How is matter created in our Universe?

Accurate measurements of the cosmic microwave background provide strong evidence that our Universe went in its earliest stage through a brief period of exponential expansion called inflation. How the inflaton field, which is responsible for inflation, gets transformed into the matter observed in the current universe is still a puzzle. Scientists have now developed a new technique to simulate this process for the first time with a new class of strongly coupled theories.

Moments before the Big Bang our Universe is believed to have a short period of exponential expansion that left the Universe cold and almost empty. After this expansion there hence has to be reheated to transition to the Big Bang at an extremely high temperature. While there are many proposals to model this reheating phase it is still an open problem how to arrive at the hot matter in thermal equilibrium that then proceeds with the Big Bang, also since there are no direct observations at this early time.

In new work, Christian Ecker, Elias Kiritsis and Wilke van der Schee describe a novel mechanism that both efficiently deposits energy in the empty universe and dynamically thermalises this energy into the radiation of which traces we can still see today. "Our method generalizes a mathematical relationship found in string theory, namely the correspondence between five-dimensional black holes and strongly interacting matter, to describe in a self-consistent way the expansion of the universe together with the energy transfer from the inflaton field to strongly coupled quantum matter", explains study co-author Dr. van der Schee affiliated to CERN and Utrecht University.

In their new method the thermal radiation of the big bang can be computed from the properties of a corresponding higher dimensional black hole as illustrated in the cartoon displayed in the figure below. A crucial feature of the strongly interacting model is that the quantum fields thermalise almost as fast as possible, which is generally a challenge in models with weaker interactions. Study co-author Prof. Kiritsis from APC Paris and the University of Crete says: "Our new method opens the gate to study the cosmological consequences of an entirely unexplored class of strongly coupled theories."

Currently their pioneering work is an interesting proof of principle of this novel mechanism which is not yet directly applicable to our Universe. "As a next step we try to couple the quantum fields in our holographic theory to the ‘normal’ particles of the Standard Model with the goal of modelling a Universe that closely resembles our own.", adds study co-author Dr. Ecker from Goethe University Frankfurt.

The results of this study have been recently published as a Physical Review Letter (link to PRL).
Corresponding author: Wilke van der Schee (wilke.s@cern.ch)

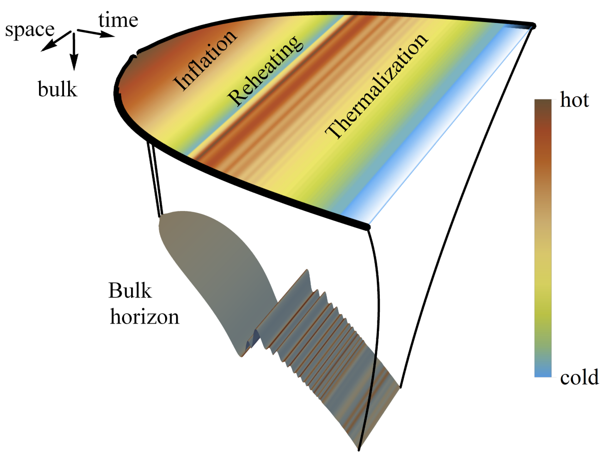

Figure 1: Illustration of the new method: the researchers compute the temperature of the expanding universe (top) from the properties of a five-dimensional black hole (bottom). After the initial inflationary expansion the universe is cold and empty and only after the inflaton field decays the universe is reheated and populated with matter.