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Primordial magnetic fields during the electroweak crossover and baryogenesis from magnetic helicity decay

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Magnetic fields are ubiquitous in the present universe. Their existence has been discussed as a relic from the early universe, which may be a consequence of some physics beyond the Standard Model. In particular, if primordial magnetic fields were generated at high temperatures, the electroweak symmetry breaking implies a transition from the hyper- (U(1)Y) magnetic field in the high-temperature phase to the ordinary (U(1)em) magnetic field in the low-temperature phase. However, this transition process has been understood only naively. We examine the electroweak symmetry breaking from the viewpoint of symmetry-breaking pattern, and characterize the evolution of magnetic fields across the crossover in a gauge-invariant manner. In particular, we point out that the baryogenesis scenario based on primordial magnetic fields suffers from both quantitative and qualitative uncertainties. This makes the previously-proposed cosmological constraints on primordial magnetic fields, which concern two baryon asymmetry problems, less robust. Consequently, the co-genesis scenario for the intergalactic magnetic fields and the baryon asymmetry of the universe may revive

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