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Parameter space and mediator properties of a 2HDM+a portal to dark energy and dark matter

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Cosmological data measure the dark-energy equation of state w at the percent level, but leave its microphysics largely undetermined, since distinct theories can reproduce the same expansion history. In the broad class of k-essence models, dark energy is a dynamical scalar with a non-canonical kinetic term, and the sound speed c_s^2 of its perturbations is what separates these theories, yet it remains essentially unconstrained. An approximate shift symmetry, which keeps the scalar light, allows it to interact with new particles only through derivatives. Through such interactions, c_s^2 would leave its imprint on the partial widths and branching ratios of a new pseudoscalar mediator, opening a possible collider window on dark-energy microphysics.

The framework is the two-Higgs-doublet model with a pseudoscalar mediator (2HDM+a), where the dark sector couples to a gauge-singlet pseudoscalar that mixes with the CP-odd state of the two Higgs doublets. This setup is a standard benchmark for dark-matter searches at the LHC and, in part of its parameter space, a candidate explanation of the excess observed near the top-quark threshold. Dark matter and dark energy would then communicate with the Standard Model through this common mediator, which inherits its couplings to quarks and leptons from the mixing. We map the regions of parameter space where this picture is viable under theoretical, electroweak-precision, and Higgs constraints, and show where dark energy reshapes the properties of the mediator. This provides the basis for future kinematic studies of the mediator's visible and invisible decay patterns, aimed at disentangling potential dark-energy and dark-matter contributions at the LHC and the FCC.

Academic position of the presenting author

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