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COUNTING BACK TO ZERO: A REVIEW OF COSMOLOGICAL MODELS THAT BEGIN UNDER CONDITIONS OF ZERO OR NEAR ZERO ENTROPY.

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ABSTRACT

In recent years there have been significant developments in cosmological models that assume zero or near zero entropy conditions for the origin of the universe. Modern versions of these models are providing quantifiable interpretations for a wide range of astronomical phenomena. These interpretations are mutually consistent but are in strong variance with interpretations based on ‘Hot Big Bang’ cosmologies. On the other hand, low entropy cosmogony models have a theoretical framework that has strong resonance with creationary requirements for cosmogony.

INTRODUCTION

Discoveries made in the first half of the twentieth century produced a remarkable opportunity to uncover details of cosmological processes that were thought to have occurred during the very first moments of the birth of the universe. This opportunity came upon the realization that the terrestrial and cosmic abundances of the elements were not random but could be directly linked to the conditions and to the nucleosynthesis processes that were expected to occur in those first moments.

Two very different classes of models were proposed that would permit primordial cosmological nucleosynthesis. One model required a pre-nucleosynthesis cosmic medium of high density and low temperature while the other required a cosmic medium of high density and high temperature –the models that have become known by the rather unfortunate names of ‘Hot Big Bang’ and ‘Cool Big Bang’ The differences in the initial temperature would eventually result in two important, far ranging but completely disparate cosmological models with very different interpretations for every major astronomical and cosmological phenomenon.

Neither model appeared at first to be able to reproduce the entire observed sequence of element abundances within the very brief window of time where early primordial nucleosynthesis was thought to be possible. In something of a compromise solution based on the HBB model the

lighter elements were assumed to form under conditions of high temperature in the first few minutes of cosmological nucleosynthesis whereas most of the 'metals' or the heavier elements and their isotopes were deemed to have been formed within the interior of stars.

However, there have always been theorists who were not at all happy with the high temperature HBB solution. There have been deep and continuing concerns about what have been perceived as major and even fatal failings in the astronomical and cosmological outworking of the model. On the other hand, the model of a universe that has its origin under conditions of low temperature has advocates who regard this alternative as being markedly superior. The 'arrow of time' has been linked at a deep level to increasing entropy and there is a gratifying simplicity and elegance about models where the beginning of time itself is linked to initial conditions of low or zero entropy.

In 1927 the very early models of low entropy such as that of Georges Lemaître, included some quite remarkable insights. Lemaître's model begins with the assumption that at time zero, entropy is zero, the cosmic temperature is absolute zero, and matter is built up from neutrons which have atomic number zero. (The National Nuclear Data Center's Nuclear Wallet Cards (2005) lists as its first isotope an element with mass number $A = 1$, symbol 'n' and atomic number $Z = 0$). From that beginning Lemaître shows that the universe will expand in three distinct phases (Lemaître, 1927). The first phase would be a phase of extremely rapid expansion and would include the fragmentation of the unstable primordial medium. It would be followed by a second slowdown phase and then a third phase of accelerating cosmological expansion, which he assumed would represent the present epoch. His first prediction was verified with the work of Hubble but it was not until 1998 that his prediction of accelerating cosmological expansion was proven correct. Another rarely recognized fact is that 30 years before the Cosmic Microwave Background (CMB) was discovered, Lemaître's model of low entropy cosmogony predicted the existence of two all-pervading observational remnants of the early universe. One being a background radiation at the temperature of liquid hydrogen. The other being a background radiation of ultra-high energy ions which Lemaître, and others, have regarded as being a potential source of the cosmic ray background. Lemaître makes the following comment with regard to the existence of background equilibrium radiations:

If all the atoms of the stars were equally distributed through space there would be about one atom per cubic yard, or the total energy would be that of an equilibrium radiation at the temperature of liquid hydrogen. (Lemaître, 1934 p.12)

In 1948 Edward Teller and Nobel Laureate, Maria Mayer, joined the search for developing a detailed and comprehensive model for nucleosynthesis processes in a creation era. They also considered an initially cold universe model. They looked at thermonuclear equilibrium reactions that would occur in a cold, dense fluid or plasma of nuclear matter, and with a large excess of neutrons. Using their initially cold universe model, they obtained quantitative predictions for the universal values of isotopic abundances for atomic numbers from 62 to 78.

In 1952 Sir Rudolf Peierls in his paper 'The Polynutron Theory of the Origin of the Elements' expanded the Mayer-Teller polynutron theory to include cosmological expansion. He shows how an initially cold universe would develop and expand from an initial singularity and would follow a density-time relationship of $6 \rho \pi G t^2 = 1$. He also shows how, when the Universe expands from a cold supra-nuclear density state through normal nuclear density it enters into a state of tension and will break spontaneously into large fragments. He estimates that, assuming the zero of the time scale coincides with the time of the starting of the expansion, it would take approximately 10^3 seconds before the break-up of the polynutron. He shows how at this time the average density of matter would be roughly equal to that of water. (Peierls 1952, p. 48).

Over the years there has been steady progress in the theoretical underpinning and sophistication of models of low entropy cosmogony. A completely new approach to matter formation, stellar formation and cosmological clustering, has now been proposed. It has been shown that cosmological nucleosynthesis, under condition of low entropy, is indeed able to produce the entire range of elements. These modern versions are built on reasonable and simple assumptions, and have implications for every branch of modern observational astronomy.

Throughout this paper entropy will be quantified in a cosmological context as the photon/baryon ratio η_γ . In the various 'Cool Big Bang' models the initial value of η_γ will often take values of either zero or a value less than 10. Such values contrast with the HBB model which has an entropy value at the onset of cosmological nucleosynthesis of around 10^8 .

A REVIEW OF COSMOLOGICAL NUCLEOSYNTHESIS IN LOW ENTROPY COSMOGONY

A model of cosmological nucleosynthesis which shows how the full range of elements can be formed in a matter of minutes

In low entropy cosmogony models, the initial cosmic environment is typically assumed to include a mix of the basic baryonic building blocks of neutrons and protons together with various proportions of leptons comprising electrons, neutrinos and photons. At temperatures near absolute zero, matter will not be in its familiar form but instead will be in a form that has been described as a sixth state of matter- a superfluid fermionic condensate whose unique characteristics are now being studied in laboratory settings.

In Aguirre's model of low entropy cosmological nucleosynthesis he defines two key parameters that are expected to have a large impact on the element abundance proportions that will be yielded. The first parameter is η_L , the initial ratio of leptons to baryons. The second, which Aguirre defines as the entropy parameter, is η_γ the ratio of photons to baryons. Aguirre says that the values chosen for η_γ and η_L can be simply assumed as the initial state for a standard Friedmann-Robertson-Walker (FRW) cosmology, or they could result from efficient baryogenesis after an early inflationary epoch. (Aguirre, 2001 p. 083512)

By varying η_γ and η_L Aguirre shows that almost any desired yield of primordial helium and metals can be obtained. For example, if $\eta_\gamma = 1$ and $\eta_L = 2.5$ cosmological nucleosynthesis would produce abundance ratios of about 15% helium by mass and solar metallicity (Aguirre, 1999, p.24). His conclusion is:

... the cosmic medium in a CBB cosmology can start out with the same level of enrichment as gas in the HBB models which has been processed by stars (Aguirre, 2001, p. 083512).

Any variation in the density and/or composition of different regions of the initial cosmic environment would result in different abundance ratios being produced in those regions. The origin of any such initial differences in density could be assumed 'ab initio' or the result of physical processes such as neutron drift. The reality appears to be that in a universe that has its origin under conditions of low or zero entropy, the application of modern nucleosynthesis codes confirms that a full range of elements can be formed in a matter of minutes in an initial brief period of cosmological nucleosynthesis without the necessity for long evolutionary timeframes.

Accelerated radioactive decay in low entropy cosmological nucleosynthesis.

A creationary cosmology appears to demand that the early formation of matter would include a period of accelerated radioactive decay. An associated issue is that a period of rapid radioactive decay might result in an unacceptably large production of radiogenic heat which might preclude the existence of life. Both of these creationary demands appear to be met by the unusual energetics of the zero entropy class of models.

At temperatures close to absolute zero it becomes possible for nucleosynthesis reactions to access the almost unlimited energy source (and energy sink) known as Fermi Degeneracy energy (or Zero Point energy). Details of the unique energetics of low entropy cosmogony can be found in the work of Michelle Kaufman on nuclear reactions and elementary-particle reactions in a cold universe. (Kaufman, 1970).

Kaufman has discussed the role of decay rates in the low entropy class of models of cosmological nucleosynthesis. She shows that in such models there exists a period of neutrino-induced, accelerated radioactive decay as an integral part of the rapid building up of the elements. Her study analyzes the differing rates of decay that will occur over the successive time increments of the brief era of cosmological nucleosynthesis. She shows that the energy, Q , released per reaction, could either be released as Fermi degeneracy energy or as thermal energy or a combination of both. If the energy goes entirely to the degeneracy energy of the products, then the decay of the reaction will occur almost immediately with no output of thermal energy. For other reactions, if only part of the energy of the reaction becomes Fermi degeneracy energy, she shows that there could be an increase in temperature. (Kaufman, 1970 p.461)

In creationary circles, one of the first to point out that radioactive decay rates are affected by ambient neutrino flux was Ted Rybka (Rybka, 1982).

The inherent timeframe of cosmological nucleosynthesis.

The era of cosmological nucleosynthesis is of necessity exceedingly brief. Early cosmological nucleosynthesis demands the availability of a large proportion of free neutrons in order to build up the elements by the process of neutron capture. Free neutrons, however, have a laboratory bench-mark half-life of only around 10 minutes. This means that the window of time that allows universal cosmological nucleosynthesis is expected to be less than about 10 minutes in order that a sufficiently high proportion of neutrons will be involved in neutron capture before the neutrons beta decay into protons. Aguirre shows how, even at zero temperature, nucleosynthesis reactions that build up the elements are extremely rapid. He says that the particle Fermi energies at early times are very high, driving reactions that are much faster than the expansion rate. (Aguirre, 1999 p.18)

A REVIEW OF THE ULTRA-RAPID FORMATION OF PROTOSTARS AND MAIN SEQUENCE STARS IN LOW ENTROPY COSMOGONY

The spontaneous breakup of the early cosmic medium.

In many published models of low entropy cosmogony the early cold cosmic medium is unstable and subject to fracturing. The spontaneous breakup of the medium will provide the almost instantaneous formation of countless numbers of protostars and protoplanets. The demonstrable outcome is that within the first half hour of creation week protostars and protoplanets will be formed which already have a 'mature' range of element abundances.

Details have been provided by a number of authors.

Ray Hively quantifies the estimates the formation time of the first protostars in low entropy cosmogony as occurring about 16 minutes into the creation era (Hively 1972, p.64).

Craig Hogan shows how an expanding universe composed of low-entropy matter spontaneously shatters as it passes through a period of metastability during a phase transition probably as a result of pion condensation. He estimates that the system shatters into large pieces containing between 10^{46} and 10^{51} nucleons (around planetary sizes) and that large enough pieces may stabilize as neutron stars or "polyneutrons." (Hogan, 1982). It is of obvious interest in a creationary scenario that Hogan indicates that the largest of these bodies may stabilize as neutron stars." This provides a source of neutron stars in the first half hour of the creation era. This is in dramatic contrast to the HBB where neutron stars are assumed to form late in the evolutionary lifetime and to have individual ages measured in billions of years.

Harvard cosmologist, David Layzer, describes a similar scenario to that of Hogan. Layzer estimates that about 20 minutes into the first day of creation a universal phase change could

‘shatter’ the expanding cosmic medium to form astronomical bodies with a range of masses that would average around 10 times the mass of the earth (Layzer, 1990, p.158). He estimates that this will occur when the early cosmic density had fallen to about a tenth that of water (Layzer, 1984, pp. 277-278).

The Jeans mass criteria for stellar formation in low entropy cosmogony models.

One of the criteria for stellar formation is the calculated value of the ‘Jeans mass’ parameter which is named after Sir James Jeans. If the mass of a potential stellar formation region is greater than its Jeans mass then the region will never collapse and stars will never form. The value of the Jeans mass itself is governed by the ambient density and temperature of the region. The reality of the HBB model is that the Jeans mass during the early high temperature regime is so enormous that it is greater than the mass of any known astronomical system! (Karttunen 1987, p. 426) No stars or protostars or any stellar system can possibly form under such conditions.

In complete contrast, a general feature of all low entropy models is that from the very first moments of the creation era the Jeans mass has a value low enough to permit the possibility of stellar formation. One calculation shows that the baryonic Jeans mass has a value of one solar mass only 30 seconds after cosmological nucleosynthesis is initiated. (Aguirre 2001 p. 083514) Such very low values at the beginning of creation week allow the early establishment of ultra-rapid stellar formation processes and consequent stellar clustering. Under such conditions the entire universe can be caught up in an extraordinary era of rapid stellar formation and clustering- and this is the hallmark of all versions of low entropy cosmogony.

Inherent timeframes for the rapidly formed primordial stars to reach Main Sequence characteristics.

It has already been shown that, in the low entropy model, primordial protostars could form in a matter of hours with metallicity levels comparable to those of stars presently observed. The question now arises as to the timeframes whereby such primordial protostars, initially subject to strong non-equilibrium processes, could achieve main-sequence stellar characteristics. Carr points out that low entropy primordial protostar formation and the subsequent development of those protostars are certainly very different from those which occur in ‘normal’ star formation. He shows how, for example, primordial protostars might have to ‘expand’ onto the main sequence of the standard H-R Diagram rather than the normal ‘contraction’ via the Hayashi track.

Carr shows explicitly that the time taken in the low entropy model for a zero metallicity primordial protostar to reach main sequence temperature and luminosity can be expressed by the relation $t_{MS} \sim 10^6 (T_{MS}/10^7 \text{ K}) M^{-2} (1 + (M/100))^2$ years where t_{MS} is the time taken in years for a star to reach the main sequence temperature and luminosity. Here, T_{MS} is the main sequence temperature and M is the mass of the star in units of the solar mass (Carr 1977a, p.21)

The main-sequence temperature for a solar-mass star is around 5,600 K. If we apply these values to the above relation we see that t_{MS} for solar mass star for a zero metallicity is the incredibly rapid time of around 570 years. It is noteworthy that Carr chose a primordial star of zero metallicity to use for his example. In other words he is attempting to establish the characteristics of the theoretical population III stars - which in the HBB are assumed to have zero metallicity. However in a creationary scenario the primordial protostars that rapidly approach the main sequence and other tracks on the H-R Diagram would not be expected to be the theoretical zero metallicity population III stars. Instead they would all be the actual stars we observe and they would have a full range of metallicities that has resulted from low entropy cosmological nucleosynthesis

Inherent timeframe for neutron star formation in the CBB.

It has already been shown that neutron stars can spontaneously form in a timeframe of just a few minutes from the creation singularity as a result of a phase change that could include the formation of a pion condensate. It is useful to consider whether there are ways to determine whether any currently observed neutron stars have characteristics that show they were formed as a result of an early phase transition. In this context Hogan has pointed out that there are a number of ways that the existence or absence of a pion-condensate phase in neutron stars might be determined and he uses the example of core cooling rates (Hogan 1982, p.430).

Inherent timeframe for black hole formation.

Black hole formation in low entropy conditions have been quantified by Carr and once again we see the remarkable rapidity of formation process in low entropy models Carr shows that protostars of a specified range will collapse directly to black holes on a free-fall timescale. He estimates the relevant free-fall time as comparable to the parameter $t_B(M)$ which he defines as the time at which half of the regions of mass M solar masses should stop expanding and form gravitationally bound systems. He obtains the relation $t_B(M) = 10^{-5} \epsilon^{-3/2} M$ secs (Carr, 1977b, p298). Carr states that the most likely value for ϵ in the early universe would be of the order of 10^{-6} (Carr, 1977b, p308). In this case his relation gives us a value for the free fall time of around 3 hours for a body of about one solar mass.

A REVIEW OF STELLAR CLUSTERING IN LOW ENTROPY COSMOGONY

The striking hierarchical patterns of stellar clustering.

Observations of astronomical systems reveal significant hierarchical patterns that are maintained through larger and larger scales of lengths. These patterns should be explicable in any comprehensive cosmological model. Examples can be seen in systems starting with the earth/moon system and continuing to the solar system itself; open clusters of a few hundred stars; globular clusters of around one million stars; individual galaxies of billions of stars; small clusters of galaxies and vast superclusters. Statistical indicators (Lachieze-Rey, 1995, p 12)

show the clear presence of clustering patterns that are not random but point to a tendency for clustering to occur at certain specific scales of size.

In the HBB model the explanations for the observed clustering patterns involve a series of 'top-down' processes whereby galaxies arrive as structureless gas clouds, and stars and stellar systems eventually condense within them. There appears to be nothing, in the published corpus of HBB cosmology, where the observed correlations between different clustering systems are explained quantitatively. Comments such as the following of Lachieze-Rey are not hard to find:

The problem of galaxy formation, or more generally, the formation of large-scale cosmic structures, remains one of the most delicate questions of cosmology, and appears to resist all analysis. There is no model today that is able to satisfactorily answer all aspects of the problem.

Low entropy explanations for the existence of hierarchical cosmological systems.

In low entropy cosmogony we have a radically different approach from the HBB. The striking patterns of stellar clustering are explained as the result of 'bottom-up' cosmological formation process whereby larger and larger mass systems will form on a hierarchical basis as the visible horizon of the universe expands at the speed of light.

This model for clustering has been developed in some detail by Layzer in a series of publications (Layzer, 1954, 1971, 1984, 1990).

Layzer shows how, as the horizon of the visible universe increases, more and more of the horizon mass becomes subject to density fluctuations, and greater and greater masses can participate in the formation of larger and larger structures. The newly formed systems will then take the role of 'particles' in a new cosmic distribution which, in turn, will have local irregularities that will result in the whole clustering process repeating. By means of this model he successfully reproduces the observed clustering pattern. Layzer also makes use of Maxwell's theories, as applied to gases, as an interesting analogy for his models of gravitational interaction on cosmic scales.

He concludes that, in his analogy of a cold expanding 'gas', the internal energy will be initially negative and he claims that this makes all the difference between his models and the HBB model. With an internal energy that is negative to begin with, he says that the internal energy of the cosmic medium must actually assume larger and larger negative values as the universe expands. Conversely, the internal energy of the cosmic medium could never have become negative if it had been positive to begin with - as is the case in an initially hot universe. Layzer comments that this is the root of the difficulties that people have in the past encountered in their often fruitless efforts to understand how gravitational clumping could have arisen in the hot big bang model. (Layzer, 1990, p.162).

Layzer does not envisage the clustering process as continuing indefinitely. He recognizes that, at extreme distances, another factor presents itself - the curvature of space itself. He defines an entity that he calls the 'curvature energy of space' and shows that if this 'curvature energy' becomes sufficiently large so that it is comparable to the magnitude of the internal energy of a newly formed cluster, then the total energy of the cluster would become zero. He interprets this as resulting in another phase change, this time analogous to that occurring in a superheated fluid. He sees the observed large filamentary structure of the Universe as a possible indication of this final form of phase change (Layzer, 1990, p.169).

This model of hierarchical growth produced by Harvard cosmologist David Layzer is certainly not just a 'hopeful conjecture' but has been developed into a rigorous mathematical model). The development of the model can be recognized as having begun with Layzer's stated goal of producing a mathematical description for the cosmic distribution of matter that can be inserted into Einstein's gravitational equations and then solved. In the course of meeting this challenge, which Layzer says presents "very great mathematical difficulties" (Layzer 1954, p.171), a new cosmological version of the virial theorem was introduced as a useful simplifying procedure (Layzer 1963, pp180-183). The mature model that eventually transpired (Layzer 1971) has now been shown to produce excellent quantitative agreement with observations of stellar clustering over ten decades of size. Layzer has shown how the model correctly predicts the clustering spectrum for gravitationally bound stellar systems over a range or more than twelve powers of ten in mass (Layzer, 1990, p.164). These remarkable results demonstrate the explanatory power of low entropy cosmogony to quantitatively account for a key series of observations that any viable and comprehensive cosmological model should be able to explain.

Inherent timescales for clusters to become gravitationally bound.

The timescales of clustering have been analyzed by A.J. Carr (Carr, 1977b, p297) who uses the assumptions of low entropy cosmogony to calculate how a spectrum of hierarchical clustering is established on the scale of the radius of the visible universe increasing at $\sim ct$ where 'c' is the speed of light. He shows how an entire spectrum of hierarchical structures of ever increasing mass is formed according to a rule whereby half of the regions of mass M solar masses should stop expanding at a time $t_B(M)$ given by $t_B(M) = 10^{-5} \epsilon^{-3/2} M$ secs. He obtains a spectrum of clustering by continuing this formation pattern.

Carr estimates the scale factor for the stellar clustering phase as $\epsilon = 0.05$ and he uses this value to show that the first regions become gravitationally bound at around 10^{-4} sec with a mass of 1 solar mass.

Using the above relation of Carr and his value of $\epsilon = 0.05$ a system of around one million solar masses would become gravitationally bound after about 15 minutes; an individual galaxy of around 10^{10} solar masses after 3 months; superclusters would be gravitationally bound after

about 28,000 yrs. It is of interest that the vast superclusters are so large that they are not yet gravitationally bound but instead participate in Hubble cosmological expansion.

Measurements of the distribution of galaxies as a test for the existence of a primordial cosmic fragmentation event based on a cold expanding universe.

A useful search for observational evidence for the existence of a single primordial cosmic fragmentation event can be found in the work of Brown, Karpp & Grady who apply the concepts of fragmentation theory to the events of an early universe. They attempt to correlate the distribution of galaxies with known empirical results from laboratory fragmentation experiments. They then assess the results with 'single-event' statistical theory. The results are certainly interesting. They state that:

The implication is that the Universe did indeed undergo a single, simultaneous, catastrophic fragmentation event. Further, the type of distribution suggests that the galactic distribution has undergone little redistribution since the Big Bang and that later breakup due to galactic interaction has been negligible (Brown 1983, p 410.)

A follow-up study by Brown looks in a more detail at the mechanism of such a catastrophic fragmentation event. He discusses how, in a cold, expanding universe, matter would be subjected to increasingly greater tension until the expansion literally tears the matter into pieces. Amplification of these masses to the galactic scale might then be provided by what he calls an 'explosive amplification' mechanism (Brown 1986, p.351).

In his follow-up study he also says that the degree of 'suddenness' with which the original fragmentation occurred may differ from one sample of galaxies to another. His conclusion is:

I favor the hypothesis that after the Big Bang, the Universe fragmented directly into the galactic masses we observe today. (Brown 1986, p.355).

A REVIEW OF THE ORIGIN OF THE COSMIC MICROWAVE BACKGROUND IN LOW ENTROPY COSMOGONY

The CMB is a background radiation at a temperature of 2.7 Kelvin that fills the entire Universe. The question of its origin is important for any review of low entropy cosmogony because there is a common perception that the HBB model has a superior explanation for the CMB and its measured temperature.

One of the better known classes of alternative models for the CMB assumes that it is produced by the radiation of thermal energy from dust grains. This model appears to have first been proposed by Fred Hoyle who searched for such dust grains and claimed that tiny whiskers of iron would be effective. Layzer has reviewed the dust grain model with the possibility that some of the primordial elements produced in an initially cold universe would be grains of a size and

consistency that could thermalize the microwave background (Layzer, 1973). Layzer also discusses the extent to which they could explain the accurate Planckian form of the MBR.

Hoyle's calculations, based on this alternative to the HBB model, predicts a temperature of 2.8 K. for the background radiation field (As quoted in Terzian, 1983, p30)

Additional support for the thermalizing model is found in the work of Edward Wright who showed how the CMB could have been produced by stellar radiation. (Wright 1982)

A similar proposal for a thermalizing model was made in creationary circles by Ackridge, Barnes, and Slusher, who showed that the CMB could be produced by dust heated up by stars over a period of 6,800 years. (Ackridge, 1981)

Observational tests for the origin of the CBR in low-entropy cosmogony.

Hogan has shown how models of the MBR in a cold expanding universe context would have subtle differences in their degree of anisotropy as compared with the 'standard model. He shows how these differences are potentially measurable with the study of quadrupole data and the ratio of quadrupole to octopole anisotropy. (Hogan 1982 p. 419).

In the course of his discussion of how these measurements can be made, he includes the significant point that there are grounds for being suspicious about the standard models that postulate primordial fluctuations which have a characteristic scale of the order of the scale of the observed structures. He says this is all the more suspicious because the scale of galaxies themselves probably has a natural explanation in gas-dynamical processes which have nothing to do with initial conditions.

CONCLUSION

Current versions of low entropy cosmogony include a theoretical framework that can easily accommodate the rapid cosmological formation timeframes of the six day Genesis account. The model is built on reasonable and simple assumptions and includes novel and testable interpretations for a wide range of astronomical phenomena. The breadth of application of its distinctive and fundamentally different approach allows many opportunities to assess its explanatory power as compared with versions of the hot big bang model. It is most satisfying that there exists such a major cosmological model that, in its most recent manifestations, has strong resonance with creationary requirements for matter and stellar formation.

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