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Cosmologically Varying Kinetic Mixing

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The portal connecting the invisible and visible sectors is one of the most natural explanations of the dark world. However, the early-time dark matter production via the portal faces extremely stringent late-time constraints. To solve such tension, in our recent work arXiv:2302.03056, we construct the scalar-controlled kinetic mixing varying with the ultralight ($10^{-33}\text{eV} < m_0 \ll \text{eV}$) CP-even scalar's cosmological evolution. In this talk, I will introduce how do we naturally realize this and eliminate the constant mixing term. Via the time-varying mixing, the keV – MeV dark photon dark matter is produced through the early-time freeze-in when the scalar is misaligned from the origin and free from the late-time exclusions when the scalar does the damped oscillation and dynamically sets the kinetic mixing. We also find that the scalar-photon coupling emerges from the underlying physics, which changes the cosmological history and provides the experimental targets based on the fine-structure constant variation and the equivalence principle violation. To protect the scalar naturalness, we discretely re-establish the broken shift symmetry by embedding the minimal model into the $\mathbb{Z}_N$ -protected model.

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