

# Message in the Sky

S. Hsu<sup>1,\*</sup> and A. Zee<sup>2,†</sup>

<sup>1</sup>*Institute of Theoretical Science  
University of Oregon, Eugene, OR 97403*

<sup>2</sup>*Kavli Institute for Theoretical Physics  
University of California, Santa Barbara, CA 93106*

We argue that the cosmic microwave background (CMB) provides a stupendous opportunity for the Creator of universe our (assuming one exists) to have sent a message to its occupants, using known physics. Our work does not support the Intelligent Design movement in any way whatsoever, but asks, and attempts to answer, the entirely scientific question of what the medium and message might be IF there was actually a message. The medium for the message is unique. We elaborate on this observation, noting that it requires only careful adjustment of the fundamental Lagrangian, but no direct intervention in the subsequent evolution of the universe.

Let us pose the following question. Suppose some superior Being or Beings got the universe going. We do not address the issue of whether or not this is likely, but merely proceed with this supposition. Furthermore, suppose that they actually wanted to notify us that the universe was intentionally created. The question we would like to ask is: How would they send us a message?

That the universe was started by superior Beings is not only the province of religious thoughts from the earliest days of the human race, but has also been a staple of science fiction. In one of our favorite scenarios, our universe is a school-assigned science experiment [1, 2] carried out by a high school student in a meta-universe. Perhaps he or she or it even started an assortment of universes like ant farms and stashed them away somewhere in the basement, out of his or her or its parent's way. Perhaps by now he has lost interest and forgotten about the universes, leaving some to expand, others to collapse, in complete futility and silence. But, perhaps not without leaving a message for the occupants....

The popular press has been rife with suggestions on where the message might be found. One suggestion, for example, is that there might be a coded message in the human genome. In the United States, people with certain religious convictions have even imagined that the message might be encoded in the rock formation of the Grand Canyon, as another example. In our opinion, such suggestions are clearly not universal enough, and they seem to require direct intervention by the Creator during the evolution of the universe. Another possibility, that a message might be hidden deep in the digits of pi or the Riemann zeta function, is also appealing, but we have no way of addressing how feasible that might be without some measure over possible realizations of mathematics.

If one of the present authors had gotten the universe going and if he had wanted to announce this fact, he would clearly want all the advanced civilizations, not just in our galaxy, but in the entire universe, to know.

The genomic sequence is limited to civilizations involving (presumably) some subset of possible life forms based on carbon. To think that the message is carved in the geological record of one particular country on some insignificant dust speck of a planet is somewhat far fetched to say the least.

We have convinced ourselves that the medium for the message is unique: it could only be the cosmic microwave background. The cosmic microwave background is in effect a giant billboard in the sky, visible to all technologically advanced civilizations. Since different regions of the sky are causally disconnected, only the Being "present at the creation" could place a message there. (There are also cosmic neutrino and gravity wave backgrounds, but given the elusive nature of neutrinos and gravity waves it seems that photons are a better choice for carriers of the message.)

The variances of the CMB temperature distribution, projected onto spherical coordinates, are given by numbers denoted by  $C_l$  [3]. Here  $l$  is the usual angular momentum quantum number which appears in spherical harmonics  $Y_{lm}$ . Currently planned experiments are capable of measuring  $C_l$ 's up to  $l \sim 10^4$ . There is a fundamental (statistical) limit on the accuracy  $\Delta C_l$  to which we can determine each  $C_l$ , due to so-called cosmic variance. Since we only have  $(2l + 1)$  possible samples, we obtain

$$\left(\frac{\Delta C_l}{C_l}\right) = \sqrt{\frac{2}{2l+1}}. \quad (1)$$

Aside from this cosmic variance, each observer in the universe sees the same  $C_l$ 's, regardless of location. This point is worth emphasizing: while different civilizations, due to their different locations, see different patterns of thermal fluctuations on the sky (since their past light cones sample different portions of the surface of last scattering), they nevertheless would measure the same  $C_l$ 's and agree on the probability distribution from which the different patterns were drawn.

The next question is what might the message be. We thought of various possibilities and decided that the best choice would be the following. We now know, and we

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\*Electronic address: hsu@duende.uoregon.edu

†Electronic address: zee@itp.ucsb.edu

suppose that any civilization advanced enough to detect  $C_l$  in the cosmic microwave background would also know, that three of the four fundamental interactions are governed by gauge theories, based on the Lie algebras  $U(1) \otimes SU(2) \otimes SU(3) \subset SU(5) \subset SO(10) \subset E(6)$  [4]. Thus, we suggest that the coded message would simply be an announcement along the line “Hey guys, the universe is governed by gauge theories, and the relevant algebras are such and such.”

As is well known, all Lie algebras are uniquely characterized [5] by Dynkin diagrams or alternatively Cartan matrices. The Cartan matrices are simply square matrices whose entries are mostly zero, with the non-zero entries equal to either 2 or  $-1$ . For example the Cartan matrix for  $E(6)$  is

$$\begin{pmatrix} 2 & -1 & 0 & 0 & 0 & 0 \\ -1 & 2 & -1 & 0 & 0 & 0 \\ 0 & -1 & 2 & -1 & 0 & -1 \\ 0 & 0 & -1 & 2 & -1 & 0 \\ 0 & 0 & 0 & -1 & 2 & 0 \\ 0 & 0 & -1 & 0 & 0 & 2 \end{pmatrix} \quad (2)$$

This could easily be coded as a sequence of bits, with the first bits specifying the coding system (by listing the simplest algebras in order of complexity), and later bits describing the actual gauge “theory of not quite everything.”

We emphasize that the message is hidden in very small temperature fluctuations in the CMB (of order  $10^{-5}$ ), presumably resulting from primordial density perturbations. As a specific suggestion for how the encoding might be done, let us assume that inflationary cosmology (to which we are by no means committed for the purpose of this paper) is correct and suppose that before the Big Bang the Creator fine tuned the inflaton potential with small deviations from flatness. These would lead to deviations from the usual scale-invariant spectrum of density perturbations. The three symbols  $(2, -1, 0)$  appearing in the Cartan matrices can be encoded by adjusting the potential to produce above, below or exactly average amplitudes of fluctuation during the evolution of  $\phi$ . (A “full stop” or period might be signified by a sharper spike in amplitude.) These amplitudes would be reflected by variances at different length scales, or equivalently, values of  $C_l$ . In the slow-roll approximation, the amplitude of density fluctuations is given by the ratio between the square of the Hubble parameter  $H^2$  and the rate of change of the inflaton field,  $\dot{\phi}$ , and so is controlled by the precise shape of the inflaton potential [6]. An advanced civilization, having independently measured the number of baryons, amount of dark energy, and so forth in the universe, could detect any small deviations from what would have resulted from scale invariant density perturbations, and interpret these as an encoded signal. We also assume that (as one definition of “advanced”) an advanced civilization will be able to de-convolve subsequent evolution of the CMB due to classical physics.

Regardless of the method employed, the amount of in-

formation that could be encoded in the numbers  $C_l$  is limited, due to cosmic variance. Assuming  $l < l_{\max}$ , how well can the  $C_l$ 's be measured? If the limiting resolution is of order  $1/\sqrt{l}$ , then the logarithm of the total number of possible messages is of order

$$\ln N \sim \ln \prod_{l=1}^{l_{\max}} \sqrt{l} \sim \frac{1}{2} \sum_{l=1}^{l_{\max}} \ln l \sim \frac{1}{2} l_{\max} \ln l_{\max}. \quad (3)$$

Taking  $l_{\max} \sim 10^4$ , we estimate no more than  $10^5$  bits of information can be encoded. This might be enough to give the first few dozen or so Cartan matrices (to establish the pattern of encoding) and the final result specifying the grand-unified gauge group and perhaps the matter representations.

Of course this is just one specific suggestion. Perhaps our collective scientific mind is still too puny to guess what the message on the billboard in the sky might read. For instance, string theorists might argue that the message would simply specify the correct string theory, assuming that such a thing exists. Certainly, many other possible messages exist [7].

We can also think of other ways of encoding [8] the message itself, and again our present knowledge of quantum mechanics and cosmology may be insufficiently advanced. Our current understanding is that the primordial fluctuations are due to quantum fluctuations. Perhaps the superior Beings are able to manipulate quantum fluctuations at will. (That may be taken as one manifestation of being superior.) We simply do not understand quantum mechanics beyond the algorithmic level. Or perhaps the “finger of God” came down during recombination and photon decoupling to imprint the desired fluctuations on the cosmic microwave background. While requiring active intervention in our universe, this is at least far more plausible than the finger of God rearranging the genomic sequence of *Homo sapiens* at some point during our evolution.

Coming to the end of our short paper, we allow ourselves to indulge in a wild speculation. Even if a hidden message turns up in the CMB, nothing in this paper requires that the superior Being (or the Ultimate Designer [1] as one of us prefers) is theistic rather than deistic in character [9]. On the other hand, perhaps the Ultimate Designer — the pimply-faced teenager mentioned in the introduction — could himself, herself, or itself live in a theistic universe. There may be levels of universes, with Ultimate Designers all the way up. Even if our own universe, which we now understand to occupy the lowest level, may be merely deistic, some of these universes could well be theistic. We could easily persuade ourselves that the notion of a hierarchy of universes is more appealing than the notion of casually disconnected parallel universes.

In conclusion, we believe that we have raised an intriguing possibility: a universal message might be encoded in the cosmic background. When more accurate CMB data becomes available, we urge that it be ana-

lyzed carefully for possible patterns. This may be even more fun than SETI.

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- [1] A. Zee, “Fearful Symmetry”, Princeton University Press, 1999 edition, page 295.
- [2] Creating a universe in a lab using inflationary dynamics of false vacuum bubbles was explored by several authors; Linde suggested using fine-tuned physical constants to send a message to the occupants. See, A. Linde, Nucl. Phys. B372: 421 1992; S. K. Blau, E.I. Guendelman and A. H. Guth, Phys. Rev. D35: 1747,1987; E. Farhi and A. H. Guth, Phys. Lett. B183: 149,1987; E. Farhi, A. H. Guth and J. Guven, Nucl. Phys. B339: 417,1990
- [3] See for example, S. Dodelson, “Modern Cosmology”, Academic Press, 2003, page 241. For the reader’s convenience we recall here the definition of  $C_l$ . The microwave temperature  $T(x, \hat{p}, \eta) = T(\eta)[1 + \Theta(x, \hat{p}, \eta)]$  measured from the point  $x$  in the direction  $\hat{p}$  at cosmic time  $\eta$  defines the fractional temperature deviation  $\Theta(x, \hat{p}, \eta)$ , which when expanded in spherical harmonics  $\Theta(x, \hat{p}, \eta) = \sum_{l=1}^{\infty} \sum_{m=-l}^l a_{lm}(x, \eta) Y_{lm}(\hat{p})$  defines the quantities  $a_{lm}$ . While we have only a single observable universe, it is commonly assumed that its CMB is drawn from a statistical distribution with  $\langle a_{lm} \rangle = 0$  and  $\langle a_{lm} a_{l'm'} \rangle = \delta_{ll'} \delta_{mm'} C_l$ .
- [4] It is an intriguing fact that the sequence  $E(6) \rightarrow SO(10) \rightarrow SU(5)$  could be obtained by successively chopping off a circle starting with the Dynkin diagram for  $E(6)$ . Mathematically,  $SO(10)$  could be regarded as  $E(5)$  and  $SU(5)$  as  $E(4)$ .
- [5] A highly useful review was given by R. Slansky, Phys. Rept. 79 (1981) 1. See in particular Section 4, Tables 5 and 6.
- [6] To encode many symbols might require rapid variation of  $\phi$ , violating the slow-roll approximation. But of course our current understanding of inflationary dynamics is quite rudimentary – limited to models which are easy to analyze.
- [7] For example, another suggestion might be the sequence of prime numbers, but this strikes us as not informative enough. (One may even conceive of civilizations for which the prime numbers may not hold as much fascination as for our own.)
- [8] Another possibility might be to hide the message inside the fine structure “constant” or some other parameter of physics. Aside from the fact that the fine structure constant evolves due to renormalization (hence is scale dependent), experimental considerations may make it hard to measure any constant to  $10^5$  bits of accuracy. Consequently, the encoded message must be even shorter.
- [9] A. Zee, “Fearful Symmetry”, Princeton University Press, 1999 edition, page 293.