Numerical Exploration of Cosmic Evolution in FLRW Universes with Various Dark Energy Models

Introduction:

The interaction between local cosmic structures (like voids) and the overall dynamics of the expansion of the universe is a fascinating area of cosmology. A well-defined spherically symmetric model that incorporates varying densities and considers local gravitational effects could yield new insights into the interplay between structure formation and cosmological expansion. Ultimately, if it can be shown that our observation of accelerated expansion could be derived from these local effects, it may lead to a paradigm shift in understanding dark energy and the universe's fate.

Basic equations:

We will consider a homogeneous and isotropic universe given by Friedmann-Lematrie-Robertson-Walker (FLRW) space-time. The main goal is to solve the corresponding system of equations in presence of source field given by various types of dark energy. Further compare the theoretical results with observational data such as i) Hubble parameter data H(z), ii) Luminosity distance vs. redshift dL(z) for type Ia supernovae using publicly available datasets (e.g., Union2.1, Pantheon).

Beside learning the basic ideas of modern cosmology the participant can learn to i) build numerical solvers for the Friedmann system, ii) simulate different dark energy models, iii) visualize and interpret cosmic expansion histories and iv) write a brief report or give a presentation on findings.

The participant should have some ideas about tensor analysis (if not we will help), numerical methods to solve system of differential equations, and definitely good level of English to communicate.

Weinberg S., Gravitation and Cosmology. Principles and Applications of the General Theory of Relativity. John Wiley and Sons. 1972

Narlikar J. V., An Introduction to Relativity. Cambridge University Press. 2010

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