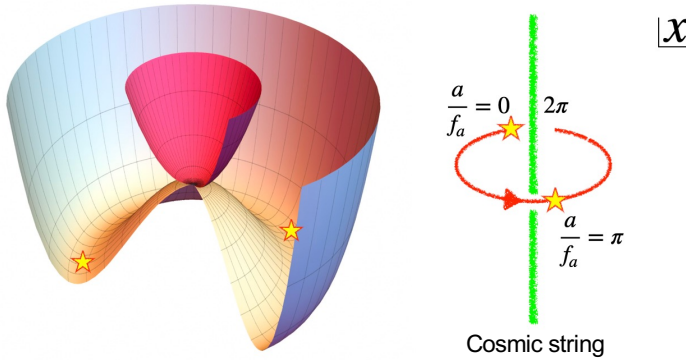


Resolving the QCD axion domain wall problem with a light axion

Fuminobu Takahashi Tohoku University J. Lee, K. Murai, F. Takahashi & W. Yin, JHEP 01 (2026) 124 (arXiv:2507.07075)

In post-inflationary QCD axion models, a domain-wall number larger than one produces a persistent string-wall network. We show that adding a massless or very light axion with a unit QCD anomaly converts the walls into cosmologically safe string bundles while preserving the Peccei-Quinn solution. Numerical simulations demonstrate bundle formation and its impact on the QCD axion dark matter abundance. Long-lived bundles may survive as cosmic strings, with possible gravitational-wave and cosmic-birefringence signatures.

1 Axion and Peccei-Quinn Mechanism



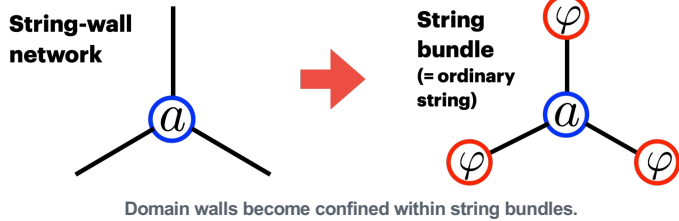
After post-inflationary PQ breaking, multiple domain walls per axion string lead to a persistent network, requiring $N_{\text{DW}} = 1$. However, we often have

$$N_{\text{DW}} > 1 \quad (N_{\text{DW}} = 3 \text{ or } 6 \text{ in DFSZ models})$$

2 A light axion resolves the domain wall problem

Adding a massless or very light axion φ with a unit QCD anomaly gives one wall per new string. [1, 3]

$$\mathcal{L} = -\frac{g_s^2}{32\pi^2} \left(N_{\text{DW}} \frac{a}{v_a} + \frac{\varphi}{v_\varphi} \right) G\tilde{G} \quad \varphi : \text{Massless (or very light) axion} \\ \text{e.g. KSVZ axion (different from } a)$$



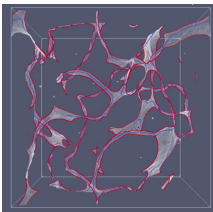
Domain walls become confined within string bundles.

3 Conditions for the string bundle formation

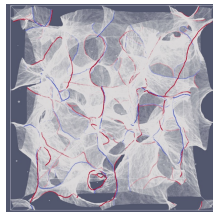
Suppose that two axions are mixed as follows:

$$V_1 = \Lambda^4 [1 - \cos(n_1 \theta_1 + n_2 \theta_2)]$$

where the DW numbers are coprime. If one of them is unity, string bundles are formed. Otherwise, we are left with domain walls [2].



(2, 1): bundles



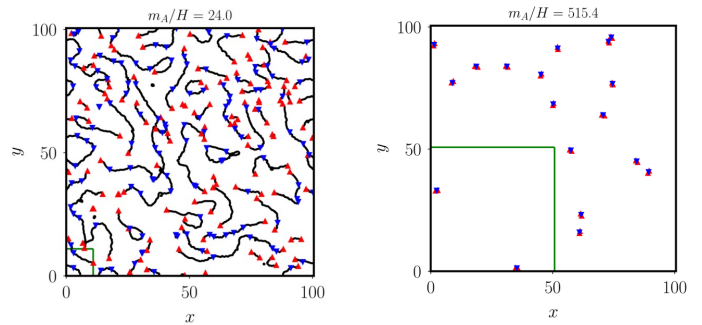
(2, 3): walls

Conclusions

Another light axion can resolve the DW problem by converting the wall network into string bundles. This changes QCD axion production and may leave observable cosmic-string relics. Topological defects are essentially the UV-physics objects!

4 Network evolution in simulations

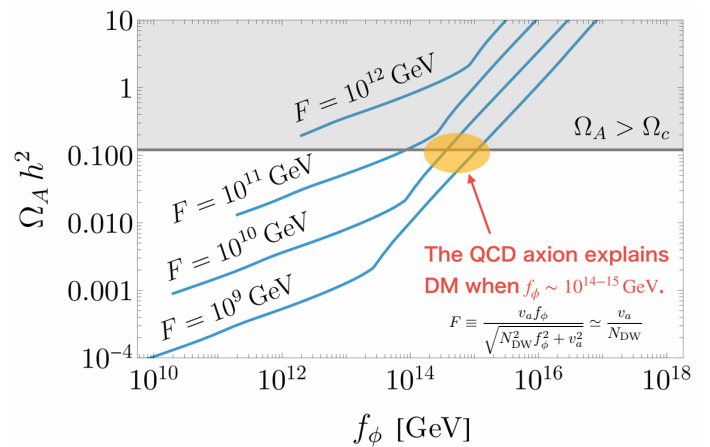
Two-dimensional example; domain wall number = 2. [1]



Extended walls disappear, and localized string bundles remain.

5 QCD axion dark matter

Bundle formation changes the axion abundance produced by domain walls. The QCD axion can account for dark matter in the benchmark below. [1]



F : QCD-axion decay constant; f_ϕ : light-axion scale.

6 Observable relics

QCD axion DM. Compared to the standard scenario with the wall number 1, the decay constant is expected to be smaller, i.e., a stronger coupling to photons.

Gravitational waves. Long-lived bundles act as global cosmic strings. Global-string dynamics can source a stochastic GW background. [4]

Cosmic birefringence. With a photon coupling, the light axion can rotate CMB polarization [1, 3, 5]. In particular, anisotropic CB is dominant compared to the isotropic one unless there are string loops close to the solar system.

References

- [1] Lee, Murai, FT, Yin, JHEP 01 (2026) 124, arXiv:2507.07075.
[2] Lee, Murai, FT, Yin, JCAP 04 (2025) 002, arXiv:2409.09749.
[3] FT and Yin, JCAP 04 (2021) 007, arXiv:2012.11576.

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