Observational Evidence for Two Cosmological Predictions Made by Bit-String Physics

H. Pierre Noyes

Stanford Linear Accelerator Center
Stanford University, Stanford, CA 94309

Abstract

A decade ago bit-string physics predicted that the baryon/photon ratio at the time of nucleogenesis $\eta = 1/256^4$ and that the dark matter/baryonic matter ratio $\Omega_{DM}/\Omega_B = 12.7$. Accepting that the normalized Hubble constant is constrained observationally to lie in the range $0.6 < h_0 < 0.8$, this translates into a prediction that $0.325 > \Omega_M > 0.183$. This and a prediction by E.D.Jones, using a model-independent argument and ideas with which bit-string physics is not inconsistent, that the cosmological constant $\Omega_\Lambda = 0.6 \pm 0.1$ are in reasonable agreement with recent cosmological observations, including the BOOMERANG data.

Key words: baryon/photon ratio, dark matter/baryon ratio, cosmological constant
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Bit-string physics (BSP) is an alternative approach to natural philosophy based on four principles:

1. Happenings can be distinguished from nothing.

2. Happenings are the same or different.

3. Happenings can be recorded and these records can be re-examined.

4. In the absence of further information, all happenings are equally probable.

This research program has a long history [14], starting with the discovery of the *combinatorial hierarchy* by A.F. Parker-Rhodes in 1961 [23], but has not attracted much attention in the mainstream literature. One difficulty, according to several of our critics, is that although BSP has produced approximate

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values for well known physical parameters it has not led to quantitative predictions prior to observation. Here we meet this difficulty in an unexpected manner by showing that recent cosmological observations support two predictions made about a decade ago when there was no available way to compare them with observation.

I now use the following arguments to develop a growing universe of bit-strings from our basic principles. If nothing happens and we have no structure to generate happenings, nothing will happen. So we start with a happening. But we can't yet know whether the "nothing happening" we are, by hypothesis, able to distinguish from this first happening is "elsewhere", or "elsewhen", or both, or.... I assume that we should use the simplest possible mathematical structures to model and develop our basic concepts. Distinguishing a happening from nothing happening is simply modeled by bit multiplication, i.e. $0 \cdot 0 = 1 \cdot 0 = 0 \cdot 1 = 0$; $1 \cdot 1 = 1$. This implies that the two cases can be compared, so we know that our "start" is most simply represented by a "1" *and* a "0". We record the two symbols (Principle 3), but still don't know which symbol refers to a happening and which to nothing happening. We now model the comparison (Principle 2) by bit addition $1 \oplus 1 = 0 = 0 \oplus 0$; $1 \oplus 0 = 1 = 0 \oplus 1$ (i.e. addition modulo 2, XOR, symmetric difference,... or, as it is referred to in the ANPA research program, *discrimination*). We know if we compare the two symbols already recorded using this operation we will necessarily produce a "1" which we record. How we keep track of what has happened should not affect the subsequent development, so we record the two "1" 's and the "0" as a column, but ascribe no significance to the order of the three symbols in the column.

We now introduce a simple algorithm called *program universe* [9,20,15] which generates a growing universe of bit-strings from the starting column. This algorithm will allow us to make arbitrary choices of either a symbol or of a row in the table, based on Principle 4. In other words, the algorithm contains a "random number generator". Of course for any realized computer simulation this can only be "pseudo-random". At each step this universe contains $P(S)$ strings of length S. As argued above the starting point required by our principles is three rows of length one, i.e. $P(1) = 3$, containing two "1" 's and one "0". The algorithm is very simple, as can be seen from the flow diagram in Fig. 1. We start with a rectangular block of rows and columns containing only the bits "0" and "1". We then pick two rows arbitrarily and if their discriminant is non-null, adjoin it to the table as a new row and recurse to picking two arbitrary rows (PICK). If the discriminant is null, we simply adjoin an arbitrary column (Bernoulli sequence) to the table and recurse to PICK. That this model contains arbitrary elements and (if interpretable in terms of known aspects of the practice of physics) an historical record ordered by the number of TICK's, or equivalently by the row length, should be clear from the outset. The forging of rules that will indeed connect the model to the *actual* practice

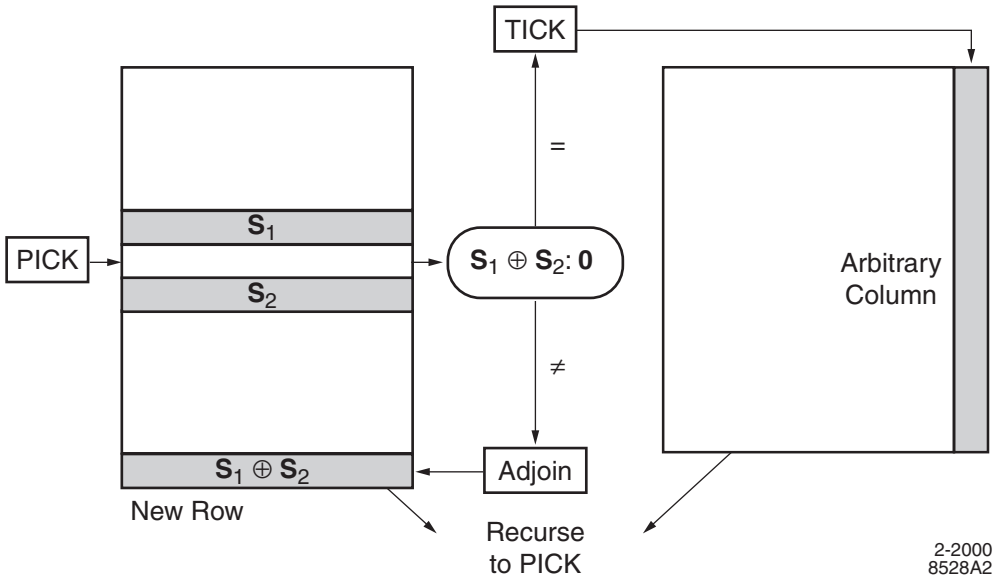

Fig. 1. Flow diagram for constructing a bit-string universe growing by one row or one column at a time (see text).

of physics is the primary research problem that has engaged me ever since the model was created.

Program universe provides a separation into a conserved set of "labels", and a growing set of "contents" which can be thought of as the space-time "addresses" to which these labels refer. To see this, think of all the left-hand, finite length S portions of the strings which exist when the program TICKs and the string-length goes from S to $S+1$. Call these *labels* of length $L = S$, and the number of them at the critical TICK $P_0(L)$, and the string length before the tick S_L. Further PICKs and TICKs can only add to this set of labels of this fixed length those which can be produced from it by pairwise discrimination, with no impact from the (growing in length and number) set of content labels; the length of the content (address) part of the string is $S_C = S - L > 0$. If $N_I \leq P_0(S_L)$ of these labels are *discriminately independent*, then the maximum number of distinct labels they can generate, no matter how long program universe runs, will be $2^{N_I} - 1$, because this is the maximum number of ways we can choose combinations of N_I distinct things taking them $1, 2, \ldots, N_I$ at a time. We will interpret this fixed number of allowable labels as a representation of the quantum numbers of systems of "elementary particles" present in our bit-string universe and use the growing content-strings to represent their (finite and discrete) locations in an expanding space-time description of the universe.

This label-content schema then allows us to interpret the events which lead to TICK as four-leg Feynman diagrams representing a stationary state scattering process. Note that for us to find out that the two strings found by PICK are the same, we must either pick the same string twice or at some previous

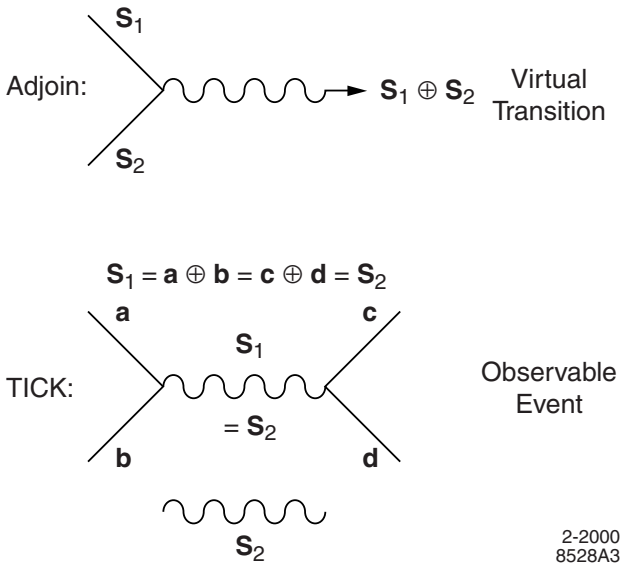

Fig. 2. Interpretation of the Adjoin and TICK operations of Program Universe as Feynman diagrams(see text).

step have produced (by discrimination) and adjoined the string which is now the same as the second one picked. Short-circuiting and reordering the actual route by which my current interpretation of this model was arrived at, we note that the two basic operations in the model which provide locally novel bit-strings (Adjoin and TICK) are isomorphic, respectively, to a three-leg or a four-leg Feynman diagram. This is illustrated in Fig. 2. Note that the internal (exchanged particle) state in the four-leg Feynman diagram is *necessarily* accompanied by an identical (but distinct) "spectator" somewhere else in the (coherent) memory.

Although the paper is not presented in bit-string language, a little thought about the solution of a relativistic three body scattering problem Ed Jones and I have found [19] shows that the driving term $\binom{>-<}{_}$ is always a four-leg Feynman diagram $(> - <)$ plus a spectator $(\ -\ )$ whose quantum numbers are *identical* with the quantum numbers of the particle in the intermediate state connecting the two vertices. We are particularly pleased that the observable events created by program universe turn out to provide *two* locally identical but distinct strings (states) needed as the starting point for this scattering theory [19]. We do not have space here to explain how, in the more detailed dynamical interpretation, the three-leg diagrams conserve (relativistic) 3-momentum but not necessarily energy (like vacuum fluctuations) while the four-leg diagrams conserve both 3-momentum and energy and hence are candidates for potentially observable events. But we *do* need to explain how this interpretation of program universe does connect up with the work on the combinatorial hierarchy.

At this point we need a guiding principle to show us how we can "chunk" the growing information content provided by the discriminate closure of the label portion of the strings in such a way as to generate a hierarchical representation of the quantum numbers that these labels represent. Following a suggestion of David McGoveran's [11], we note that *we can guarantee that the representation has a coordinate basis and supports linear operators by mapping it to square matrices.*

The mapping scheme originally used by Amson, Bastin, Kilmister and Parker-Rhodes [1] satisfies this requirement. This scheme also uses bit-string discrimination, multiplication (hence the *field* Z_2), and *discriminate closure*; these are the basic formal elements we "derived" above from our basic principles. First note, as mentioned above, that any set of n discriminately independent (*d.i.*) strings will generate exactly $2^n - 1$ discriminately closed subsets (*dcss*). Start with two d.i. strings $\mathbf{a}$, $\mathbf{b}$. These generate three d.i. subsets, namely $\{\mathbf{a}\}$, $\{\mathbf{b}\}$, $\{\mathbf{a}, \mathbf{b}, \mathbf{a} \oplus \mathbf{b}\}$. Require each dcss ($\{\ \}$) to contain only the eigenvector(s), of three 2×2 *mapping matrices* which (1) are non-singular (do not map onto zero) and (2) are d.i. Rearrange these as strings. They will then generate seven dcss. Map these by seven d.i. 4×4 matrices, which meet the same criteria (1) and (2) just given. Rearrange these as seven d.i. strings of length 16. These generate $127 = 2^7 - 1$ dcss. These can be mapped by 127 16×16 d.i. mapping matrices, which, rearranged as strings of length 256, generate $2^{127} - 1 \approx 1.7 \times 10^{38}$ dcss. But these cannot be mapped by 256×256 d.i. matrices because there are at most 256^2 such matrices and $256^2 \ll 2^{127} - 1$. Thus this *combinatorial hierarchy* terminates at the fourth level. The mapping matrices are not unique, but exist, as has been proved by direct construction and an abstract proof [2]. It is easy to see that the four level hierarchy constructed by these rules is *unique* because starting with d.i. strings of length 3 or 4 generates only two levels and the dcss generated by starting with d.i. strings of length 5 or greater cannot be mapped.

Making physical sense out of these numbers is a long story [14]. In order to underpin our claim that we can model a finite particle number version of relativistic quantum mechanics with particle creation, etc. using bit-strings we give on the next page the predictions of coupling constants and mass ratios calculated using our theory. As in any mass, length, time theory we are allowed three empirical, dimensional constants which are measured by standard techniques to connect our abstract theory to measurement. These we take to be the mass of the proton m_p, Planck's constant $\hbar$ and the velocity of light c. Everything else is calculated. Agreement with observation, given below, is not perfect; we believe it is impressive. For more detail see [14].

Comparison of Bit-String Predictions of Coupling Constants and Mass Ratios with Experiment

$$G_N^{-1}\frac{\hbar c}{m_p^2} = [2^{127}+136]\times\left[\mathbf{1}-\frac{\mathbf{1}}{\mathbf{3\cdot 7\cdot 10}}\right] = 1.693\ 31\ldots\times 10^{38}$$

$$\text{experiment} = 1.693\ \mathbf{58}(21)\times 10^{38}$$

$$\alpha^{-1}(m_e) = 137\times\left[\mathbf{1}-\frac{\mathbf{1}}{\mathbf{30\times 127}}\right]^{-1} = 137.0359\ \mathbf{674}\ldots.$$

$$\text{experiment} = 137.0359\ 895(61)$$

$$G_F m_p^2/\hbar c = [256^2\sqrt{2}]^{-1}\times\left[[\mathbf{1}-\frac{\mathbf{1}}{\mathbf{3\cdot 7}}\right] = 1.02\ \mathbf{758}\ldots\times 10^{-5}$$

$$\text{experiment} = 1.02\ 682(2)\times 10^{-5}$$

$$sin^2\theta_{\text{Weak}} = 0.25\left[\mathbf{1}-\frac{\mathbf{1}}{\mathbf{3\cdot 7}}\right]^2 = 0.2267\ldots$$

$$\text{experiment} = 0.22\mathbf{59}(46)$$

$$\frac{m_p}{m_e} = \frac{137\pi}{\langle x(1-x)\rangle\left\langle\frac{1}{y}\right\rangle} = \frac{137\pi}{\left(\frac{3}{14}\right)\left[1+\frac{2}{7}+\frac{4}{49}\right]\left(\frac{4}{5}\right)} = 1836.15\ \mathbf{1497}\ldots \quad (1)$$

$$\text{experiment} = 1836.15\ 2701(37)$$

$$m_\pi^{\pm}/m_e = 275\left[\mathbf{1}-\frac{\mathbf{2}}{\mathbf{2\cdot 3\cdot 7\cdot 7}}\right] = 273.12\ \mathbf{92}\ldots$$

$$\text{experiment} = 273.12\ 67(4)$$

$$m_{\pi^0}/m_e = 274\left[\mathbf{1} - \frac{\mathbf{3}}{\mathbf{2\cdot 3\cdot 7\cdot 2}}\right] = 264.2\ \mathbf{143}\ldots$$

$$\text{experiment} = 264.1\ 373(6)]$$

$$m_\mu/m_e = 3\cdot 7\cdot 10\left[1 - \frac{3}{3\cdot 7\cdot 10}\right] = 207$$

$$\text{experiment} = 206.768\ 26(13)$$

$$G^2_{\pi N\bar{N}} = \left[\left(\frac{2M_N}{m_\pi}\right)^2 - 1\right]^{\frac{1}{2}} = [195]^{\frac{1}{2}} = 13.96\ldots.$$

$$\text{experiment} = 13.3(3),\ \text{or greater than}\ \ 13.9$$

Making the case that these constructions give us the quantum numbers of the standard model of quarks and leptons with exactly 3 generations has only been sketched [13].A tentative bit-string representation of the quantum numbers of the (three generation) standard model of quarks and leptons using bit-string labels of length sixteen is given in Fig. 3.

Fortunately we do not require the completely worked out scheme to make interesting cosmological predictions. The ratio of dark to "visible" (i.e. electromagnetically interacting) matter is the easiest to see. The electromagnetic interaction first comes in when we have constructed the first three levels giving 3+7+127 =137 dcss, one of which is identified with electromagnetic interactions because it occurs with probability $1/137 \approx e^2/\hbar c$. But the construction must first complete the first two levels giving $3 + 7 = 10$ dcss. Since the construction is "random" and this will happen many, many times as program universe grinds along, we will get the 10 non-electromagnetically interacting labels 127/10 times as often as we get the electromagnetically interacting labels. Our prediction of $M_{DM}/M_B = 12.7$ is that naive.

The $1/256^4$ prediction for N_B/N_γ is comparably naive. Our partially worked out scheme of relating bit-string events to particle physics [13,14], makes it clear that photons, both as labels (which communicate with particle-antiparticle pairs) and as content strings will contain equal numbers of zeros and ones in appropriately specified portions of the strings. Consequently they can be readily identified as the most probable entities in any assemblage of strings generated by whatever pseudo-random number generator is used to construct

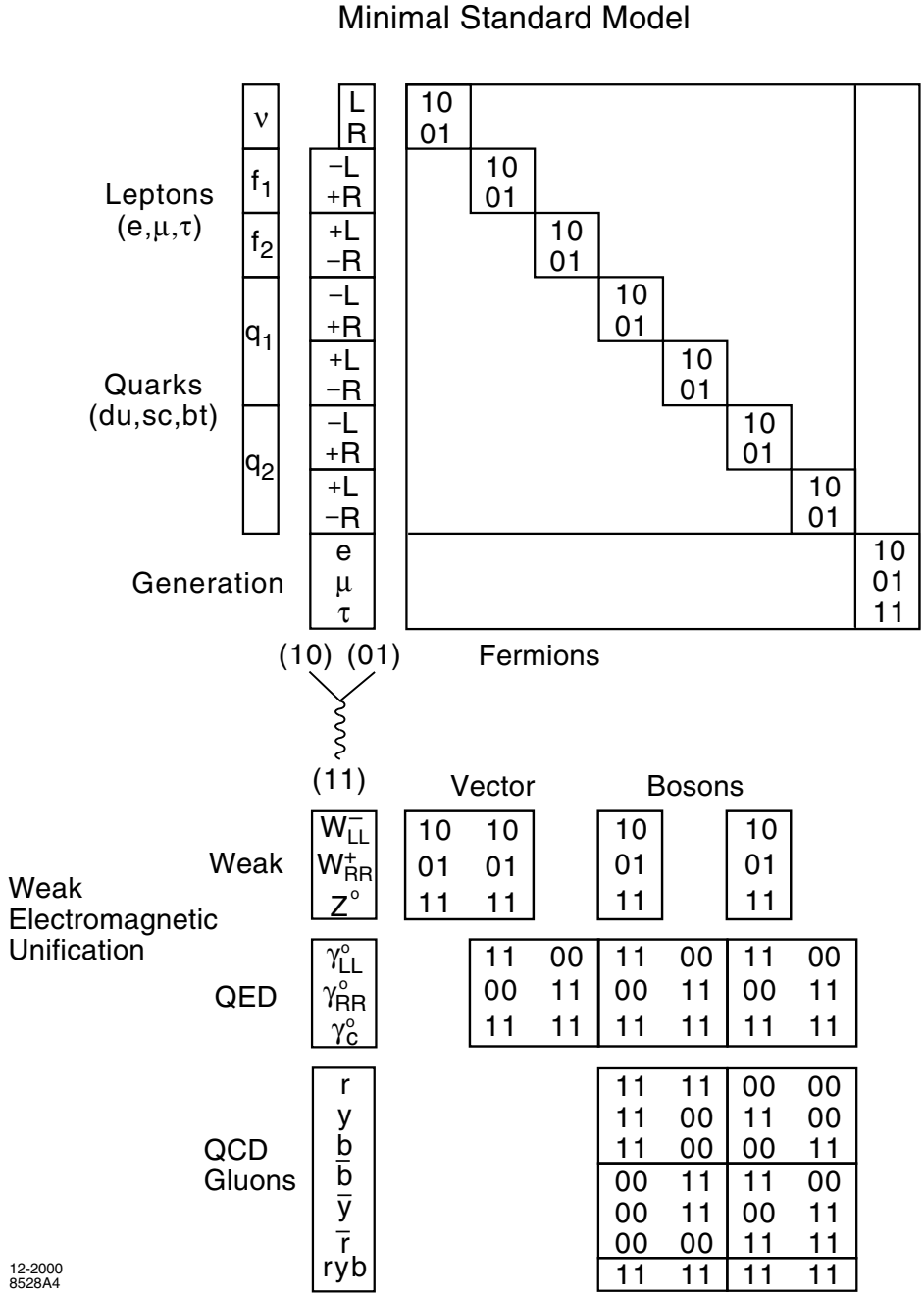

Fig. 3. Skeleton of a label scheme for labels of length 16 which conveys the same quantum number information as the standard model of quarks and leptons.

the arbitrary actions and bit-strings needed in actually running program universe. This scheme also makes the simplest representation of fermions and anti-fermions contain one more "1" and one less "0" than the photons (or *visa versa*). (Which we call "fermions" and which "anti-fermions" is, to begin with, an arbitrary choice of nomenclature.) Since our dynamics insures conventional quantum number conservation by construction, the problem is to show how program universe introduces a bias between "0" 's and "1" 's once the full

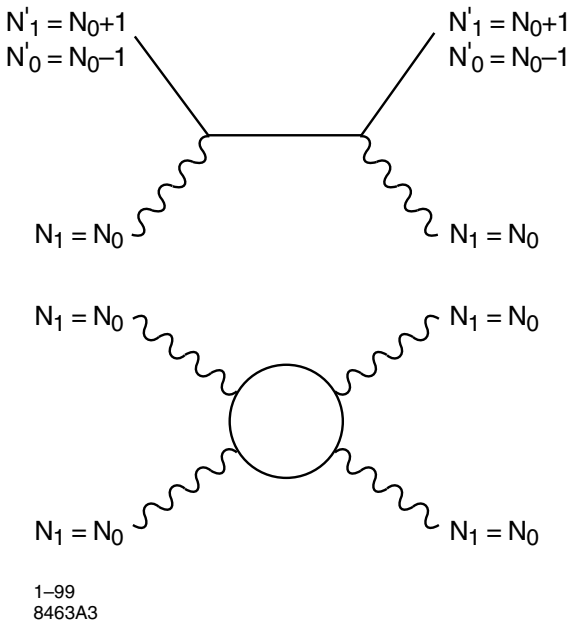

Fig. 4. Comparison of bit-string labeled processes after the label length is fixed at 256 interpreted as baryon ($N_1' = N_0 + 1$) photon ($N_1 = N_0$) and photon-photon scattering. Here N_1 and N_0 symbolize, respectively, the number of ones and zeros in the label part of the string (which is of length 256). Program universe guarantees that, in the absence of further considerations, the content part of the strings will have an equal number of zeros and ones with very high probability as the string length (universe) grows.

interaction scheme is developed; this problem is analogous to the corresponding problem in conventional theories. However, our theory requires no "fine tuning".

We saw above that program universe has to start out with two one's and one zero. Subsequent PICKs and TICKs are sufficiently "random" to insure that (at least statistically) we will generate an equal number of zeros and ones, apart from the initial bias giving an extra one. Once the label length of 256 is reached, which is the label length required by the combinatorial hierarchy mapping scheme discussed above, and sufficient space-time structure ("content strings") generated and interacted to achieve thermal equilibrium, this label bias for a 1 compared to equal numbers of zeros and ones will persist for 1 in 256 labels. We must now count the number of equilibrium processes leading to baryon-photon scattering relative to the number leading to photon-photon scattering. We start from the most probable and the next most probable classes of scattering processes, which are presented in Figure 4. Because baryon number is conserved, and the even-odd character of the labels is conserved by discrimination, we interpret the bias as specifying baryon number for one of the 256 labels in the initial (or equivalently the final) state. This requires the baryon bias of 1 to appear in one and only one of the four initial (or final, because of baryon number conservation) state labels of length

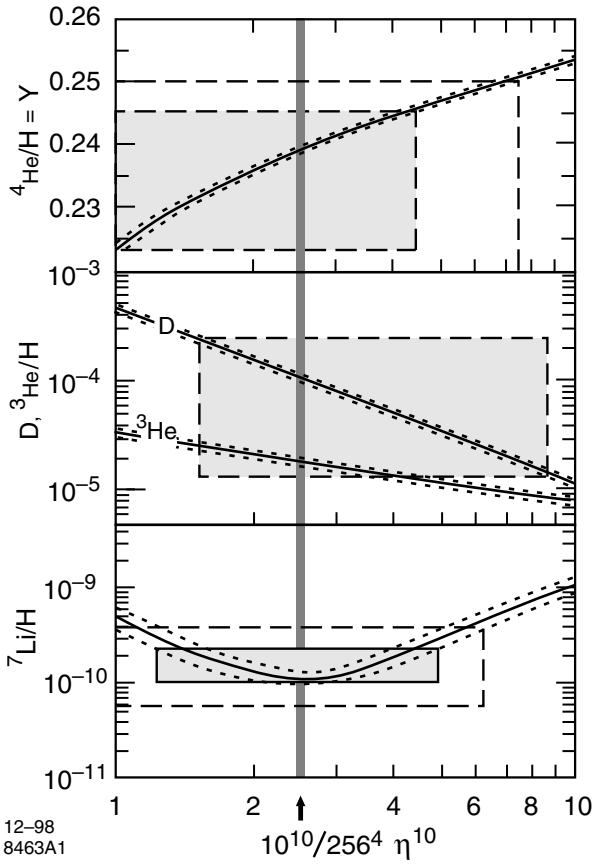

Fig. 5. Comparison of the bit-string physics prediction that $\eta = 256^{-4}$ with accepted limits on the cosmic abundances as given by Olive and Schramm in [24], p. 119.

256. Then, simple case counting gives the baryon to photon ratio as $1/256^4$ for any representational scheme which requires photons to have equal numbers of zero's and ones, and assigns baryon number to any one of the 256 slots in the label. Of course this conclusion rests on the interpretation of the strings causing observable TICK's as four-leg Feynman diagrams; that interpretation still needs some work on the details. As a trivial example of how this could work for labels of much shorter length take the baryon-antibaryon-photon vertex to be $\mathbf{B} \oplus \bar{\mathbf{B}} \oplus \gamma = \mathbf{0}$ with $\mathbf{B} = (1110)$, $\bar{\mathbf{B}} = (0010)$ and $\gamma = (1100)$. We conclude that, in the absence of further information, $1/256^4$ is the program universe prediction for the baryon-photon ratio at the time of big bang nucleosynthesis.

We now demonstrate that our two predictions can be compared with observation, by showing that, together with the currently accepted value of the Hubble constant, they allow us to predict the normalized matter density Ω_M with reasonable precision. We recall that the predictions are that (a) the ratio of baryons to photons was $\eta = 1/256^4 = 2.328\ldots \times 10^{-10} = 10^{-10}\eta^{10}$ at the time of nucleogenesis and that (b) $\Omega_{DM}/\Omega_B = 127/10 = 12.7$. Comparison of prediction (a) with observation is straightforward, as is illustrated in Figure 5.

Comparison with observation of prediction (b) that the ratio of dark to baryonic matter is *not* straightforward, as was clear at DM98. This question remained unresolved at DM2000. However, according to the standard cosmological model, the baryon-photon ratio remains fixed *after* nucleogenesis. In the theory I am relying on, the same is true of the of the dark matter to baryon ratio. Consequently, *if* we know the Hubble constant, *and* assume that only dark and baryonic matter contribute, the normalized matter parameter Ω_M can *also* be predicted, as we now demonstrate.

We know from the currently observed photon density (calculated from the observed 2.728 °K cosmic background radiation) that the normalized baryon density is given by [21]

$$\Omega_B = 3.67 \times 10^{-3} \eta_{10} h_0^{-2} \tag{2}$$

and hence, from our prediction and assumptions about dark matter, that the total mass density will be 13.7 times as large. Therefore we have that

$$\Omega_M = 0.117 h_0^{-2} \ . \tag{3}$$

Hence, for $0.8 \geq h_0 \geq 0.6$ [6], Ω_M runs from 0.183 to 0.325. This clearly puts no restriction on Ω_Λ.

Our second constraint comes from integrating the scaled Friedman-Robertson-Walker (FRW) equations from a time after the expansion becomes matter dominated with no pressure to the present. Here we assume that this initial time is close enough to zero on the time scale of the integration so that the lower limit of integration can be approximated by zero [26]. Then the age of the universe as a function of the current values of Ω_M and Ω_Λ is given by

$$\begin{aligned} t_0 &= 9.78 h_0^{-1} f(\Omega_M, \Omega_\Lambda) \ Gyr \\ &= 9.78 h_0^{-1} f(0.117 h_0^{-2}, \Omega_\Lambda) \ \text{Gyr} \end{aligned} \tag{4}$$

where

$$f(\Omega_M, \Omega_\Lambda) = \int_0^1 dx \sqrt{\frac{x}{\Omega_M + (1 - \Omega_M - \Omega_\Lambda)x + \Omega_\Lambda x^3}}. \tag{5}$$

For the two limiting values of h_0, we see that

$$\begin{aligned} h_0 &= 0.8, \quad t_0 = 12.2 f(0.183, \Omega_\Lambda) \ \text{Gyr} \\ h_0 &= 0.6, \quad t_0 = 16.3 f(0.325, \Omega_\Lambda) \ \text{Gyr}. \end{aligned} \tag{6}$$

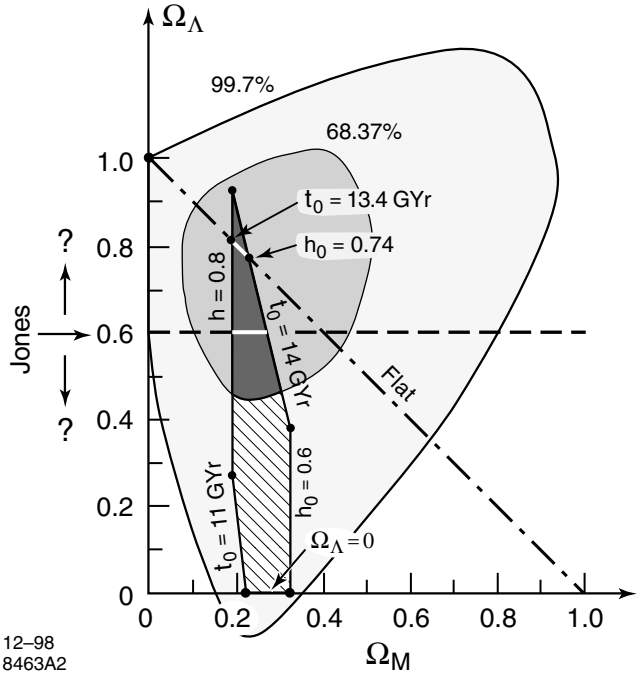

Fig. 6. Limits on $(\Omega_M, \Omega_\Lambda)$ set by combining the Supernovae Type Ia data from Perlmutter, et al. with the Cosmic Ray Background Experiment (COBE) satellite data as quoted by Glanz [3] (dotted curves at the 68.37% and 99.7% confidence levels) compared with the predictions of bit-string physics that $\eta_{10} = 10^{10}/256^4$ (cf. Fig. 5) and $\Omega_{\rm Dark}/\Omega_B = 12.7$. We accept the constraints on the scaled Hubble constant $h_0 = 0.7 \pm 0.1$ [5] and on the age of the universe $t_0 = 12.5 \pm 1.5$ Gyr (solid lines). We include the predicted constraint $\Omega_\Lambda > 0$). The Jones estimate of $\Omega_\Lambda = 0.6$ is indicated, but the uncertainty was not available in 1998.

The results are plotted in Figure 6 in comparison with data available in 1998. We emphasize that these predictions were made and published over a decade ago when the observational data were vague and the theoretical climate of opinion was very different from what it is now. The figure reproduced here was presented at ANPA20 (Sept. 3–8, 1998, Cambridge, England) and given wider circulation in [16]. The calculation that $\Omega_\Lambda = 0.6$ included in the figure and briefly discussed below was made by E.D. Jones before there was any observational evidence for a cosmological constant, let alone a positive one [7].

The precision of the relevant observational results had improved considerably by DM2000,where the preliminary version of this paper was presented [17]. Using an analysis due to Lineweaver [8], our prediction was still in excellent agreement with observation. Thanks to still more recent analyses of the BOOMERANG data and other observations [25], we now face a still more stringent test, as shown in Figure 7.

As in 1998, we find it useful to make use of an unpublished prediction of Ω_Λ

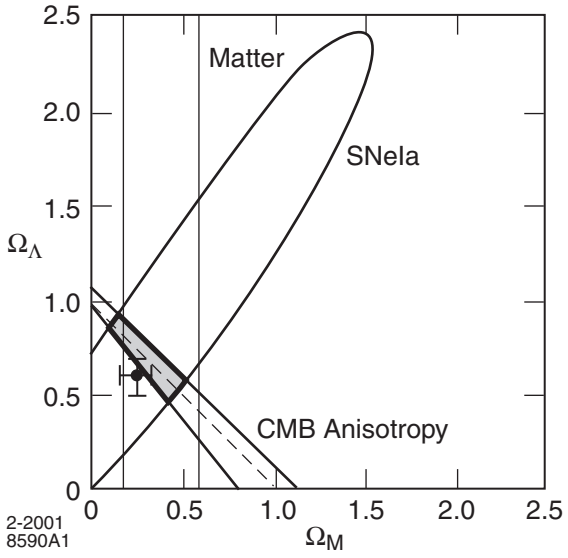

Fig. 7. Comparison of the bit-string physics and the Jones predictions with currently accepted cosmological data.

by E.D. Jones [7]. In contrast to the situation then, he is now prepared to set definite limits on his prediction based on considerations of his calculation made while preparing his paper for publication. Further, the estimate given above ($\Omega_\Lambda \sim 0.6 \pm 0.1$), which was made before and independent of our calculations reported above, falls squarely in the middle of the region allowed in 1998, and continues to do so despite the remarkable observational progress made in the interim.

The Jones calculation depends only on self-consistency arguments and requires the external input of an astrophysical quantity, such as the mass of the universe in Planck units, to calibrate the parameters. As a model-independent argument, it can not calculate the needed input from some first principles. Thus, the argument presumably can be improved by combining it with the bit-string physics model. Research in that direction is in progress.

We find it remarkable that the four epistemological principles with which we start seem to lead to (a) the overall structure of elementary particle physics together with a number of the basic constants calculated using no free parameters and (b) the gross cosmological state of the universe as measured by Ω_M and Ω_Λ. We hope that these facts will motivate others to investigate how this might come about.

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