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# The Infinite Fractal Universe

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With regard to cosmology, we live at a very privileged time. When we read about exciting and revolutionary paradigm changes, in which our most fundamental ideas about nature undergo radical revisions, the drama usually has taken place well before we were born. Today, however, we have the rare opportunity of witnessing at first hand a profound transformation in our understanding of how the Universe is structured. This ongoing change of cosmological paradigms from a “small” finite cosmos to an infinite fractal cosmos began about two decades ago and is in full swing at present.

The short version of what is happening goes like this. For about 50 years the Big Bang model of the Universe has provided an excellent explanation for the basic cosmological observations: a very large-scale expansion, an approximately uniform background of microwave radiation and a unique set of abundances for the atomic elements. However, there were some technical problems with this model, such as an acausal beginning of spacetime, a lack of magnetic monopoles, an unexpectedly high degree of uniformity, and an enigmatic knife-edge balance between the open and closed states. Then in the early 1980s Alan Guth showed how these and other problems with the Big Bang model could be solved in one fell swoop with the Inflationary Scenario<sup>1</sup>, which postulated a very brief period of ultra-rapid expansion shortly after the Big Bang. The theory of Inflation gained analytical and observational support over time and is now fully accepted by cosmologists as a cornerstone of the Big Bang paradigm. But, an ironic thing has happened. Although the Inflationary Scenario was developed to rescue the Big Bang model, the most logical consequence of pursuing the concept of Inflation is the replacement the Big Bang paradigm with a much grander and more encompassing paradigm. According to Guth<sup>2</sup> and a growing number of leading cosmologists, the most natural version of Inflation theory is Eternal Inflation in which Inflation is, was and always will be occurring on an infinite number of size scales. The new paradigm that cosmologists have arrived at by several routes is an infinite fractal hierarchy that has “universes” within “universes” without end. The astronomer Carl Sagan<sup>3</sup> once referred to the general idea of an infinite fractal universe as “strange, haunting, evocative – one of the most exquisite conjectures in science or religion.”

That is the basic story, but because of the profound changes the fractal paradigm will have on our understanding of the Universe and the place of humans within that Universe, it is important to explore the implications of this new vision. Firstly, there is no edge or boundary of the Universe; space is infinite in all directions. What we used to refer to as “The Universe” can be more appropriately called the “observable universe”

(note the small “u”) or the “Hubble Volume,” and it is only a tiny part of what one might call our “metagalaxy” or “level 1 universe”. We currently have no way of determining the size of our metagalaxy or the number of galaxies it contains, but we could reasonably assume that both figures would be vastly beyond anything previously contemplated. There would be an infinite number of these level 1 universes, and on an unimaginably large scale they too would be organized into level 2 universes, and so on without limit. Secondly, time is also infinite in the unbounded fractal Universe. Whereas our Hubble Volume may have come into being and began to expand approximately 13.7 billion years ago, the Universe has always existed and always will. Parts of the Universe may be created or annihilated, may undergo expansion or contraction, but the infinite fractal hierarchy remains unchanged overall, and thus is without any temporal limits. Thirdly, there is no limit to size scales. In the infinite fractal paradigm there is no class of largest objects that would cap off the cosmological hierarchy; the hierarchy is infinite in scale. This fact removes one of the more suspect aspects of the old paradigm. Natural philosophers had long noted the unusual fact that within the Big Bang paradigm humans found themselves roughly in the middle of nature’s hierarchy of size scales. This anthropocentric state of affairs seemed to violate the Copernican concept that when humans appear to be at the center of the cosmos, we should suspect that a bias is leading us astray. In an infinite fractal hierarchy there is no center of the Universe, nor any preferred reference frame.

Some interesting questions immediately arise. Why are fractal hierarchies so ubiquitous in nature? By studying empirical phenomena within the observable universe, how much will we be able to learn scientifically about the parts of the Universe that lie beyond our observational limits? Does the infinite cosmological hierarchy have a bottom-most scale of sub-atomic particles as is currently thought, or is this another artificial limit to an infinite fractal Universe that actually extends without limits to ever-smaller scales?

Centuries ago Immanuel Kant, J.H. Lambert and a few others proposed an infinite hierarchical model of nature based largely on natural philosophy arguments. This general hierarchical paradigm never garnered a large following, but it was kept alive by numerous rediscoveries. In the 1800s and 1900s quite a few scientists, including E.E. Fournier d’Albe, F. Selety, C.V.L. Charlier and G. de Vaucouleurs, argued for hierarchical cosmological models based on the hierarchical organization within the observable universe. Then towards the end of the 1970s, the mathematician B. B. Mandelbrot<sup>4</sup> gave the hierarchical paradigm new life and widespread exposure by developing the mathematics of fractal geometry and demonstrating that fractal phenomena based on hierarchical self-similarity are ubiquitous in nature. In this way natural philosophers, empirical scientists, mathematicians and theoretical physicists have all found their way, slowly but surely, to the infinite fractal paradigm. There are many routes to this paradigm, and certainly there are a large number of distinct versions<sup>5,6,7</sup> of the basic paradigm that have their own unique theoretical explanations for why nature is organized in this manner, but the general paradigm that nature is an infinite hierarchy of worlds within worlds has fully arrived, and will probably be our dominant cosmological paradigm for the foreseeable future.

## References

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