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Applying the Stefan-Boltzmann Law to a Cosmological Model (a Brief Note)

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Abstract

This brief note brings the reader up-to-date with the recent successes of the new Haug-Tatum cosmology model. In particular, the significance of recent proof that the Stefan-Boltzmann law applies to such a model is emphasized and a rationale for this is given. Remarkably, the proposed solutions of this model have incorporated all 580 supernova redshifts in the Union2 database. Therefore, one can usefully apply this thermodynamic law in the form of a continually expanding black-body universe model. To our knowledge, no other cosmological model has achieved such high-precision observational correlation.

Keywords

Haug-Tatum Cosmology, Stefan-Boltzmann Law, Flat Space Cosmology, CMB, Cosmic Thermodynamics, $R_h = ct$ Cosmology Model, Black Body

1. Introduction and Background

Haug and Wojnow [1] have recently proven that the following equation can be derived using the Stefan-Boltzmann law:

$$T_t \cong \frac{\hbar c^3}{8\pi G k_B \sqrt{M_t M_{pl}}} \cong \frac{\hbar c}{4\pi k_B \sqrt{R_t R_{pl}}} \tag{1}$$

wherein T_t is cosmic temperature at any time t, M_t is cosmic mass at any time t, R_t is cosmic radius at any time t, M_{pl} is the Planck mass, and R_{pl} is the "Planck radius" equal to two Planck lengths, which happens to be the Schwarzschild radius for a Planck mass black hole. All other symbols are the well-known physical constants. In doing so, Haug and Wojnow noted that Tatum *et al.* [2] had previously published this formula in 2015 as their key cosmic thermodynamic formula for Flat Space Cosmology (FSC). And, because the FSC model is a unique "growing black hole" variant of $R_h = ct$ cosmology, the Schwarzschild formula relationship between cosmic mass M_t and cosmic radius R_t naturally applies at any cosmic time t.

Here, it is notable that, by having the Planck mass and Planck length in the above cosmological equation, a model of Planck scale quantum cosmology can be explored. Thus, as Haug and Tatum have recently shown, such a model can be potentially useful in solving seemingly intractable cosmological problems [3]-[5].

Aside from offering a plausible solution to the Hubble tension problem, it is also notable that the Haug-Tatum cosmological model approach, by virtue of predicting a cosmic age of approximately 14.6 billion years [6], offers a possible solution to the early galaxy formation problem revealed by recent James Webb Space Telescope (JWST) observations. Remarkably, the above-proposed solutions have incorporated all 580 supernova redshifts in the Union2 database. This accurate and precise observational correlation, in conjunction with obedience to the Stefan-Boltzmann law, is what makes such a model both unique and powerful with respect to other models at the present time.

To better understand the usefulness of the Haug-Tatum model, the reader will benefit greatly from reading reference [3], wherein the authors derived the correct distance-vs-redshift formula for a $R_h = ct$ cosmology model that follows the assumptions of FSC. They discovered that the current standard cosmology model (ΛCDM) distance-vs-redshift formula underestimates the distances to high redshift galaxies *relative* to such estimates within the FSC $R_h = ct$ cosmology model. To put this succinctly, both models (ΛCDM and FSC, now Haug-Tatum) give essentially the same distance for low redshifts, but at larger and larger redshifts, their distance estimates significantly and continually diverge. As detailed in this Haug-Tatum reference, this finding appears to be the crux of their model success with respect to the Union2 supernova database redshifts and potentially solving the Hubble tension. The reader will also greatly benefit from reading reference [5] about the importance of Equation (1), and the new Tatum-Haug-Wojnow publication [7] concerning one of its most important implications with respect to the surprisingly simple mathematical relationship between the Hubble parameter and the Cosmic Microwave Background (CMB) temperature within this variant of $R_h = ct$ cosmology.

2. Discussion

Readers unfamiliar with a growing black hole variant of $R_h = ct$ cosmology model may find the above background to be implausible. However, it should be noted that theoretical treatment of the observable universe as a growing black hole-like object has a long and respectable scientific tradition dating back to at least 1972 with Pathria's publication in the journal *Nature* [8]. Furthermore, the possible significance of recently discovered mathematical relationships between our universe and black holes and black hole-like objects is gaining scientific interest among reputable physicists and cosmologists [9]-[11]. For readers with a scientific interest and an open mind, one should perhaps begin with physicist Ethan Siegel's article entitled "Are We Living in a Baby Universe that Looks Like a Black Hole to Outsiders?" [12].

A reader might also object to the application of the Stefan-Boltzmann law to the thermodynamics of our expanding universe. Those unfamiliar with the nature of the CMB radiation spectrum will object by saying something along the lines of the Stefan-Boltzmann law applying only to a perfect or near-perfect black body. However, such an objection ignores the recent observational proof that the CMB spectrum is that of a near-perfect black body [13]-[16]. As Martin White so nicely described it, in a 1999 lecture at University of Illinois:

"…the *black body* spectrum of the CMB, the most perfect black body ever measured in nature, confirms the cosmological origin of the CMB…".

We further explain the relevance of this finding, with respect to the current paper, as follows: It is currently believed that the expansion evolution of the universal radiation spectrum (correlating to the time-dependent temperature T_t) can be modeled as black body radiation following characteristic apparent temperature changes in both magnitude and curve shape. In a growing (*i.e.* expanding) black hole model of a hollow black body, the radiant power density per unit wavelength per unit area follows Planck's law. Hawking had previously calculated the *external* radiation temperature of such a black hole [17]. In a similar manner, the 2015 FSC model calculates the *internal* radiation temperature of a black hole-like black-body universe according to Equation (1). It is notable that both equations (*i.e.* those of Hawking and FSC) differ *only* by the magnitude of the time-dependent mass terms in the denominator. The only exception to this is that the temperature of the Planck mass black hole FSC universe becomes identical to the temperature of a Hawking Planck mass black hole. The FSC rationale for this difference is that its scaling cosmic temperature T_t is more realistic for modeling the *interior* of a growing black hole-like universe. Thus, it is reassuring but not surprising that Haug and Wojnow were able to derive Equation (1) using the Stefan-Boltzmann law. Furthermore, there is a theoretical black hole complementarity rationale for believing that the internal radiation temperature of a black hole might, in fact, be substantially different from its external radiation temperature [18]-[20].

As mentioned above, the Stefan-Boltzmann law is most accurately applied to a perfect or a near-perfect black body. Strictly speaking, while it is possible in theory to create a near-perfect black body, creation of a *perfect* black body in the laboratory is believed to be impossible, in much the same way that reducing matter to absolute zero in the laboratory is believed to be impossible. The observational proof provided by the Cosmic Background Explorer (COBE), that the early universe of the Recombination Epoch was a near-perfect black body (to within about one part per one hundred thousand), was enormously consequential for cosmology becoming a serious scientific undertaking. See again [13].

For the purposes of this paper, it is important to realize that the CMB spectrum measured by COBE is *today's measurement* of the global thermal radiation spectrum of the observable universe. Effectively, this spectrum is an *evolved* snapshot of the 3000K universe some thousands of years after its Big Bang origin. We know this because the 2009 Fixsen temperature of today's observed spectrum corresponds to a black body temperature of 2.72548K (not 3000K). This result fits nicely with current theory that a black body undergoing adiabatic expansion (or contraction) will undergo a predictable evolution of its radiation temperature, frequency spectrum and curve shape *in accordance with the Stefan-Boltzmann law.* So, today's measurement of the thermal radiation spectrum of deep space (*i.e.* beyond the hot gas clouds and dust of our galaxy) is that of a near-perfect black body. This is a key point in understanding the accuracy and precision of Tatum *et al.*'s (2015) FSC model and the new Haug-Tatum Cosmology model. We believe that the observable universe is best modeled as a hollow, near-perfect black body undergoing continual adiabatic expansion. Whether one wishes to accept that our expanding universe has a thermal radiation spectrum very much like that of a black hole, nature's most near-perfect black body, depends upon how much one understands the significance that Equation (1) is derivable using the Stefan-Boltzmann law. See again [1].

In terms of prior art, we find relatively few papers in the scientific literature that take an interest in applying the Stefan-Boltzmann law to the universe before or after the Recombination Epoch at approximately 3000K. This is somewhat surprising, considering the growing interest in modeling the universe as an expanding black hole-like object (see again [11] and [12]). A rare exception is the 2018 publication by Gim and Kim [21], which uses an "effective Stefan-Boltzmann law" of their own derivation to provide a possible scenario to explain the thermodynamic origin of warm inflation scenarios and GUT baryogenesis at the end of inflation.

The exact meaning of the above recent progress in Planck scale quantum cosmology is the subject of vigorous scientific debate, as it should be. Nevertheless, the mathematical power of the new Haug-Tatum cosmology model (see again references [3] [4] and [6]) appears to be on solid foundation. No other model to date offers compelling solutions to the Hubble tension problem and the early galaxy formation problem by linking 580 Union2 database supernova redshifts with a single cosmic T_0 value (2.7276 ± 0.0723K), a single cosmic H_0 value (66.8943 ± 0.0287 km/s/Mpc), and a single cosmic age (14.622028851 billion years ± 421,876 years). Such precisions are a direct result of the newly discovered mathematical relationship between the value of the time-dependent Hubble parameter and the value of the time-dependent CMB temperature [7].

Finally, although it would be correct to say that the Haug-Tatum model is limited by the *global* nature of its many cosmic parameter predictions, one can also say that this is the strength of such a model. And, though it may be the dream of all cosmologists, there is no model of cosmology to date which is supremely accurate on all scales of cosmic space and time. To put it most simply, all scientific models have their limitations.

3. Summary

This brief note has brought the reader up-to-date with the recent successes of the new Haug-Tatum cosmology model. In particular, the significance of recent proof that the Stefan-Boltzmann law applies to such a model has been emphasized and a rationale for this has been given. Remarkably, the proposed solutions of this model have incorporated all 580 supernova redshifts in the Union2 database. Therefore, one can usefully apply this thermodynamic law in the form of a continually expanding black-body universe model. To our knowledge, no other cosmological model has achieved such high-precision observational correlation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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