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A mysterious blowup in cosmological effective field theories

By Prof. Jean-Pierre Eckmann

The lecture delved into the problem of singularities and divergences in cosmological effective field theories, emphasizing their mathematical and physical implications for our understanding of the universe's evolution.

Prof. Eckmann began by framing the central question: *How long does the universe live?*—a provocative inquiry that, in this context, refers not to cosmic lifespan in a biological sense, but to the persistence of well-behaved mathematical solutions describing the universe's dynamics. Within cosmological EFTs, the emergence of divergences often signals a breakdown of the effective description, suggesting that new physical mechanisms or scales must be introduced beyond that point.

A key insight from the talk was the analogy between cosmological equations and Burgers' equation, a fundamental nonlinear partial differential equation known for its shock-forming, diverging solutions. By studying the shape and behavior of these divergences, Prof. Eckmann showed that cosmological field theories can exhibit similar phenomena: when there is mass concentration near the edge of the initial condition's support, the solutions may evolve toward singularities within finite time. This leads to a "blowup," where quantities like density or potential become infinite, marking the end of the effective theory's validity.

The lecture also touched upon cosmological gravitational potential fluctuations, which play a crucial role in the structure formation of the universe. These fluctuations, when modeled through effective field approaches, may experience instabilities analogous to those in simpler nonlinear systems. Prof. Eckmann proposed that the true divergence time in such cosmological models should be derived by comparison with the divergence time of Burgers' equation, offering a powerful heuristic for estimating when and how breakdowns occur in complex systems.