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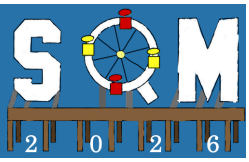

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Cosmic Trajectories calculation with state of the art lattice QCD equation of state

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We compute the full cosmic trajectories of the early Universe across the QCD phase diagram as the plasma cools from $T \simeq 500$ MeV to 30 MeV, assuming β-equilibrated matter.
The trajectories are obtained by simultaneously solving baryon-number, electric-charge, and lepton-asymmetry conservation, closed by a state-of-the-art lattice-QCD equation of state: a fourth-order Taylor expansion in the chemical potentials that merges the latest $(2+1)$-flavor susceptibilities with charm-quark contributions, thus delivering a consistent $(2+1+1)$-flavor equation of state.
Results are compared with an ideal quark-gluon plasma and with a hadron-resonance gas to highlight interaction effects.
Two cases of primordial lepton asymmetries are analyzed: a symmetric configuration ($\ell_e = \ell_\mu = \ell_\tau = \ell/3$) and an asymmetric one ($\ell_e = 0,\ \ell_\mu = -\ell_\tau$).
Increasing $|\ell|$ systematically drives the trajectories toward larger values of μ_B and more negative μ_Q. In the asymmetric case, a non-monotonic "bounce"develops when the τ chemical potential reaches m_τ, generating a maximum in $\mu_B(T)$, the position of which depends on ℓ_τ. Assuming a modest μ_Q-dependence of the lattice-QCD critical end point estimates (obtained at $\mu_Q = 0$), the trajectories for all lepton asymmetries explored ($|\ell|$
$lesssim 0.1$) lie to their left, implying that in a standard cosmological scenario the QCD transition is almost certainly a smooth crossover. Nevertheless, we estimate the magnitude of baryon and lepton asymmetries needed to obtain a cosmic trajectory closer to the QCD critical point, providing inputs for future studies of the strong-interaction epoch.

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