rather, they are statistical analyses placing some doubt on dark energy *dominance* and thus cosmic *acceleration*. These papers are well worth reading.

4. Superiority of FSC compared to inflationary cosmology

As detailed in the recent FSC summary paper [10], there are at least 11 categories in which FSC appears to be superior to standard inflationary cosmology. What makes FSC so powerful in this regard is its ability to make very specific predictions for observations which can be used to falsify the theory if FSC is incorrect. To date, FSC as a global parameter observational predictor has not been falsified.

Standard inflationary cosmology, on the other hand, has largely been cobbled together from observations and would be difficult to falsify because it makes few, if any, falsifiable predictions. The reader should remember that the various theories of cosmic inflation contained ad hoc adjustments to accommodate

observations [22, 23] and that the presumed “inflaton” energy field of inflation was invented before the actual cosmological vacuum energy now called dark energy was discovered approximately two decades later. It is notable that, rather than attempt to apply the newly discovered dark energy as a scalar quantity also at work in the early universe, standard inflationary cosmologists have generally assumed the dark energy field to be something entirely distinct from their theoretical inflaton energy field. There has also been an assumption that the post-inflationary energy density of the vacuum must have been a *constant* over the great span of cosmological time. And yet, the theoretical discrepancies created by this “cosmological constant problem” [24, 25] are considered by many to be the most embarrassing problem in all of physics. A discussion of this problem is included later.

What follows are several selected categories of particular importance from the FSC summary paper. The reader is encouraged to read this paper for the full discussion as to how FSC appears to be superior to standard inflationary cosmology, particularly in terms of falsifiability.

4.1 Cosmic dawn and the formation of the first quasars and galaxies

As noted in several recent papers [26, 27], standard inflationary cosmology cannot easily explain the surprisingly early formation of the first quasars and galaxies. As detailed in a recent FSC paper [28], temperature curve differences between the two models are such that cosmic dawn, at z redshifts of about 15–20, occurred in the FSC model much earlier than in standard inflationary cosmology. A comparison of the two temperature curves is shown below in **Figure 4**, with features of the standard inflationary model as illustrated in Bowman’s recent paper [29].

The blue line is the radiation temperature (T_R) curve expected in standard inflationary cosmology, and the green line is the radiation temperature curve expected in FSC. The dashed red line represents the spin temperature (T_S), and the solid red line represents the baryonic gas temperature (T_G).

One should note how these cosmic times differ with respect to a given model’s radiation temperature. Judging from these temperature curve differences, cosmic dawn in FSC would have been at about 20–50 million years after the Planck epoch as opposed to the standard inflationary cosmology cosmic dawn at about

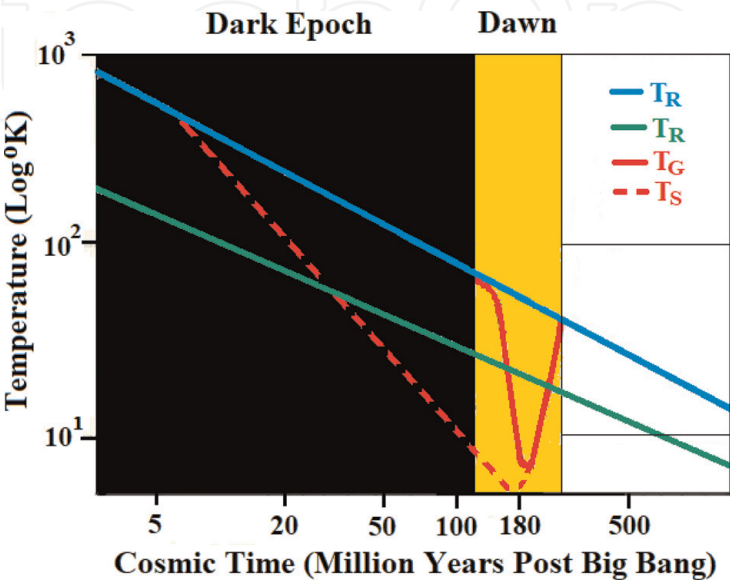


Figure 4.
Cosmic temperature vs. time in standard cosmology (blue) and FSC (green).

110–250 million years. Thus, FSC, by the relative flatness of its temperature curve, allows for considerably more time between the formation of the first stars and the formation of the first quasars and galaxies.

4.2 Predictions pertaining to primordial gravity waves

FSC is a steadily expanding cosmology model, which would not be expected to produce inflationary B-mode primordial gravity waves. There is nothing “explosive” about the FSC early universe in comparison with the standard inflationary early universe. Thus, FSC predicts that inflationary B-mode primordial gravity waves will never be detected. Such unequivocal detection of inflationary waves would falsify FSC. The continued failure to detect such waves, if the sensitivity of detection methods can be made sufficiently high, should be considered to strongly favor FSC over standard inflationary cosmology.

4.3 Predicting the magnitude of CMB temperature anisotropy

The angular power spectrum of the CMB clearly fits with a spatially flat universe. As noted following the BOOMERanG Collaboration report [30] of CMB anisotropy observations, their results are “closely fitting the theoretical predictions for a spatially flat cosmological model with an exactly scale invariant primordial power spectrum for the adiabatic growing mode” [31]. Furthermore, the COBE DMR experiment [32] measured a CMB RMS temperature variation of 18 micro-Kelvins. This translates to a dT/T anisotropy value of $(0.000018)/2.725$ equal to 0.66×10^{-5} . This measurement fits within the range of FSC temperature anisotropy predictions for the beginning and ending of the recombination/decoupling epoch [33]. This result clearly favors FSC.

4.4 Predicting the Hubble parameter value

In standard inflationary cosmology, the Hubble parameter value can only be determined by observation. That is to say that there is no theoretical ability within standard cosmology to derive a Hubble parameter value. The FSC model, on the other hand, *predicts* the current global H_0 value to be 66.89 kilometers per second per megaparsec. This fits the 2018 Planck Collaboration [11] and 2018 DES [12] Hubble parameter values. Therefore, this category strongly favors FSC in comparison with standard inflationary cosmology.

4.5 Quantifiable entropy and the entropic arrow of time

One of the problems within the standard inflationary model is in quantifying cosmic entropy. Entropy is typically defined in terms of the total number of possible microstates and the probability of a given set of conditions with respect to that number of microstates. These values are impossible to quantify in an infinite-sized inflationary universe or multiverse. FSC, on the other hand, is a *finite* model with a spherical horizon surface area. And, since the Bekenstein-Hawking definition of black hole entropy applies to the FSC model, values for cosmic entropy can be calculated for any time, temperature, or radius of the FSC model. Thus, the “entropic arrow of time” is clearly defined and quantified in the FSC model. The quantifiable entropy of the FSC model allows for model correlations with cosmic entropy theories, such as those of Roger Penrose [34] and Erik Verlinde. Thus, the entropy rules of FSC potentially allow for falsifiability. This feature favors the FSC model, particularly with respect to Verlinde’s “emergent gravity” theory (see below).

4.6 Clues to the nature of gravity, dark energy, and dark matter

The reader is referred to the recent FSC paper [35] with this title for an in-depth discussion of how cosmic entropy in the FSC model may provide tantalizing clues with respect to the fundamental nature of gravity. In short, the FSC model appears to be the cosmological model correlate to Verlinde’s “emergent gravity” theory [36, 37]. Verlinde’s landmark paper from 2011 provides strong theoretical support for gravity being an *emergent property* of cosmic entropy. The corresponding FSC paper makes a case for the correctness of Verlinde’s theory. As discussed in the FSC paper, if gravity is an emergent property of cosmic entropy, then one might entertain the possibility that dark energy and dark matter could also be emergent properties of cosmic entropy. For instance, perhaps galactic and perigalactic features attributed to dark matter (such as platelike galactic rotation and gravitational lensing) could be an unexpected large-scale effect of the entropy of the known galactic baryonic matter. If this turns out to be the correct interpretation, then gravity, dark energy, and dark matter might be as difficult to define at the quantum level as “quantum consciousness” within two connected neurons.

The recent observations of Brouwer et al. [38] appear to be in support of Verlinde’s “emergent gravity” theory as it pertains to dark matter. The discovery of quantum gravity, other than quantum gravity somehow connected to entropy at the quantum level, would falsify Verlinde’s “emergent gravity” theory. At present, standard inflationary cosmology, by virtue of its inability to precisely define cosmic entropy, has no capacity to incorporate Verlinde’s theory. This appears to favor FSC, particularly in light of the above-mentioned recent observational findings.

4.7 The cosmological constant problem

The “cosmological constant problem” is a long-standing problem in theoretical physics. It underscores standard cosmology’s inability to unify general relativity with quantum field theory (QFT). Excellent expositions on this subject have been provided by Weinberg [24] and Carroll [25]. QFT theorists calculate a cosmological constant value which differs from observational measurements of the vacuum energy density by a magnitude of approximately 10^{121} ! Suffice it to say, this discrepancy is so large that it is often referred to as the most embarrassing problem in all of theoretical physics.

In standard inflationary cosmology, it has been assumed that the post-inflationary energy density of the cosmic vacuum must be constant, rather than scalar, over the remainder of cosmic time. However, general relativity does indeed allow for the vacuum energy density to be a dynamic scalar over time, so long as $\Lambda = 3H_t^2/c^2$. Cosmological models incorporating scaling vacuum energy density are called “quintessence” models. FSC is one such model. In FSC, the vacuum energy density scales downward by 121.26 logs of 10 over the cosmic time interval since the Planck epoch. Perhaps of even greater interest is that the Bekenstein-Hawking cosmic entropy value scales upward in direct proportion to the expanding surface area of the cosmic horizon. If one were to count the current number of Planck radius microstates within the FSC horizon, the model indicates this entropy number to be $10^{121.26}$. Thus, by its implication of a possible relationship between vacuum energy (i.e., dark energy) and total cosmic entropy (as discussed in Section 4.6), FSC also offers a possible explanation for the magnitude difference between the Planck epoch vacuum energy density calculated by QFT theorists and today’s observed vacuum energy density of approximately 10^{-9} J.m^{-3} . Since the FSC model stipulates these values and standard inflationary cosmology has no basis for deriving them, the FSC model appears to be superior with respect to potentially resolving the cosmological constant problem.

4.8 Dark matter and dark energy quantitation

As reported by the Planck Collaboration, the ratio of dark matter to visible (baryonic) matter is observed to be approximately 5.5 parts dark matter to 1 part visible matter. However, there are already significant differences observed between the dark matter-to-visible matter ratios in the galaxies quite near to us (essentially co-movers) and the above dark matter-to-visible matter ratio determined from Planck CMB observations. *Perhaps this ratio is scalar over the great span of cosmic time. If the co-mover ratio is ultimately found to be approximately 9.2, as predicted by FSC, one can then conclude that total matter energy density at present is equal in absolute magnitude to dark energy density.* This equality of opposite sign energy densities is what one would expect for a spatially flat universe. Otherwise, if one energy density dominated the other, there should be detectable global spatial curvature corresponding to the dominating energy density. One could, in fact, make a strong case that the spatial flatness of the CMB proves the equality of total matter and dark energy densities at the time of the recombination/decoupling epoch. This should nullify any Planck Collaboration conclusions (such as dark energy dominance) which are obviously contrary to their own observations of spatial flatness.

Despite the fact that FSC and standard inflationary cosmology differ somewhat with respect to the percentages of total matter vs. dark energy predicted for the co-moving universe, there is one thing about this energy density partition on which everyone agrees: it is truly remarkable that total matter energy density and dark energy density are *of the same order of magnitude at the present time*. As physicist I. I. Rabi once famously remarked, “Who ordered that?!” This is often referred to as the cosmological “coincidence problem.” Standard cosmology simply accepts this coincidence problem with no further explanation or rationale. However, FSC *stipulates* perpetual equality of absolute magnitude of these two energy densities as a requirement for a perpetually spatially flat universe. One can consider this expectation of energy density equality to be a falsifiable FSC prediction with respect to future measurements of total matter energy density in comparison with dark energy density. *An in-depth statistical analysis of approximate co-movers with the Milky Way should give us a better idea of the dark matter-to-visible matter ratio in the current epoch.*

With respect to standard cosmology’s current belief in cosmic acceleration due to dark energy, the reader is referred to the references [17] thru [21] mentioned earlier. Cosmic acceleration is clearly not proven at the present time, despite the indisputable presence of dark energy as definable within general relativity. There are relative differences in luminosity distance and angular diameter distance formulae in standard inflationary cosmology and $R_h = ct$ modified Milne-type models (like FSC). Two comparative graphs from FSC reference [39] are shown in **Figures 5 and 6**.

The significance of the relative luminosity distance and relative angular diameter distance comparisons between these two competing models is paramount. An observer of distant Type Ia supernovae expects particular luminosity distances and angular diameter distances to correspond with particular redshifts. If, instead, he or she observes greater-than-expected luminosity distances (i.e., unexpected “dimming” of the supernovae) or greater-than-expected angular diameter distances, this can easily be misinterpreted by a standard inflationary model proponent as indicative of cosmic acceleration. However, *entirely predictable supernova luminosity distances within a realistic Milne-type universe containing matter, as opposed to a standard model universe, could be one possible explanation for the Type Ia supernovae observations since 1998. Obviously, cosmic acceleration would not then be required to explain these observations.* This possibility, combined with the standard model tension problem presented above (i.e., spatial flatness and dark energy dominance cannot *both* be

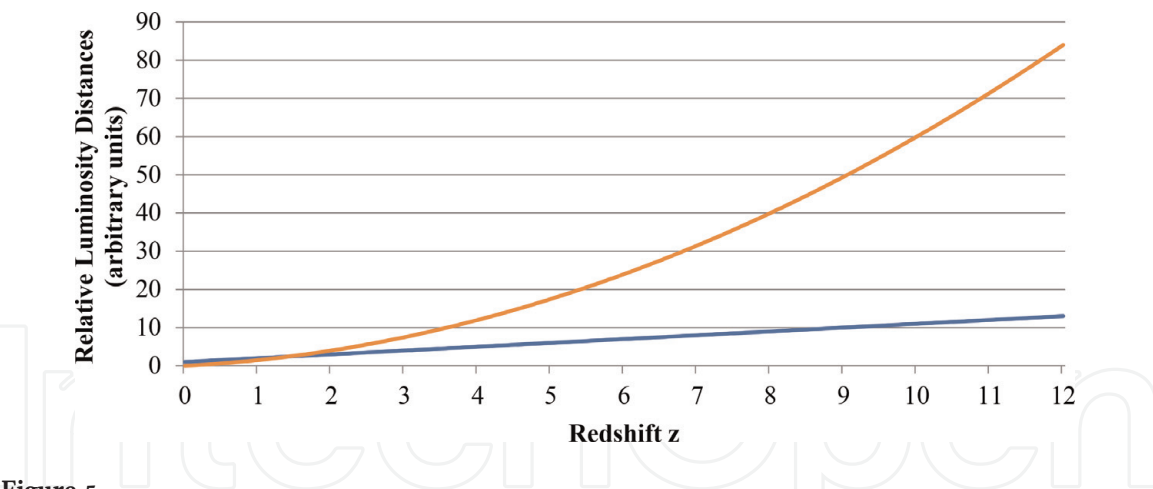


Figure 5.
Relative luminosity distances vs. redshift z for standard (blue) and Milne (red).

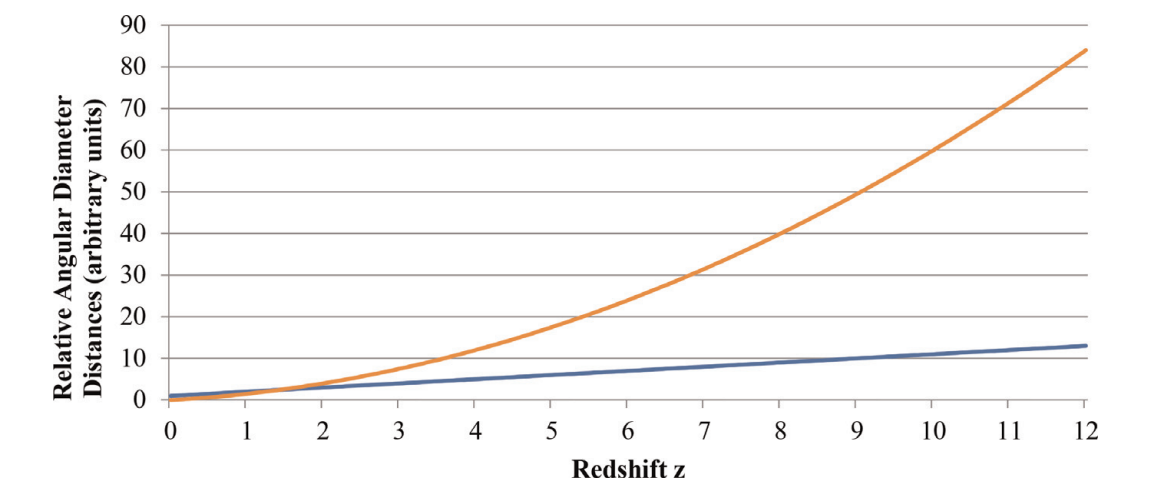


Figure 6.
Relative angular diameter distances vs. z for standard (blue) and Milne (red).

true at the same time), and the FSC *stipulation* of what standard model proponents refer to as the “coincidence problem,” strongly favors FSC with respect to its predictions concerning dark matter and dark energy quantitation.

4.9 Requirements for new physics

Cosmic inflation theory was invented before the spatial-flattening effects (on positively curved space-time) of cosmic vacuum energy (dark energy) were discovered in 1998 [40–42]. Guth [43] and others [44, 45] believed at the time of its invention that a special energy field with inflating features (called by Guth the “inflaton”) was required within the initial 10^{-32} s of universal expansion. It was believed that this energy field was necessary in order to flatten out a presumed highly curved space-time during and immediately following the inception of expansion. Thus, inflation appeared to be a clever solution to the cosmological “flatness problem,” as well as the cosmological “horizon problem.” The latter problem was presumed at the time to exist because most cosmologists believed, without any real evidence, that the universe is infinite and thus otherwise difficult to explain in terms of its remarkable homogeneity in all observational directions.

For reasons mentioned near the end of the “Introduction and Background” section, FSC solves these cosmological problems without requiring an inflationary epoch. In contrast to inflationary models, in which the total cosmic matter

generation is exclusively limited to within a tiny fraction of a second of the Big Bang, the FSC model is a perpetual matter-generating model with some similarities to the model presented in the 2019 publication entitled “A Perpetual Mass-Generating Planckian Universe” by Sapar [46]. This concept of perpetual matter generation has a long tradition going back at least to Hoyle, although Hoyle’s particular matter-generating theory was falsified by the discovery of the cosmic microwave background in the 1960s. Here it is important to recognize that the mystery of matter generation is inherent in *all* cosmology models. FSC simply models perpetual matter generation, while inflationary models imply, without any real evidence, that all universal matter was nearly instantaneously created.

This author speculates that the negative energy (i.e., gravitationally repelling) vacuum may be continually diluted of its original highly concentrated Planckian energy during cosmic expansion and that gravitationally attracting positive energy in the form of matter is continually created as an offset. This would be in keeping with the spatial curvature rules of general relativity. One should remember that, according to general relativity, a flat space-time is flat precisely because it contains net zero total energy. Furthermore, a globally and perpetually spatially flat universe which begins from a net zero total energy state (Guth’s “free lunch” idea) would presumably maintain net zero total energy throughout its expansion. Otherwise, a fully self-contained universe, such as a FSC universe, would violate conservation of energy.

Despite the ongoing mystery of matter generation in all cosmology models, for the arguments made above, and for the perpetual matter generation rationale offered in Dr. Sapar’s paper, this category appears to favor FSC in comparison with standard inflationary cosmology.

5. Summary and conclusions

This chapter has introduced the reader to the heuristic FSC cosmology model. Like all useful heuristics, FSC provides a means for accurately calculating a variety of parameters. The founding principle for the construction of this model is Hawking’s singularity theorem. Accordingly, all assumptions of this model are intrinsically linked to Hawking’s theorem and its implications with respect to widely accepted time-symmetric properties of general relativity. Black holes and black hole-like objects are now known to exist. Furthermore, we know that such objects range over a remarkably wide, fractal-like scale. Our universe may simply be the largest of these objects which can be observed, albeit from the inside!

Beginning with Penrose and Hawking, the black hole-like properties of the universe have continued to fascinate and surprise us. Our current golden age of astrophysical observations and new theories certainly promises even more surprises ahead.

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