Qualitative Analysis of Born-Infeld Electrodynamics as an Effective Cosmological Fluid

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We investigate the dynamics of a homogeneous and isotropic Friedmann–Lemaître–Robertson–Walker (FLRW) universe populated by stochastic Born-Infeld (BI) electromagnetic fields. BI is a nonlinear electrodynamic (NLED) theory introduced to solve the problem of the infinite self-energy of a point charge in Maxwell theory. To ensure that the BI effective fluid is consistent with the FLRW metric, we average the stochastic background fields using a weighted version of the standard Tolman-Ehrenfest procedure, specific to NLED theories. We investigate whether the dynamics of an early-time FLRW universe dominated by a BI effective fluid allows for the amplification of magnetic fields as a proposed solution for the problem of cosmological magnetogenesis. Additionally, under a modification of the BI Lagrangian, equivalent to the addition of a cosmological constant, the dynamics admit a bouncing solution within the physical regime for a closed universe; while the flat and open universes admit either a monotonically increasing or decreasing scale factor, $\dot{a} \neq 0$. Without the modification, a BI fluid-only universe is unable to violate the strong energy condition, $\rho_{BI} + 3p_{BI} \geq 0$, and thus cannot produce the accelerated expansion of the universe or a bounce. In on-going work we aim to investigate the propagation of perturbations in the background bouncing and flat universe solutions, using the covariant framework for gauge-invariant perturbations. It is important to note that in order to close the dynamical system used to model the background, we are required to assume a static relationship between the electric and magnetic field magnitudes. We choose the simplest case of proportionality, $E^2 = \sigma B^2$, where $\sigma \geq 0$. In the infinite conductivity limit ($\sigma = 0$), corresponding to ideal magneto-hydrodynamics (MHD), we find that the unmodified BI fluid behaves qualitatively the same as Maxwell electrodynamics, and similarly for the modified case, with the introduction of a cosmological constant. The choice of closure condition is made for simplicity and will be generalised in future work.