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The shift-invariant orders of an ALP

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Usually, effective field theories (EFTs) for axion-like particles (ALPs) are built assuming a shift symmetry for the ALP due to the global U(1) Peccei-Quinn (PQ) symmetry that is at the heart of the axion mechanism. However, it is generally believed that global symmetries, in particular axion shift symmetries, can only be approximate. Therefore, it is important to include shift-breaking interactions in the EFT description and find a clear way to implement the different power countings of the shift-conserving and shift-breaking sectors. Focusing on the flavorful effective Yukawa couplings to Standard Model fermions, I will present Jarlskog-like flavor invariants which act as order parameters for shift symmetry breaking of the axion. In this description, shift-breaking couplings are characterized in an explicit and flavor-invariant way and it is straightforward to give different power countings to the shift-conserving and shift-breaking sectors. I will discuss properties of the invariants like their evolution under RG flow and their connection to CP violation. Finally, I will discuss examples of matching UV theories to the invariants and how they can be used to identify shift-breaking contributions in observables.

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