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Dark Matter, Baryogenesis, and Gravitational Waves from Axion Rotations

We propose a paradigm where the (QCD) axion's unexplored cosmological evolution, a rotation in the field space, gives rise to the dark matter abundance, the observed baryon asymmetry of the Universe, and/or gravitational waves. The rotation is initiated by explicit Peccei-Quinn symmetry breaking effective in the early Universe. The abundance of axion dark matter is determined by the rotational speed via the mechanism we call kinetic misalignment. With the aid of the Standard Model sphaleron processes (and potentially the neutrino Majorana mass term), the Peccei-Quinn charge associated with the rotation is transferred to the baryon asymmetry. We name these baryogenesis mechanisms by axiogenesis (and lepto-axiogenesis). The paradigm with dark matter and baryogenesis predicts 1) an axion coupling stronger than predicted by the conventional evolution and 2) an electroweak phase transition temperature higher than in the Standard Model (or instead the presence of the neutrino Majorana mass). If the axion couples to a dark photon, this new axion dynamics can also generate gravitational wave signals across the entire range of observable gravitational wave frequencies.

Primary authors: CO, Raymond (University of Minnesota); HARIGAYA, Keisuke (Institute for Advanced Study); PIERCE, Aaron (University of Michigan)

Presenter: CO, Raymond (University of Minnesota)

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