Holography and Emergence

Dennis Dieks
History and Philosophy of Science, Utrecht University

In the search for a quantum successor to Einstein's GRT, "holography" has become an important theoretical principle. The core idea of holography is that a lower dimensional quantum theory without gravitation (for instance, defined on the two-dimensional surface of a sphere) is capable of describing physical phenomena that include manifestations of gravity in a higher dimensional spacetime (such as the interior of the sphere).
This important idea raises several questions that relate not only to theoretical physics but also to more general foundational, conceptual and philosophical issues. Most importantly, holographic ideas touch on philosophical questions of emergence and reduction.

That gravity has a peculiar status among all physical forces may to some extent be called intuitively plausible. Gravity distinguishes itself because it is universal: it applies to all forms of matter and energy, and relates to the general framework of space and time itself---this might strike one as similar to the universal character of thermodynamic descriptions and might suggest that gravity originates from some deeper layer of reality. Moreover, gravity is notoriously more difficult to quantize than other forces. This suggests that gravity possesses properties that are not shared by the ordinary physical forces represented in the standard model. Moreover, studies of black hole physics have led to the hypothesis that many or perhaps all results of quantum gravity theories within a volume can be stated in terms of physical properties of the boundary of this volume. This seems only a small step from the notion that gravity in the bulk is generated by processes described on the surface of the bulk. Ideas of this kind will be critically considered here.

I intend to discuss a number of detailed holographic scenarios in order to see whether it is justified to say that they provide examples of emergence of gravity or/and space-time. Roughly speaking, the definition of emergence to be used here is the possibility of a transition to a new level of description in which novel behavior is displayed---a behavior that in its general features is robust under variations in the details of the physics of the pre-emergence level (as in the transition from the description of systems in terms of atoms and molecules to a statistical or thermodynamic description). This question of emergence is directly related to the question of whether one theory in a holographic pair can justifiably be called more fundamental than the other.

The first scenario to be discussed is 't Hooft's original formulation of the holographic hypothesis; the second is the AdS/CFT duality from string theory, and the third is Erik Verlinde's recent proposal to view gravity as a phenomenon that is grounded in statistical processes. Although these proposals bear affinities to each other, I will argue that only Verlinde's account realizes emergence in a straightforward and uncontroversial way: gravity and spacetime here arise as thermodynamic phenomena in a coarse-grained description of micro phenomena in which there is no gravity. That means that the concept of emergence, of higher dimensional gravity from lower dimensional non-gravitational processes, does not apply to AdS/CFT in its usual interpretation. However, the analysis of Verlinde's scheme may cast new light on the interpretation of AdS/CFT, and it may accordingly be possible to create room for emergence also in that context.

Reference.

Dennis Dieks, Jeroen van Dongen and Sebastian de Haro, "Emergence in Holographic Scenarios for Gravity",
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