How Problematic is the Near-Euclidean Nature of the Universe's Spatial Geometry ?

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Abstract

With the advent of non-Euclidean geometries in the nineteenth century, the extent to which "physical space" can be described in terms of the Euclidean notions of geometry that held sway for more than two millenia became a pressing open question. As emphasized by Riemann in his celebrated 1854 inaugural lecture [1], the geometrical nature of physical space can only be deduced from experience and it is a well known fact that Riemann's insight played a key role in the development of Einstein's general theory of relativity, in which gravitation is viewed no longer as a force, but instead, as a manifestation of spacetime curvature. Quite remarkably, modern observations based on Einstein's theory indicate that the spatial geometry of the expanding universe on the largest accessible distance scales is very nearly Euclidean [2]. This basic empirical fact is at the core of the so-called "flatness problem", which is widely perceived to be a major outstanding problem of modern cosmology and as such forms one of the prime motivations behind inflationary models. An inspection of the literature and some further critical reflection however quickly reveals that the typical formulation of the flatness problem is fraught with many questionable arguments and misconceptions and that it is moreover imperative to distinguish between different varieties of problem. I will argue that the observational fact that the large-scale universe is so nearly flat is ultimately no more puzzling than similar "anthropic coincidences", such as the specific (orders of magnitude of the) values of the gravitational and fine-structure constants. In particular, there is no fine-tuning problem. The usual arguments for the flatness and horizon problems found in inflationary discourses in fact address a mere *single* issue underlying the standard FLRW cosmological models, but this single issue becomes a genuine theoretical problem only under additional assumptions, which are usually kept implicit and are at any rate highly speculative.

References

[1] Riemann, G. F. B., *Über die Hypothesen, Welche der Geometrie Zugrunde Liegen* (1854), Göttingen Inaugural Lecture.

[2] Ade, P. A. R. et al. (2016), "Planck 2015 Results. XIII. Cosmological Parameters," Astronomy & Astrophysics, Planck Collaboration. arXiv : `1502.01589`.