DOES THE UNIVERSE IN FACT CONTAIN ALMOST NO INFORMATION?

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At first sight, an accurate description of the state of the universe appears to require a mind-bogglingly large and perhaps even infinite amount of information, even if we restrict our attention to a small subsystem such as a rabbit. In this paper, it is suggested that most of this information is merely apparent, as seen from our subjective viewpoints, and that the algorithmic information content of the universe as a whole is close to zero. It is argued that if the Schrödinger equation is universally valid, then decoherence together with the standard chaotic behavior of certain non-linear systems will make the universe appear extremely complex to any self-aware subsets that happen to inhabit it now, even if it was in a quite simple state shortly after the big bang. For instance, gravitational instability would amplify the microscopic primordial density fluctuations that are required by the Heisenberg uncertainty principle into quite macroscopic inhomogeneities, forcing the current wavefunction of the universe to contain such Byzantine superpositions as our planet being in many macroscopically different places at once. Since decoherence bars us from experiencing more than one macroscopic reality, we would see seemingly complex constellations of stars etc., even if the initial wavefunction of the universe was perfectly homogeneous and isotropic.

Key words: complexity, chaos, symmetry-breaking, decoherence.
1. INTRODUCTION

One of the most striking features of the universe we inhabit is its complexity. When going swimming after setting up an over-night hydrodynamics batch job on the computer, it is easy to start marveling over the system of currents, waves and vortices in the pool, and ask oneself silly questions like "how on earth can nature calculate all this in real time?". Quite apart from the fact that many of the non-linear partial differential equations that nature appears to integrate with ease are numerically ill-posed as initial value problems, exhibiting chaotic behavior, the sheer number of bytes required to store the initial data for a system such as Niagara falls at a reasonable resolution are mind-boggling. Indeed, if we were to take classical General Relativity seriously, then space is a continuum locally isomorphic to $\mathbf{R}^3$, which means that to describe the location of something we need to specify three real numbers. Of course, this already constitutes an infinite amount of information — to specify a generic real number completely would be equivalent to specifying an infinite number of seemingly random decimals. Likewise, to specify a quantity such as the electric field $E$ at even a single point would involve specifying real numbers, i.e., an infinite amount of information. This has disturbed many authors in the past, and has been one of the motivations for attempts to replace continuum physics by some discrete alternative, e.g. [1-3].

In this paper, we will instead take the viewpoint of the old phrase “it’s just a figment of your imagination”, and argue that continuum physics can be maintained without involving infinite quantities of information, and indeed without invoking any new physics whatsoever. The argument will basically go as follows.

- The wave function of the universe shortly after the big bang had some quite simple form, which can be described with very little algorithmic information.
- By the Heisenberg uncertainty principle, this initial state involved micro-superpositions, microscopic quantum fluctuations in the various fields.
- The ensuing time-evolution involved non-linear elements that exhibited chaotic behavior (such as the well-known gravitational instability that is held responsible for the formation of cosmic large-scale structure), which amplified these micro-superpositions into macro-superpositions.
- In the no collapse version of quantum mechanics, the current wavefunction of the universe is thus a superposition of a large number of states that are macroscopically extremely different (Earth forms here, Earth forms one meter further north, etc).
- Since macroscopic objects inevitably interact with their surroundings,