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Glueball Dark Matter under Precision Control: Relic Abundance, Portals, and Direct Detection

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Confining dark sectors offer a minimal and predictive route to composite dark matter (DM). I connect nonperturbative glueball physics to cosmological evolution and to laboratory searches. Using lattice-calibrated thermodynamics, we revisit the relic abundance of stable scalar glueballs and show that strong-coupling effects can shift standard abundance estimates by up to an order of magnitude, yielding a robust mapping between the confinement scale and the observed DM density (including its dependence on the dark-to-visible temperature ratio). We then show how heavy-fermion portals can naturally suppress electromagnetic couplings of composite states, opening broad viable parameter space for heavy glueball/axion-like DM. Finally, I present new results for C-odd vector glueball ("oddball") DM coupled to photons via light electrically charged vector-like fermions portal, namely, its coherent nuclear scattering dominated by two off-shell photons. Matching an EFT to nonperturbative glueball form factors predicts a steep scaling, $\sigma_{\rm SI} \propto \Lambda_D^{2.15} m_\psi^{-8}$, so current and next-generation xenon detectors probe a distinctive light-portal window with $\Lambda_D \sim$ sub-GeV - few GeV and $m_\psi \sim$ few - tens of GeV, compatible with collider and precision constraints.

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