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A Natural Dark Matter–Dark Energy Interaction from Axion–Monopole Dynamics

We propose a natural framework for interacting dark matter and dark energy based on axion–monopole dynamics in a dark gauge sector. Dark matter is composed of dark 't Hooft–Polyakov monopoles, while dark energy is an ultralight axion whose coupling to the dark gauge field induces an axion-dependent dyon mass through the Witten effect. This generates a direct dark matter–dark energy interaction. We show that generic models with a significant dark matter–dark energy coupling suffer from a naturalness problem: the Coleman–Weinberg potential induced by the interaction is typically much larger than the dark-energy scale. In our model, the corrections arise from a monodromy tower of dyon states, allowing them to be exponentially suppressed. In the minimal setup, the interaction strength is predicted to be $\sim 0.1\%$, below the sensitivity of current observations. We discuss scenarios in which cosmological population of higher-charge dyons can enhance the interaction to the percent level, producing an apparent phantom dark-energy equation of state.

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