MAGIC

Science of the Cosmos

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Expansion of the Universe in Bianchi I Cosmology

The standard cosmological model assumes spatial homogeneity and isotropy, assumptions that are supported by cosmic microwave background observations on scales larger than 100 Mpc. However, local measurements suggest that these assumptions may break down at smaller scales. In this work, we revisit the Friedmann model and extend its methodology to the anisotropic Bianchi I metric, which allows for distinct scale factors along each spatial direction. We derive the equations of motion for these scale factors and define directional Hubble functions analogous to the standard Hubble parameter. The energy densities of cosmological fluids (matter, radiation, and cosmological constant) are adapted to the anisotropic framework, incorporating directional pressure components.

Analytical solutions for the scale factors are obtained for matter-dominated and cosmological-constant-dominated universes, revealing asymptotic convergence to the Friedmann solutions at late times. Our results confirm that anisotropies decay as $t^{2/3}$ in a matter-dominated era and as $e^{\sqrt{\Lambda/3}\,t}$ in a Λ-dominated regime, preserving consistency with large-scale isotropy. Future work will focus on expressing directional Hubble functions in terms of redshift and angular position to probe anisotropies at different scales using type Ia supernovae and low-z galaxies, aiming to determine the scale below which the Friedmann model ceases to be valid.

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