Pseudodyons from dark topological defects

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Dark photon by SU(2) → U(1) [→ Z_2]

Setup

Field Contents

$A_{\rm D}^a$: SU(2)$_{\rm D}$ Gauge Field

A: U(1)$_{\rm QED}$ Gauge Field

ϕ^a, η^a: SU(2)$_{\rm D}$ Adjoint scalar

Symmetry breaking

$$V(\phi,\eta) = \frac{\lambda_1}{2}\left(\phi^a\phi^a - v_1^2\right)^2 + \frac{\lambda_2}{2}\left(\eta^a\eta^a - v_2^2\right)^2 + \kappa\left(\phi^a\eta^a\right)^2$$

$(\lambda_1 v_1^4 \gg \lambda_2 v_2^4)$ $(\kappa > 0)$

$$\mathrm{SU(2)_D} \xrightarrow{\langle\phi^a\rangle = v_1\delta_3^a} \mathrm{U(1)_D} \xrightarrow{\langle\eta^a\rangle = v_2\delta_1^a} Z_2$$

Gauge field mixing

Kinetic mixing: $-\frac{c_1}{2\Lambda}\phi^a F_{\mu\nu}F_{\rm D}^{a\mu\nu} \rightarrow \frac{\epsilon}{2}F_{\mu\nu}F_{\rm D}^{\mu\nu}$

Magnetic mixing: $-\frac{c_2}{16\pi^2\Lambda}\phi^a F_{\mu\nu}\tilde{F}_{\rm D}^{a\mu\nu} \rightarrow -\frac{\theta_{\rm mix}}{16\pi^2}F_{\mu\nu}\tilde{F}_{\rm D}^{\mu\nu}$ (total derivative)

↑dimension 5 → naturally suppressed

(cf. U(1)$_{\rm QED}$×U(1)$_{\rm D}$ → $[\epsilon F_{\mu\nu}F_{\rm D}^{\mu\nu}] = 4$)

U(1)$_{\rm QED}$×U(1)$_{\rm D}$ description

$\frac{\epsilon}{2}F_{\mu\nu}F_{\rm D}^{\mu\nu}$

$-\frac{\theta_{\rm mix}}{16\pi^2}F_{\mu\nu}\tilde{F}_{\rm D}^{\mu\nu}$ (total derivative)

$F_{{\rm D}\mu\nu} := \frac{\phi^a}{v_1}F^a_{{\rm D}\mu\nu}$: Effective U(1)$_{\rm D}$ field strength

Valid away from monopoles

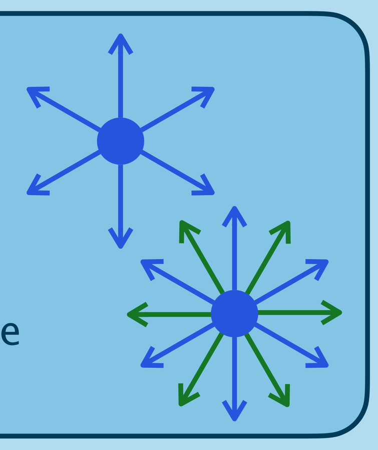
Topological Defects in the Dark Sector

Monopoles / Dyons

Formed at SU(2)$_{\rm D}$→U(1)$_{\rm D}$

Stabilized by $\pi_2\left(\mathrm{SU(2)/U(1)}\right) = \mathbb{Z}$

θ–term quantizes the electric charge

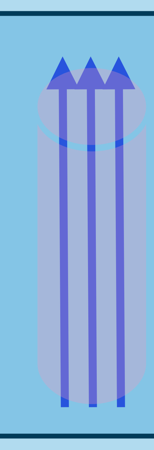


Strings

Formed at U(1)$_{\rm D}$ → Z_2

Stabilized by $\pi_1\left(\mathrm{SU(2)}/Z_2\right) = Z_2$

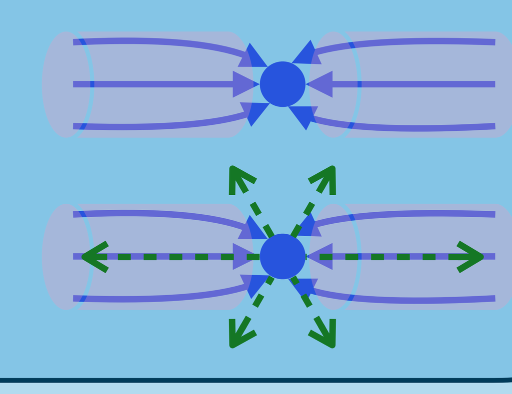
Magnetic field goes through it



Beads

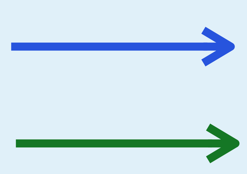
Formed at U(1)$_{\rm D}$ → Z_2

Monopoles with the magnetic fields confined in strings



Q: How do dark topological defects interact with QED?

Induced electromagnetic fields



U(1)$_{\rm D}$ symmetric phase

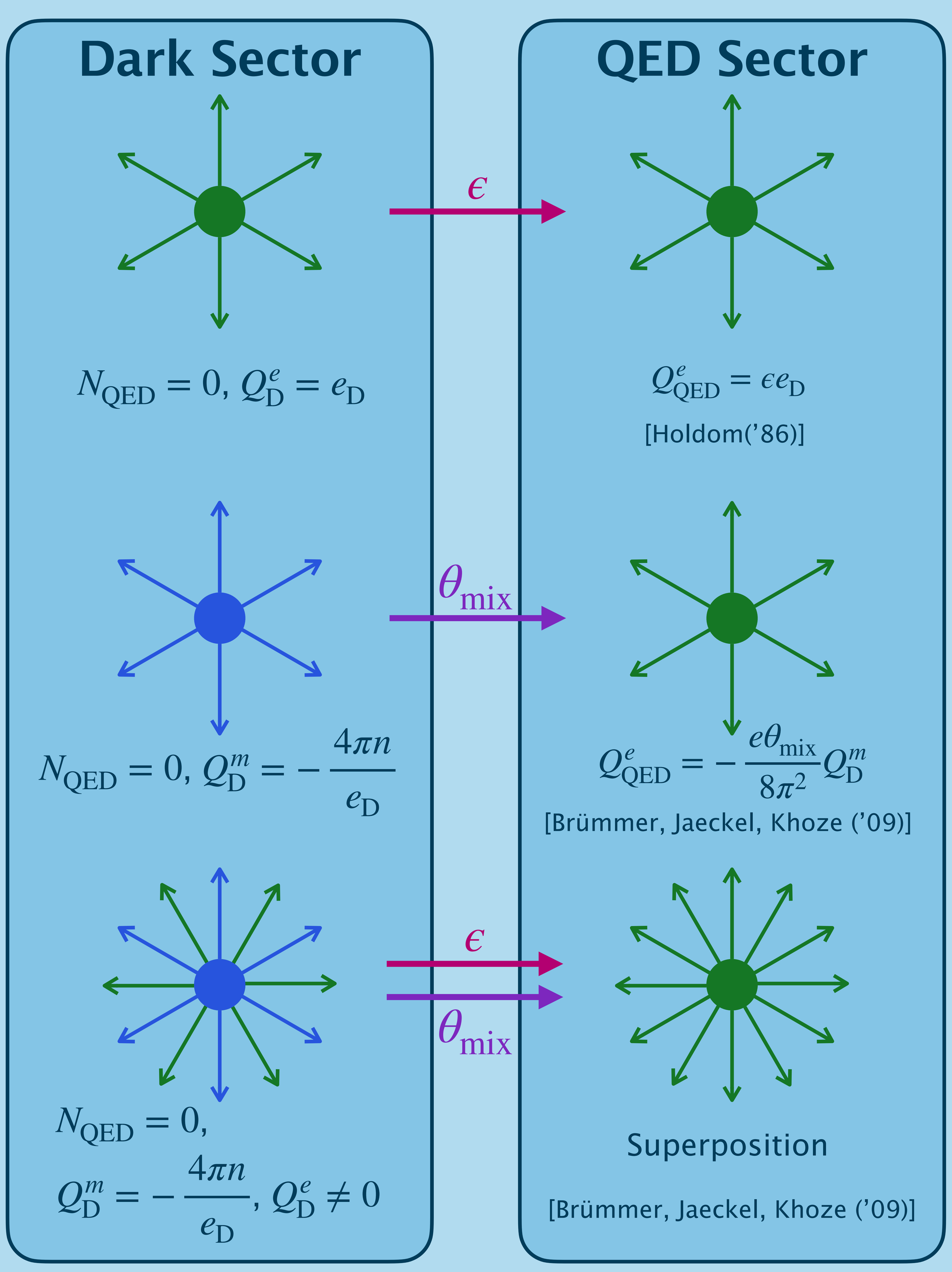
QED Noether charge

EoM:

$$\partial_\mu F^{\mu\nu} - \epsilon\partial_\mu\left(\frac{\phi^a}{v_1}F_{\rm D}^{a\mu\nu}\right) + \frac{\theta_{\rm mix}}{8\pi^2}\partial_\mu\left(\frac{\phi^a}{v_1}\tilde{F}_{\rm D}^{a\mu\nu}\right) = eJ^\nu_{\rm QED}$$

$$\rightarrow N_{\rm QED} = \frac{1}{e}Q^e_{\rm QED} - \frac{\epsilon}{e}Q^e_{\rm D} + \frac{\theta_{\rm mix}}{8\pi^2}Q^m_{\rm D}$$

(Q: electric / magnetic charge defined by field flux)



U(1)$_{\rm D}$ broken phase

Decoupled basis

$$\begin{pmatrix} 1 & \frac{\epsilon}{1-\epsilon^2} \\ 0 & \frac{1}{1-\epsilon^2}\end{pmatrix}\begin{pmatrix} A' \\ A'_{\rm D}\end{pmatrix} := \begin{pmatrix} A \\ A_{\rm D}\end{pmatrix} \rightarrow \begin{cases} \partial_\mu F'^{\mu\nu} = eJ^\nu_{\rm QED} & \leftarrow \text{involves only } A' \\ \partial_\mu F'^{\mu\nu}_{\rm D} - m'^2_{\rm D}A'^\nu_{\rm D} = \frac{e_{\rm D}}{\sqrt{1-\epsilon^2}}J^\nu_{\rm D} + \frac{\epsilon e}{\sqrt{1-\epsilon^2}}J^\nu_{\rm QED} & \leftarrow \text{involves only } A'_{\rm D}\end{cases}$$