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Cosmic Evolution of the Standard Model Flavor Charges

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Since all the Standard Model (SM) parameters have been measured to precision at the percent level or smaller, one would aim to have a framework which describes baryogenesis as precise as possible, where the measured SM parameters are used as inputs. At high temperature before the electroweak symmetry breaking, the SM contains 15 approximate U(1) symmetries with the associated flavor charges. To describe the evolutions of these flavor charges in a flavor-basis-covariant manner such that physical observables are flavor-basis-independent, a total of five density matrices in flavor spaces are required: three for quarks and two for leptons. Taking into account the quantum chromodynamics and electroweak sphaleron interactions together with all the Yukawa interactions, we obtain the complete flavor-covariant Boltzmann equations. By imposing chemical equilibrium in the lepton sector, we further derive a new effective quark-flavor-covariant formalism which can be used when baryogenesis occurs through number asymmetry generation in the quark sector. To verify the consistency of this complete formalism, we first apply it to leptogenesis scenarios, reproducing previous results which utilize the effective lepton-flavor-covariant formalism up to small corrections due to the quark chemical equilibrium approximations used in the latter formalism. Then, for the first time, we apply the complete formalism as well as the effective quark-flavor-covariant formalism to a cloistered baryogenesis scenario where number asymmetries are generated in the quark sector, showcasing the good agreement between the results from the two formalisms. Finally, we release the first generic baryogenesis public code BOLEH (BaryOn and Lepton charge Evolution in the Hot big bang) where all the SM interactions are taken into account.

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