The Census Taker’s Hat

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Abstract  If the observable universe really is a hologram, then of what sort? Is it rich enough to keep track of an eternally inflating multiverse? What physical and mathematical principles underlie it? Is the hologram a lower dimensional quantum field theory, and if so, how many dimensions are explicit, and how many “emerge?” Does the Holographic description provide clues for defining a probability measure on the Landscape?

The purpose of this lecture is first, to briefly review a proposal for a holographic cosmology by Freivogel, Sekino, Susskind, and Yeh (FSSY), and then to develop a physical interpretation in terms of a “Cosmic Census Taker:” an idea introduced in [1]. The mathematical structure – a hybrid of the Wheeler-DeWitt formalism and holography – is a boundary “Liouville” field theory, whose UV/IR duality is closely related to the time evolution of the Census Taker’s observations. That time evolution is represented by the renormalization-group flow of the Liouville theory.

Although quite general, the Census Taker idea was originally introduced in [1], for the purpose of counting bubbles that collide with the Census Taker’s bubble. The “Persistence of Memory” phenomenon discovered by Garriga, Guth, and Vilenkin, has a natural RG interpretation, as does slow roll inflation. The RG flow and the related C-theorem are closely connected with generalized entropy bounds.

1 Introduction

Of all the “String Inspired” cosmological scenarios, only one seems to me to have an element of inevitability to it. The facts and principles that drive it are as follows:

• Observational evidence supports the existence of a period of slow-roll inflation during which the universe exponentially expanded by a factor no less than $e^{50}$.
The universe grew to a size which is at least 1,000 times larger (in volume) than the portion which is observable.

- A small residual vacuum energy of order $10^{-123} M_p^4$ remained at the end of inflation and now dominates the energy density of the universe. If this situation persists, then not only is the universe at least 1,000 larger than what can be seen; it is 1,000 larger than what can ever be seen [2, 3].

- String Theory apparently gives rise to an immense Landscape of de Sitter vacua [4–7] with a very dense “discretuum” of vacuum energies. None of these vacua are absolutely stable: each can decay to vacua with smaller cosmological constant.

- Black Hole (or Observer) Complementarity [8–10], and the Holographic Principle [11, 12], have been confirmed by string theory, at least in a certain wide class of backgrounds [13–15]. The implication is twofold. On the one hand, observer complementarity requires the identification of a causal patch; conventional quantum mechanics only makes sense within such a patch. The Holographic Principle requires that a region of space be described by boundary degrees of freedom whose number does not exceed the area, measured in Planck Units.

- Inflation, if it lasts long enough, has a tendency [16–21] to populate the Landscape with a great diversity of nucleated “pocket universes.”

The first two items imply that all of observable cosmology consisted of a roll from one value of the vacuum energy (probably no bigger than $10^{-14} M_p^4$), to its final current value. How and why the universe began with such an unnatural energy density is not explained by any standard theory, but the Landscape suggests the following guess: At some point in the remote past the universe occupied a point on the Landscape with a much higher vacuum energy, perhaps of order one in Planck units. Rolling, unimpeded, to a vacuum energy of $10^{-14}$ without getting stuck in a local minimum is unlikely. (Think of rolling a bowling ball from the top of Mount Everest to sea level.) It is far more likely that the universe would get stuck in many minima, and have to tunnel [22] multiple times, before arriving at the very small vacuum energy required by conventional slow-roll inflation. We will not dwell on Anthropic issues in this paper, but I would point out that a long period of conventional inflation appears to be required for structure formation [23]. The argument is similar to the well-known Weinberg argument concerning the cosmological constant.

These considerations strongly suggest that the period of conventional slow-roll inflation was preceded by a tunneling event from a previous neighboring vacuum. In other words, the observed universe evolved by a sudden bubble nucleation from an “Ancestor” vacuum, once removed on the Landscape. It seems obvious that one of the next big questions for cosmology will be to find the theoretical and observational tools to confirm or refute the past existence of an Ancestor, and to find out as much as we can about it. If we are lucky and the amount of slow-roll inflation that followed bubble nucleation is as small as observational evidence allows, then we have a chance of seeing features of the Ancestor imprinted on the sky [23]. The two smoking guns would be: