QCD Axion Dark Matter in String Theory

Naomi Gendler, Harvard University

Dark World to Swampland 2024

Based on 2407.07143 with Doddy Marsh

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Axion experiments can teach us about where we live in the string theory landscape.

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Upshot: A signal gives an indication of the underlying string theory geometry of our universe.

Outline of this talk

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4. Geometric intuition

Axions from string theory

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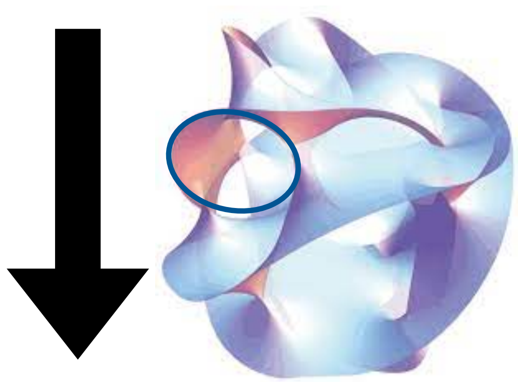

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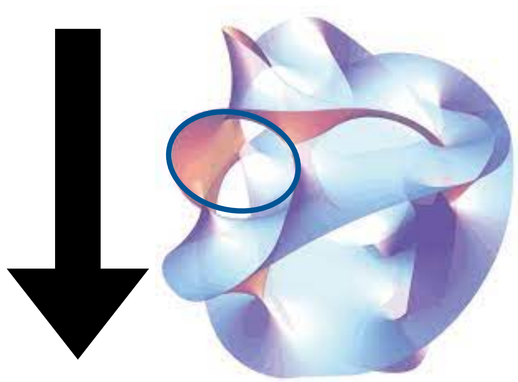

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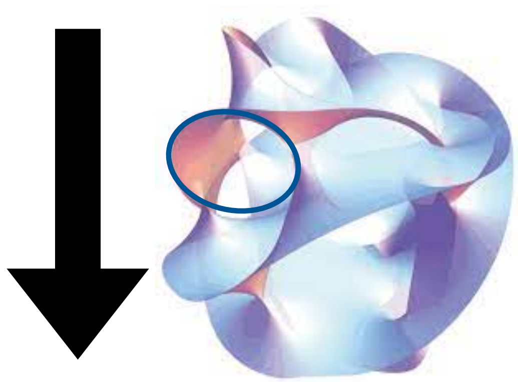

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These manifolds can have hundreds of 4-cycles

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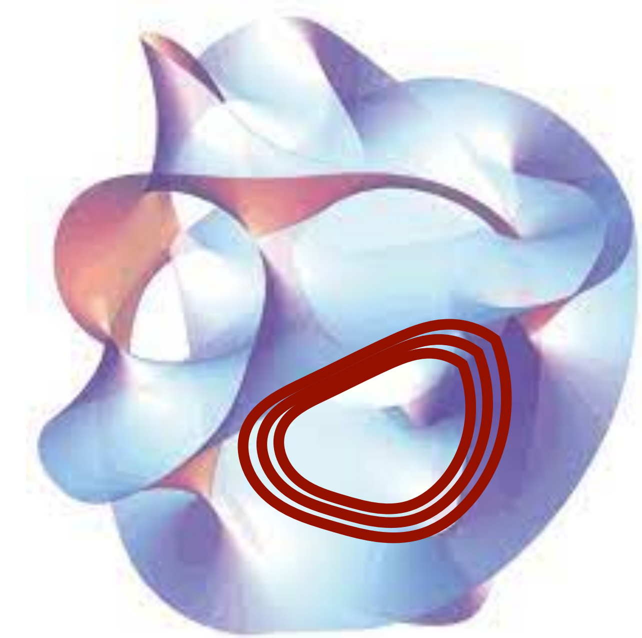

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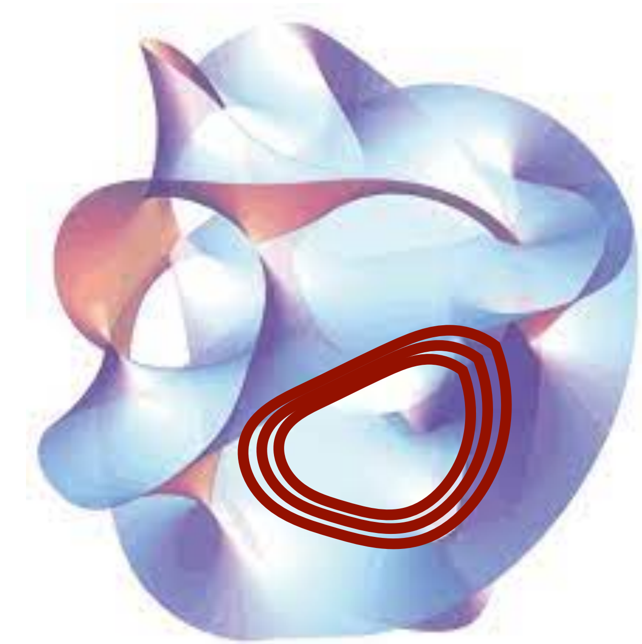

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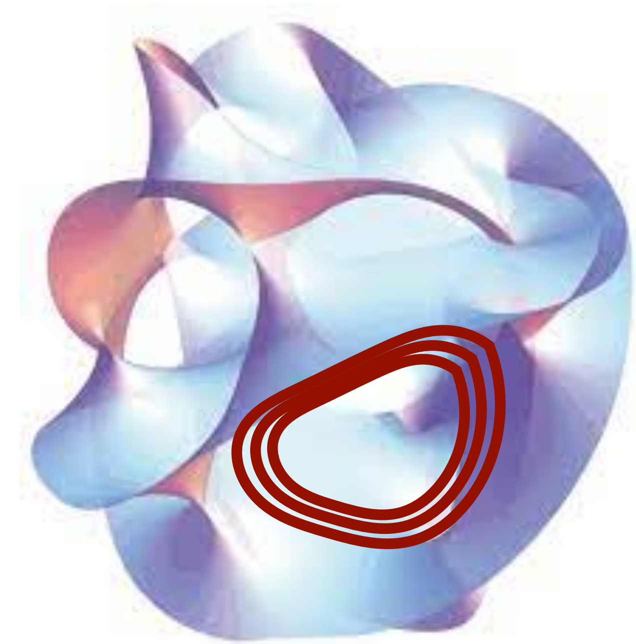

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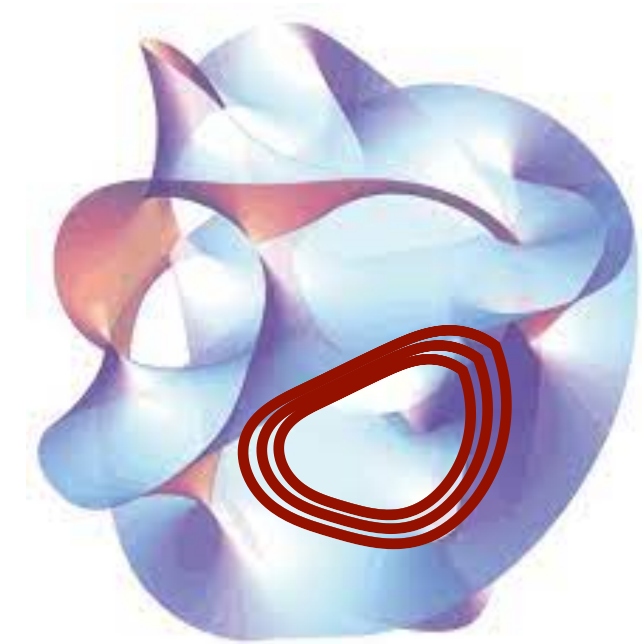

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φ_i: phases set by UV physics (assumed O(1))

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- We will choose a four-cycle $\Sigma^{(4)}_{\mathrm{QCD}}$ to host a toy model of QCD on a stack of D7-branes and arrange that it reproduces the known gauge coupling at low energies.

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Goal: compute the amount of QCD axion dark matter in this setup.

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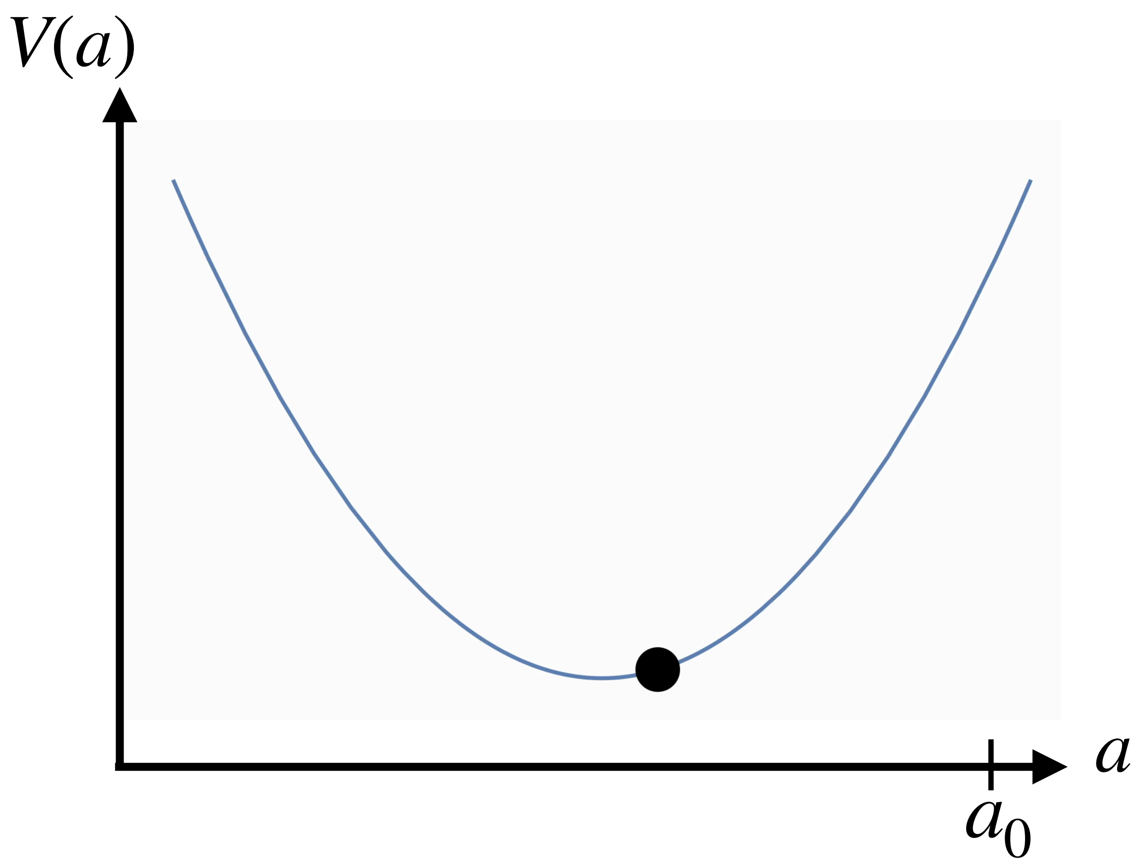

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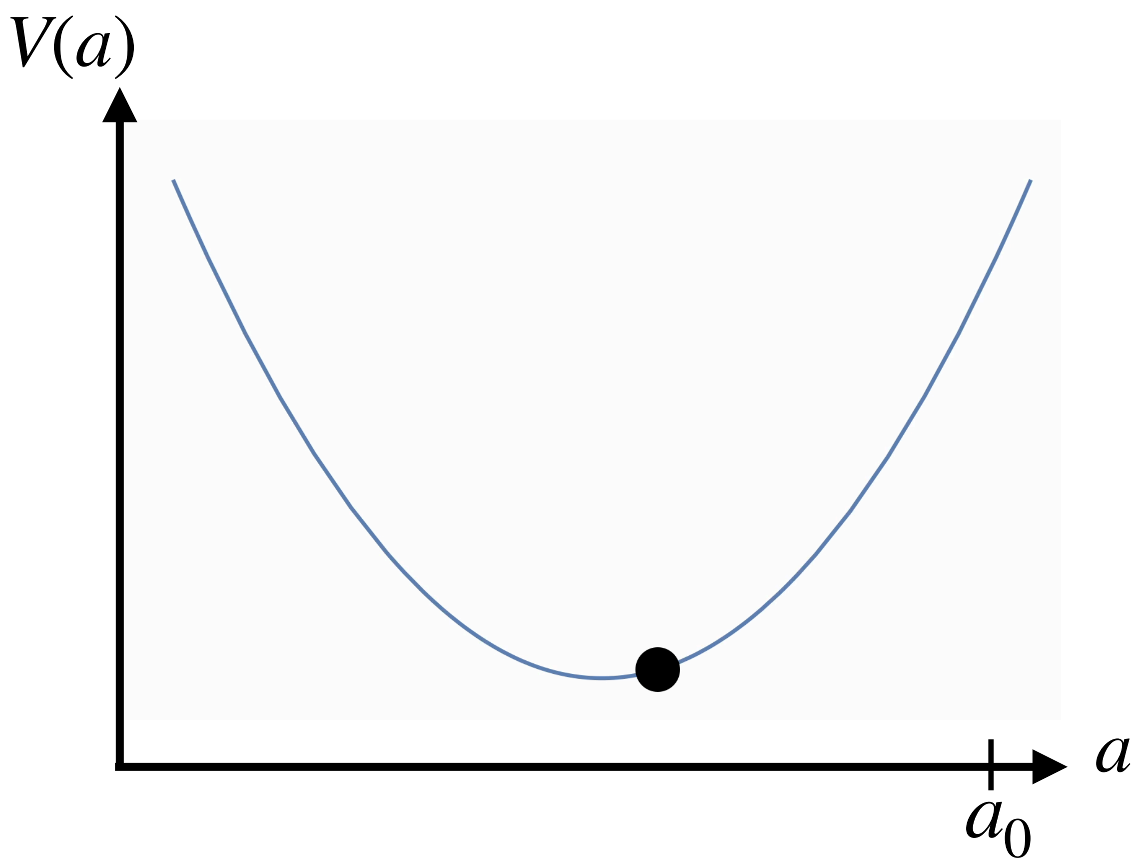

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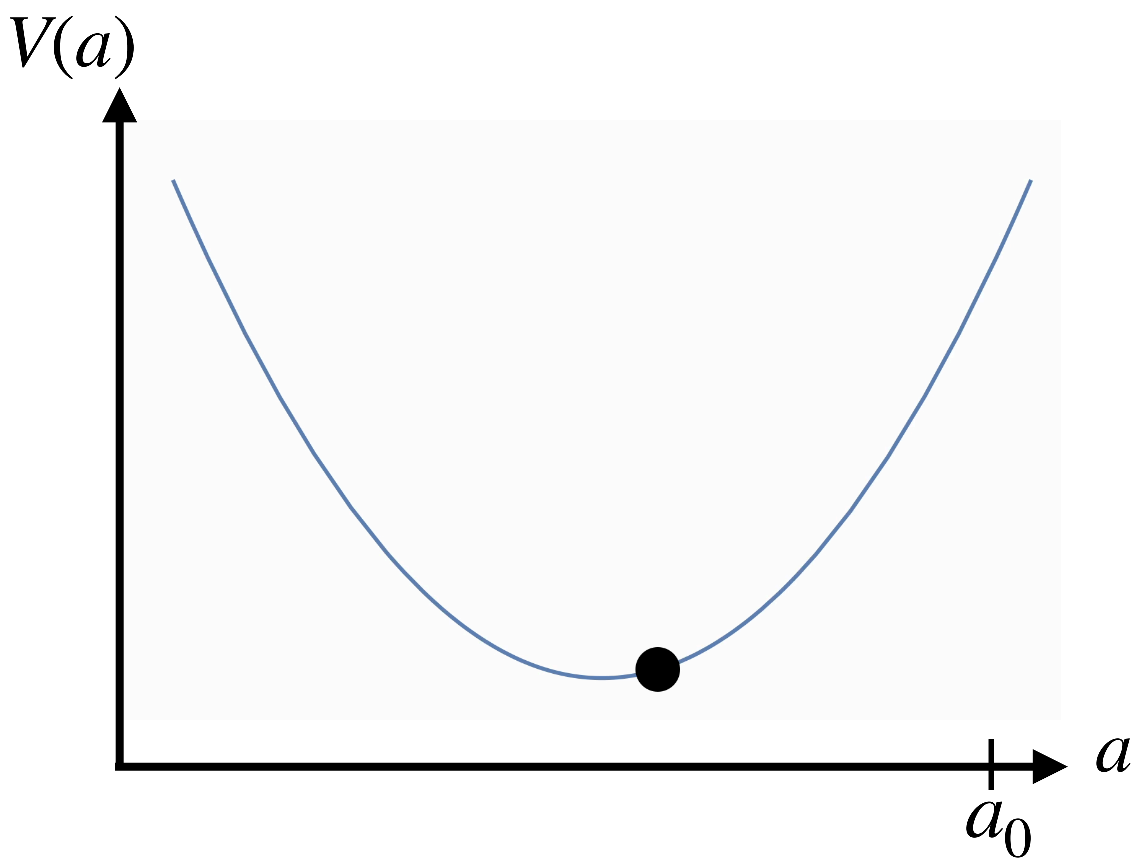

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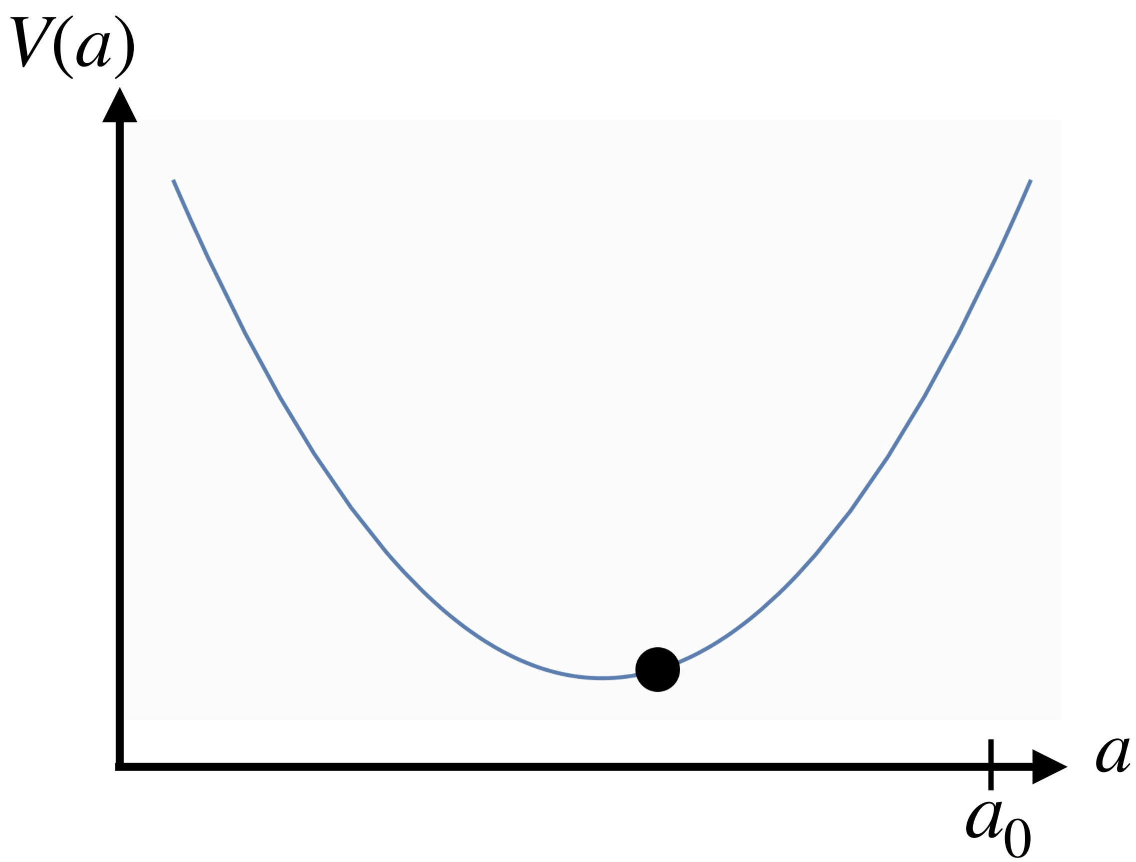

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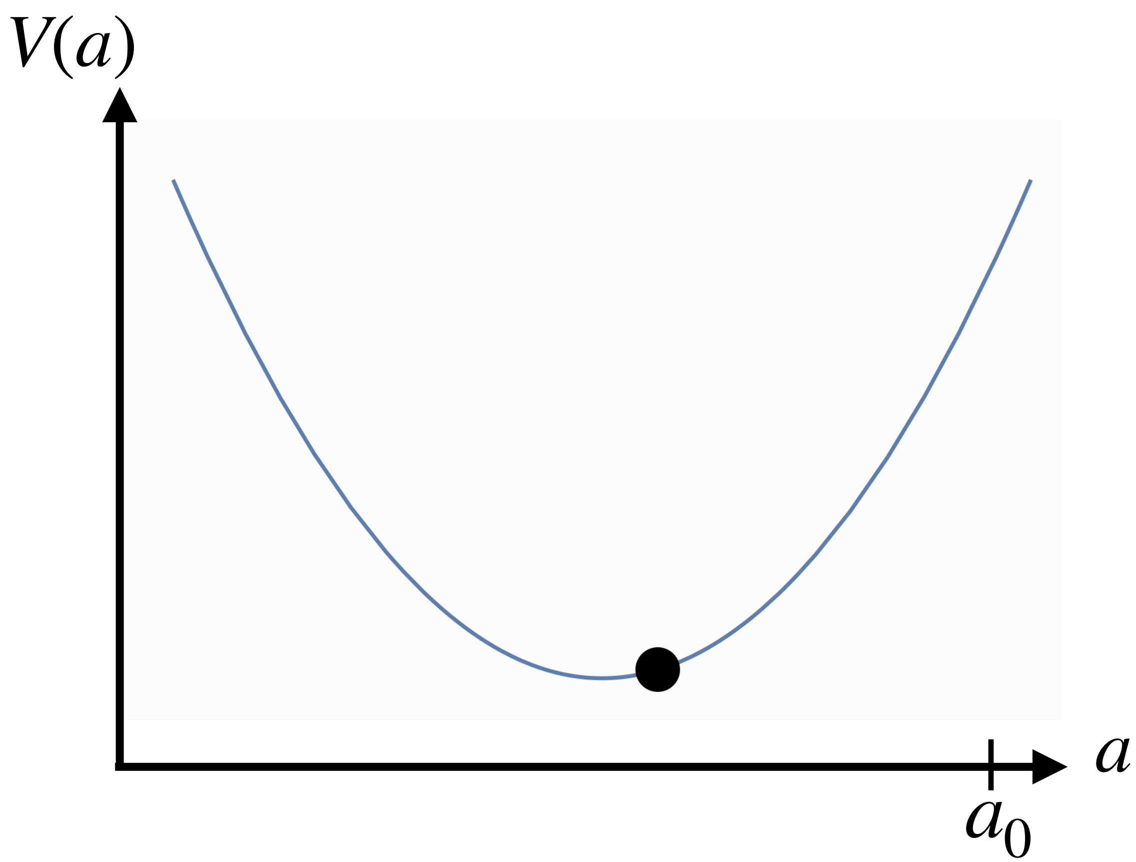

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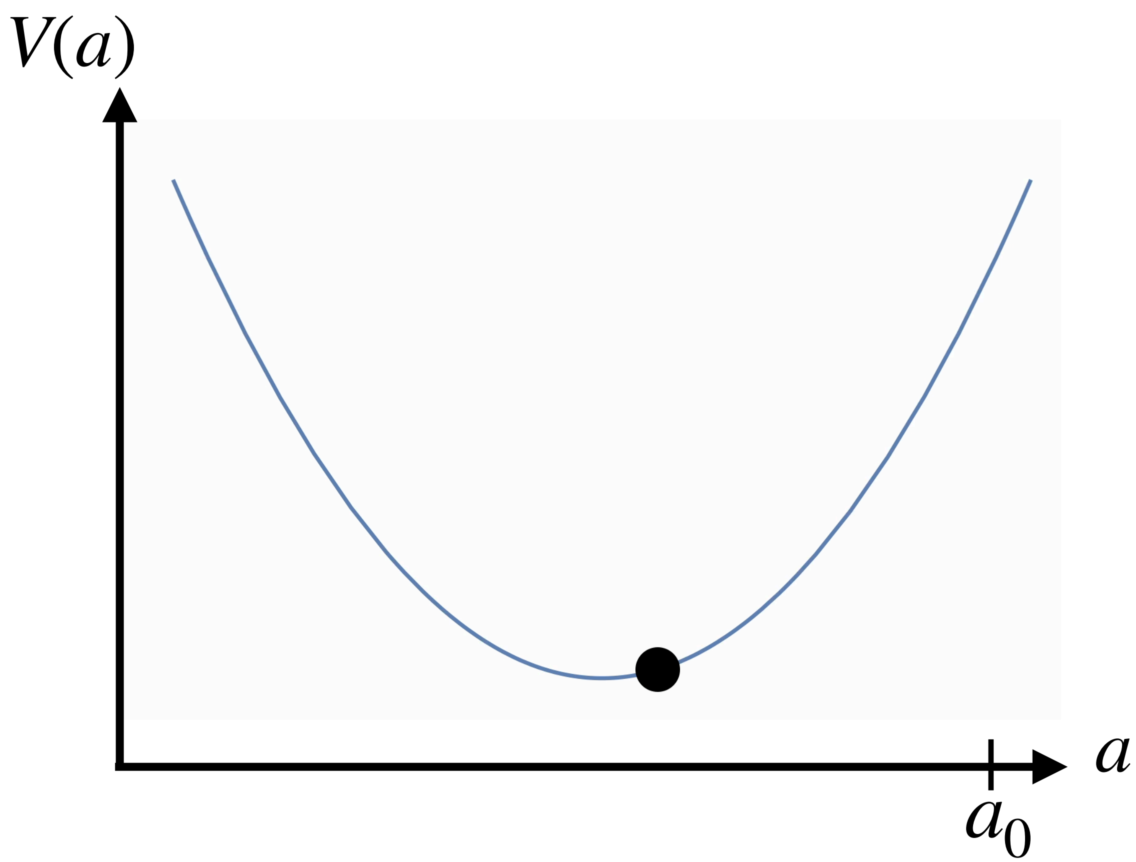

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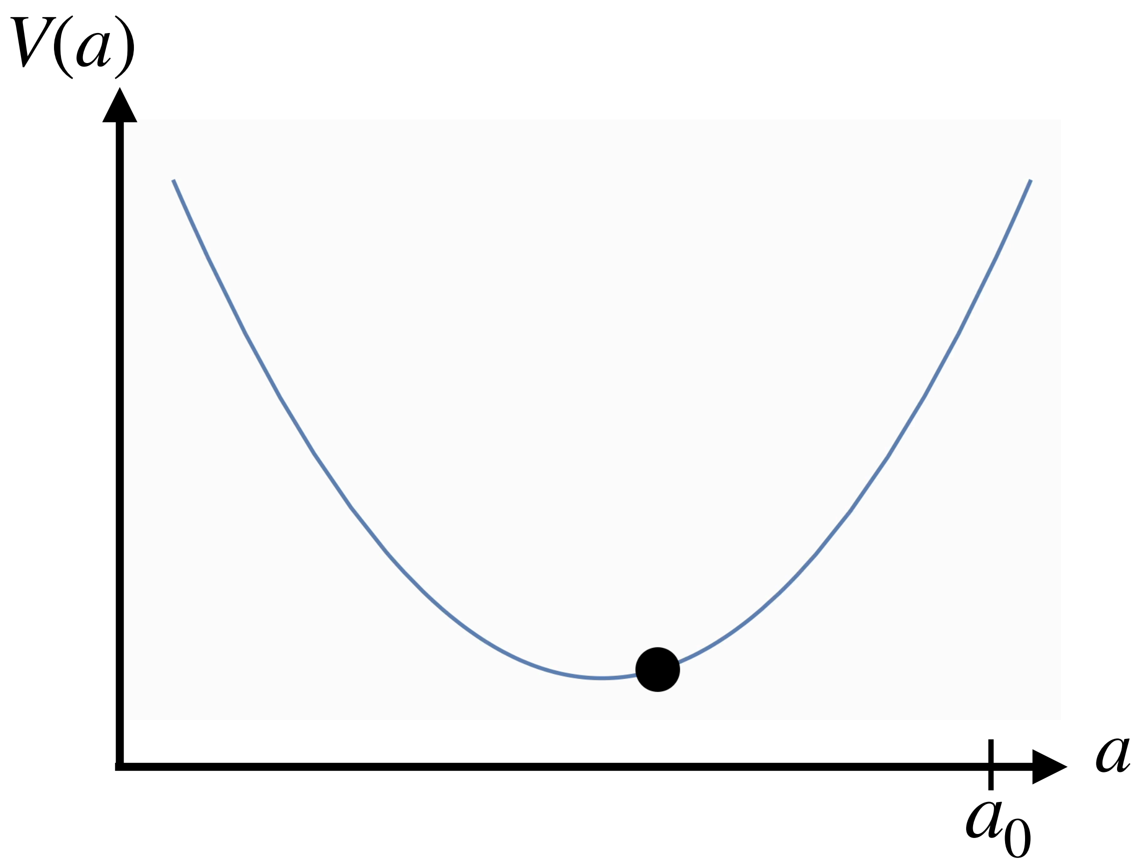

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Amount of dark matter produced by the QCD axion is $\propto \frac{1}{m_a^{7/6}}$.

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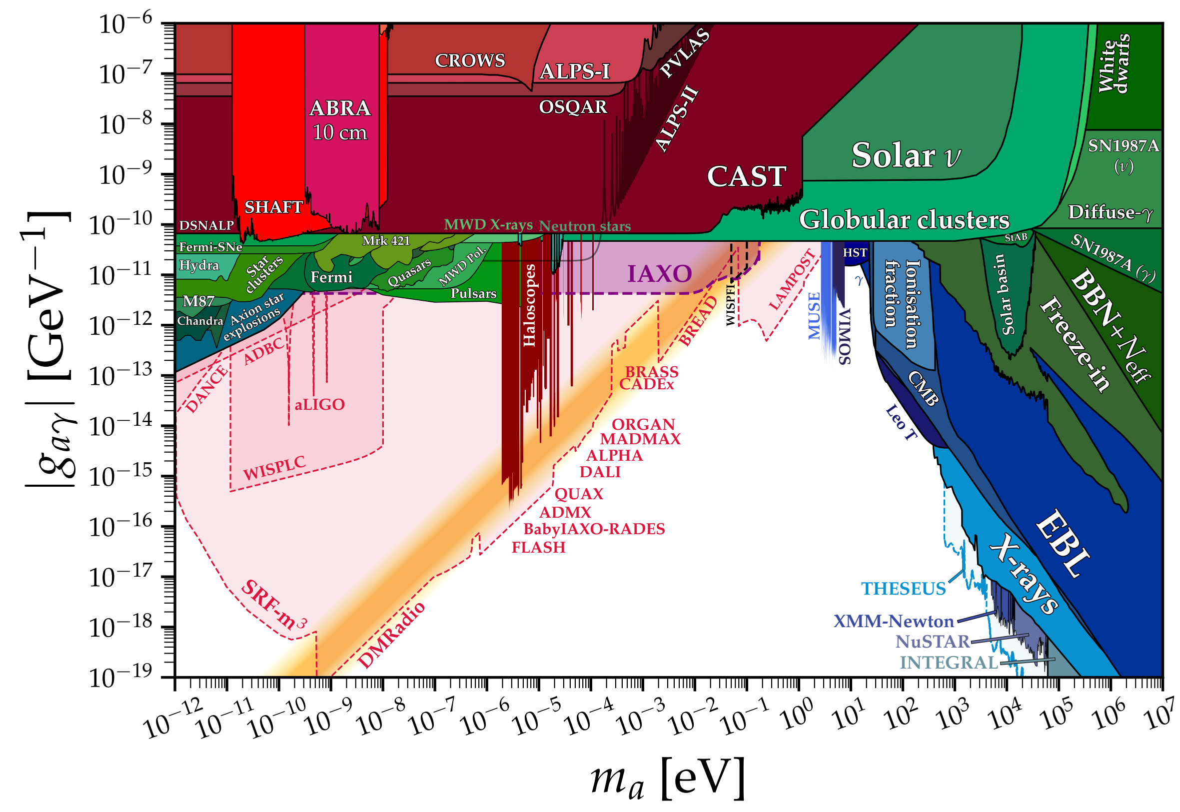

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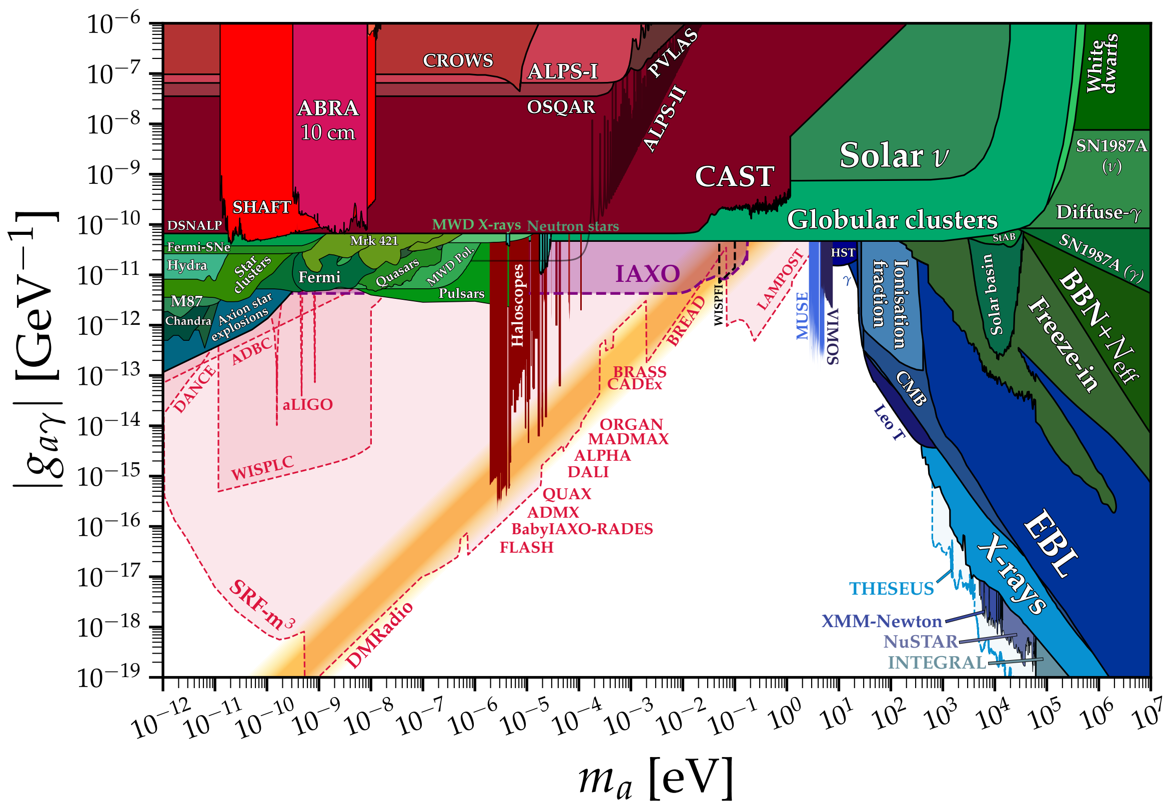

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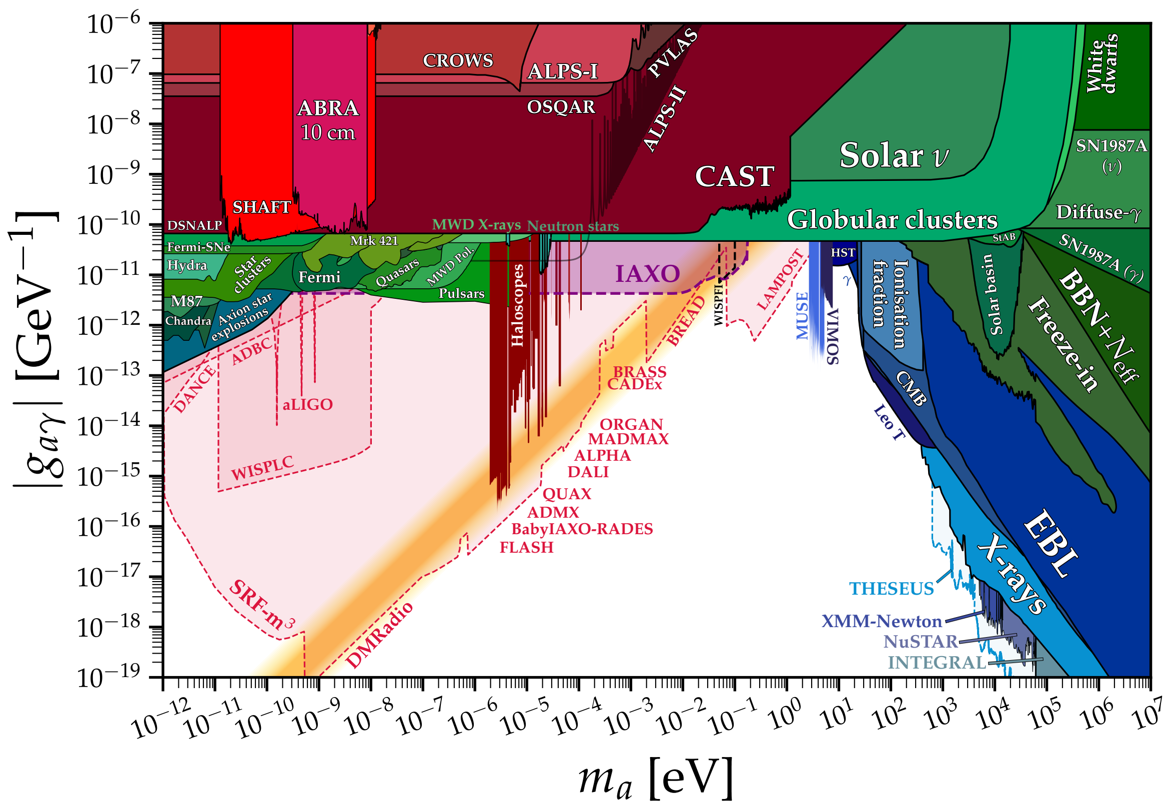

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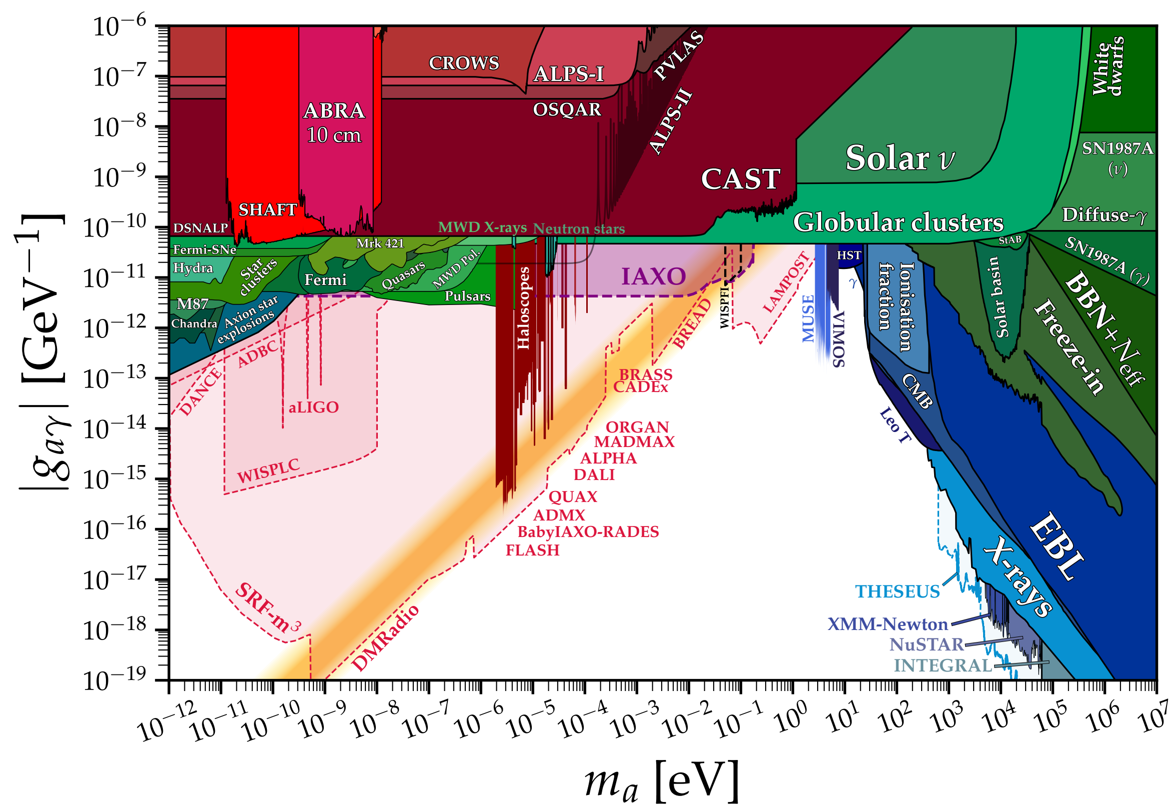

Idea: use a precise measurement of m_{QCD} to learn about the geometry of extra dimensions

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5. Calculate the **mass of the QCD axion:**

$$m_{QCD} = \frac{\sqrt{\Lambda_{QCD}^4}}{f_{QCD}}$$

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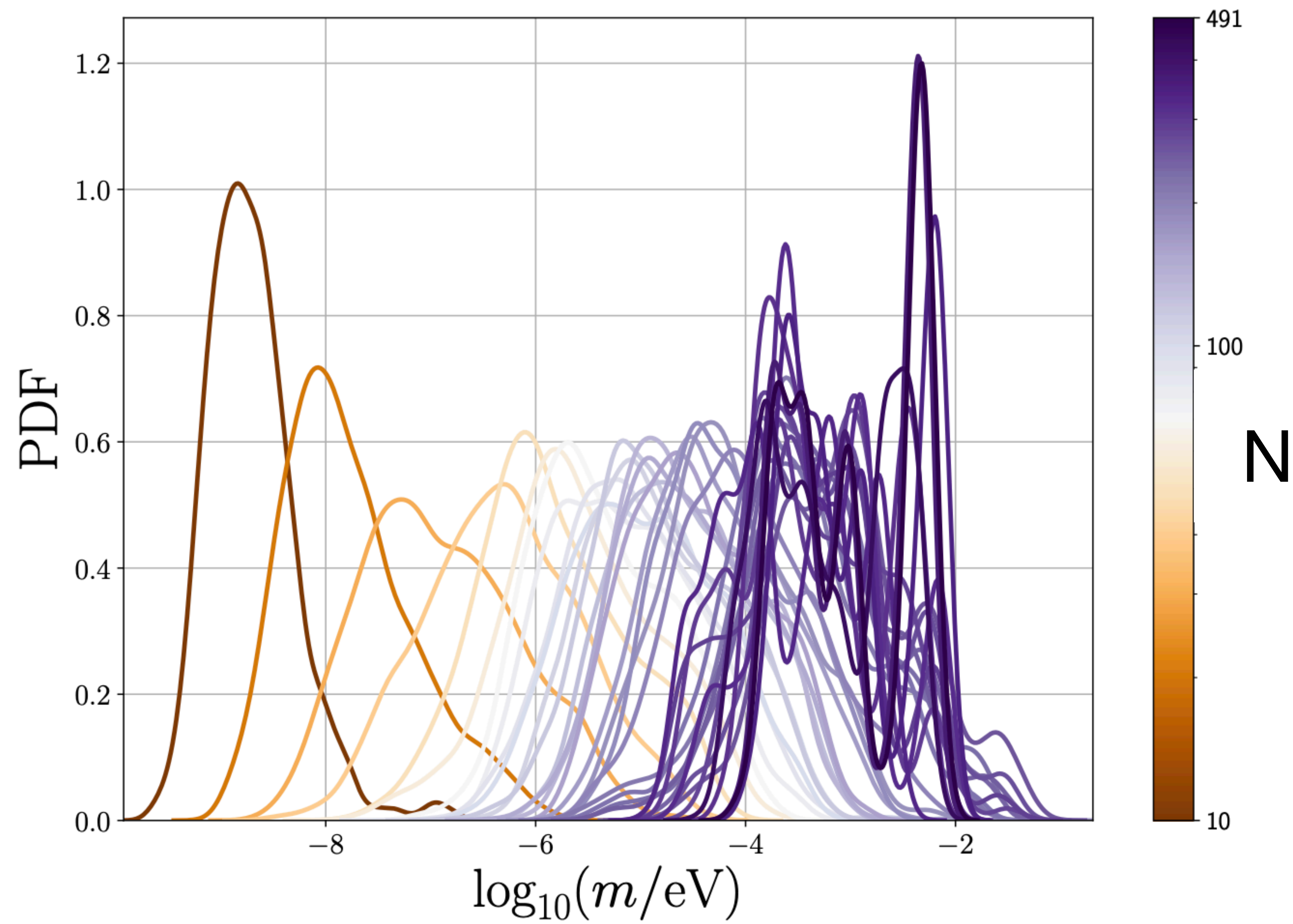

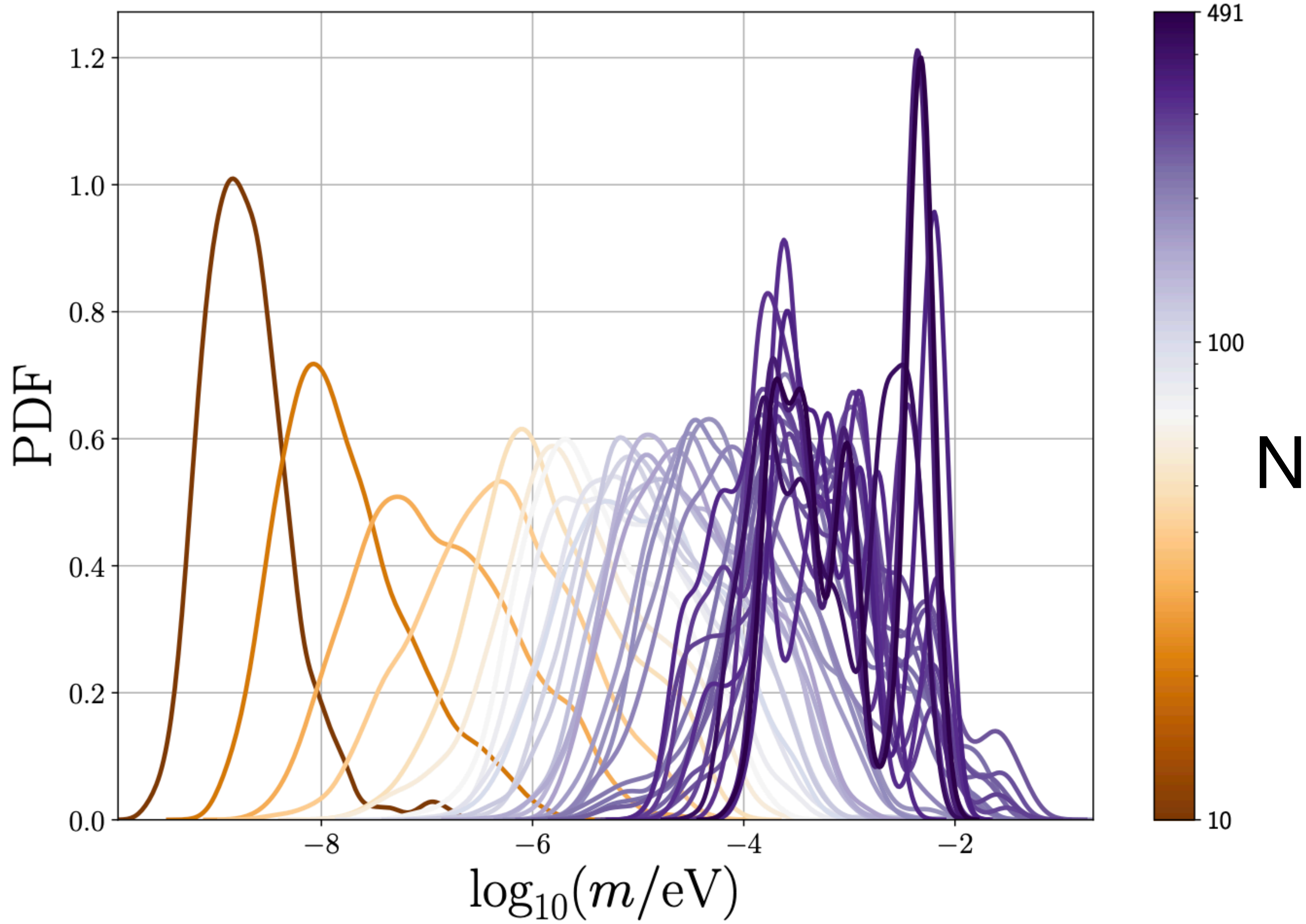

PDF
1.2
1.0
0.8
0.6
0.4
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−6
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$\log_{10}(m/\mathrm{eV})$
491
100
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N

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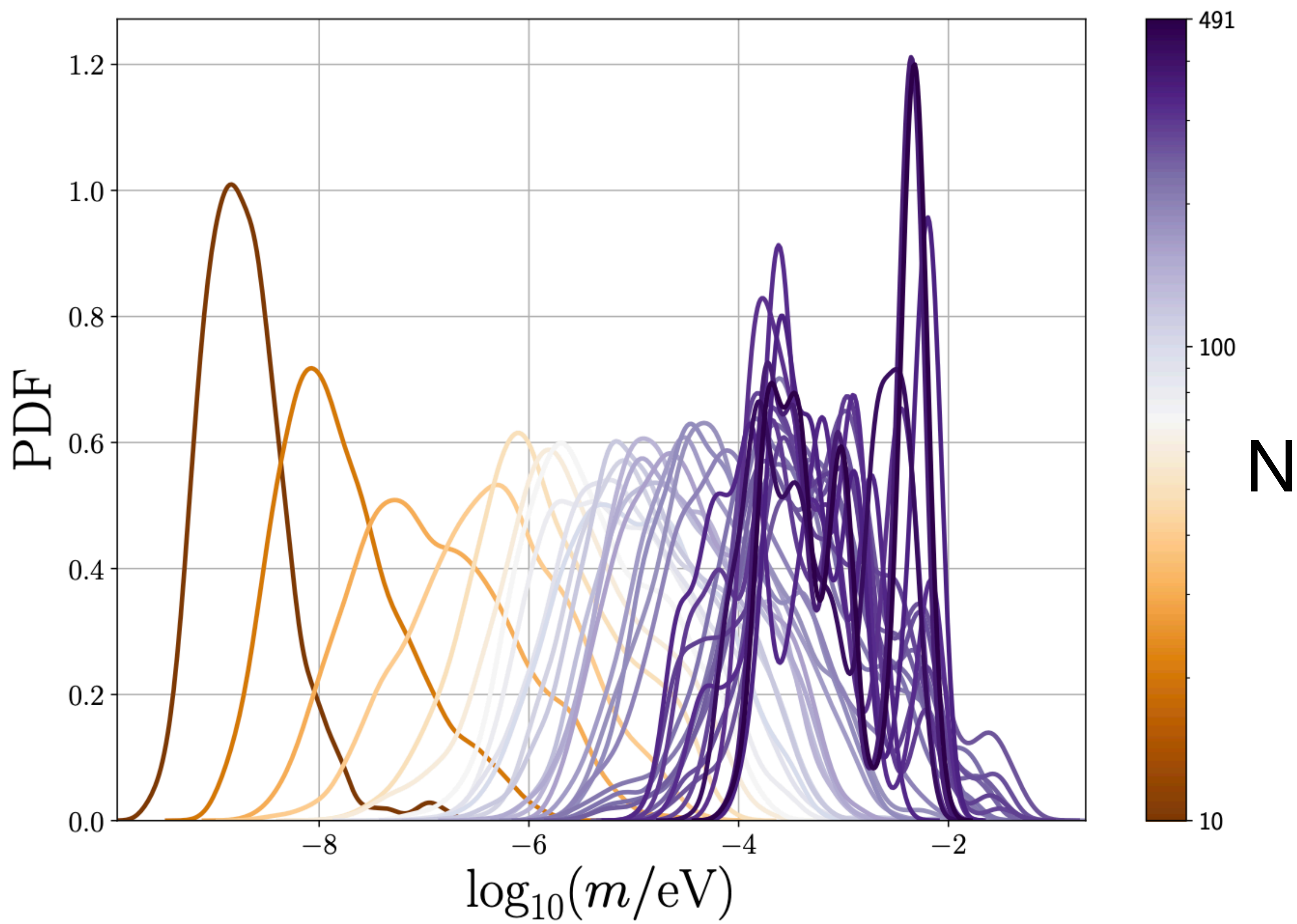

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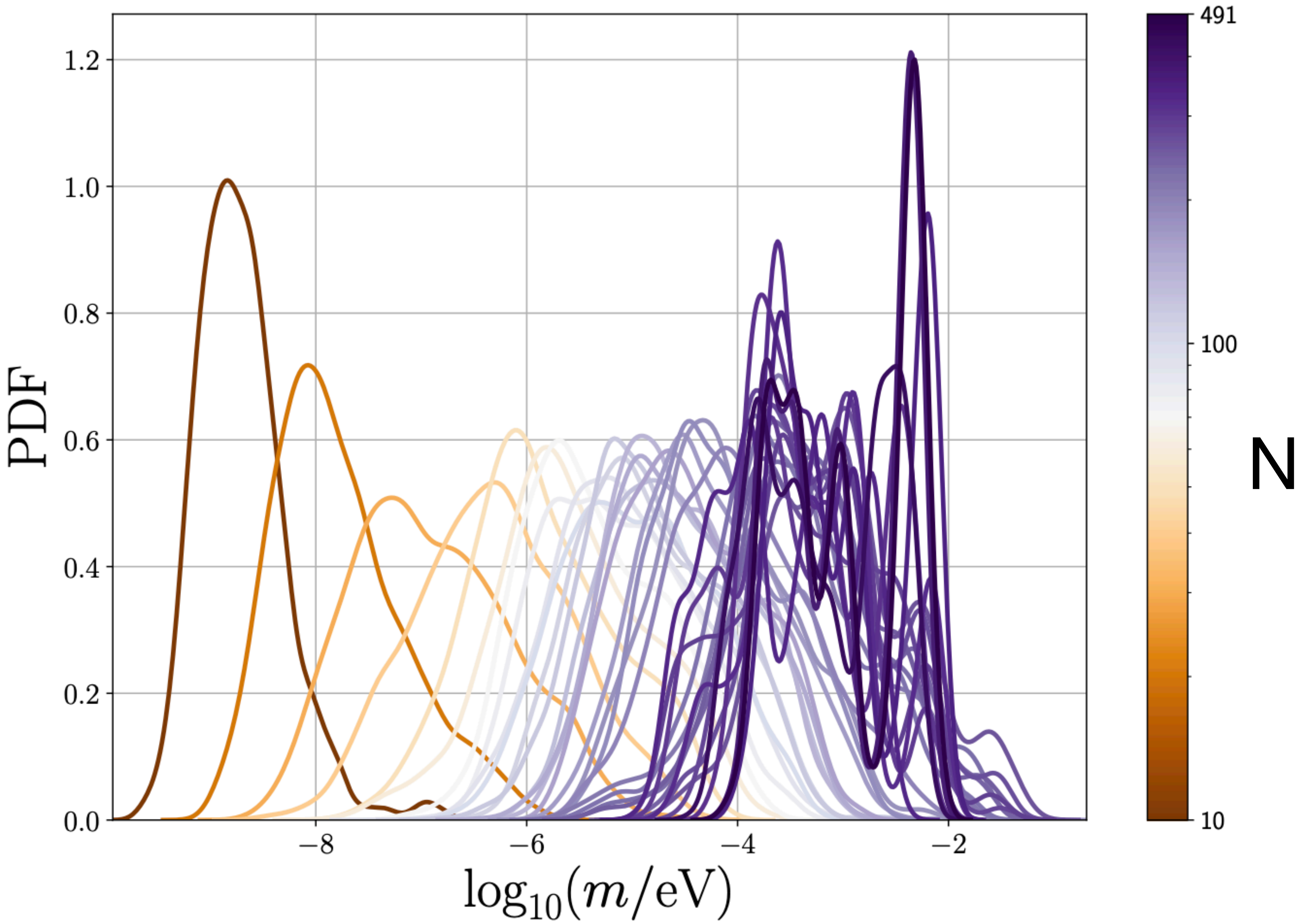

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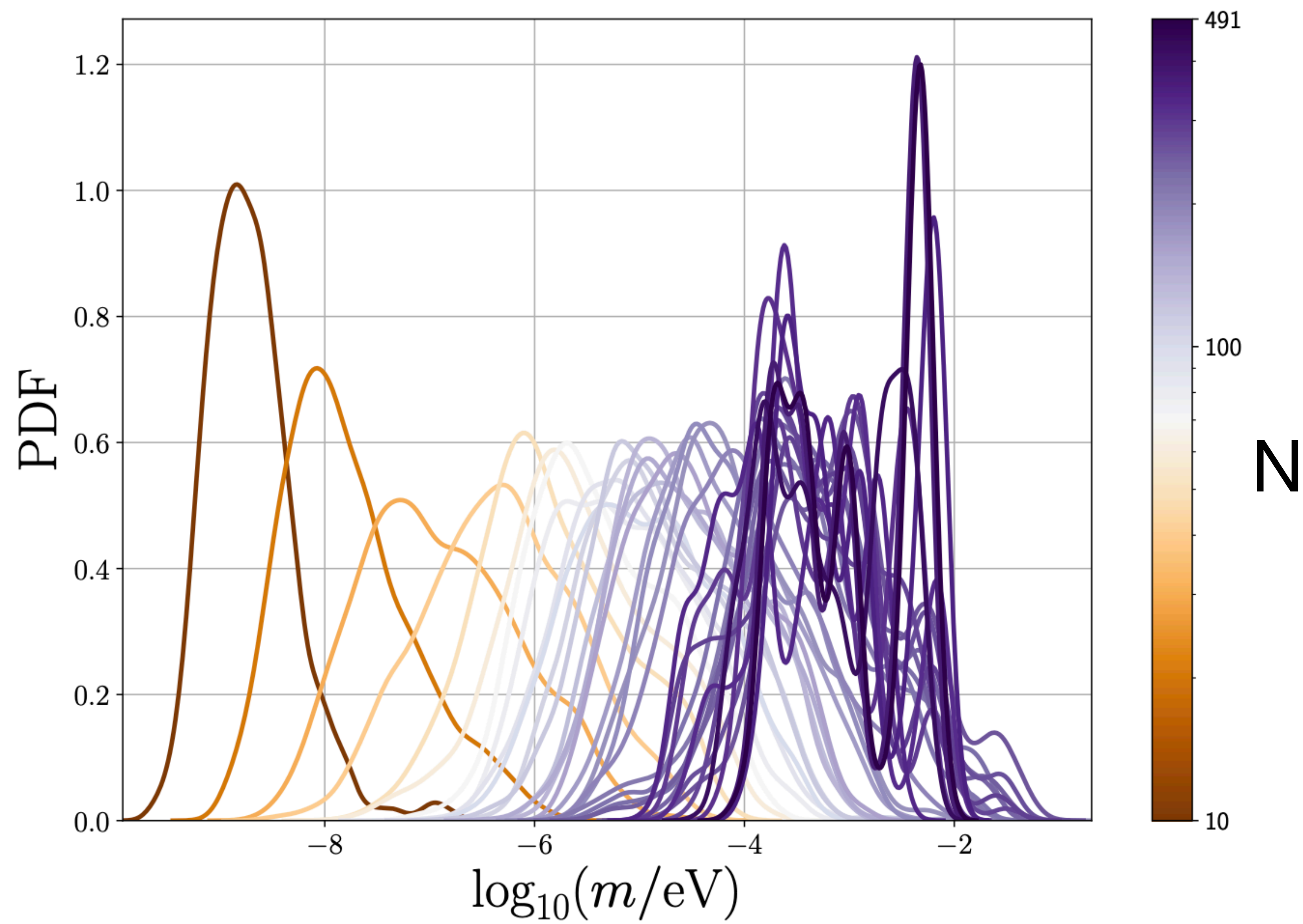

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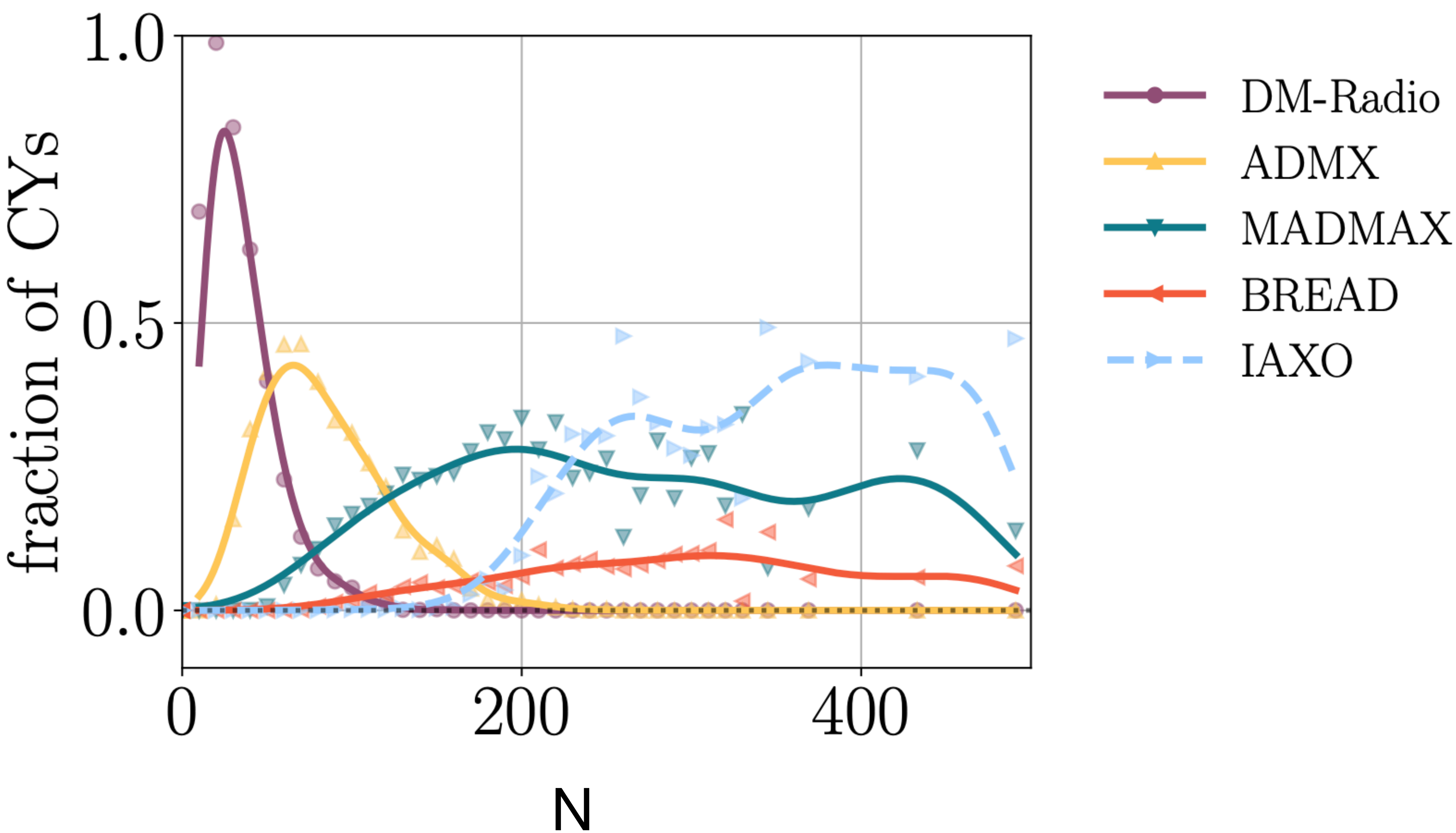

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All of these behaviors are a consequence of one underlying fact:

As N increases, hierarchies in instanton scales increase.

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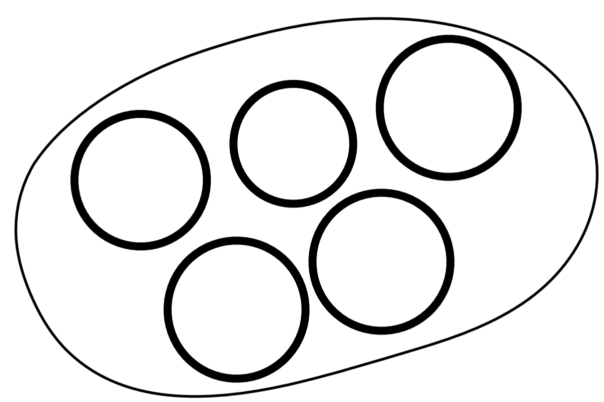

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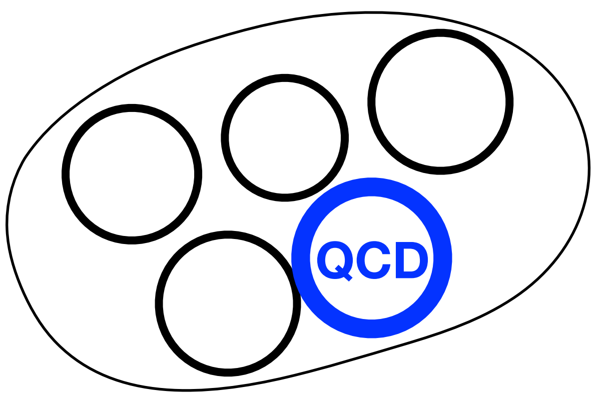

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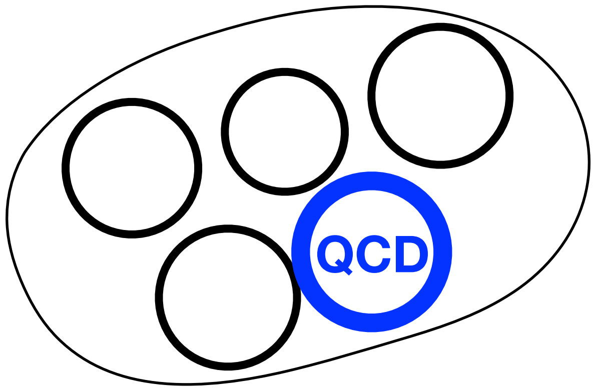

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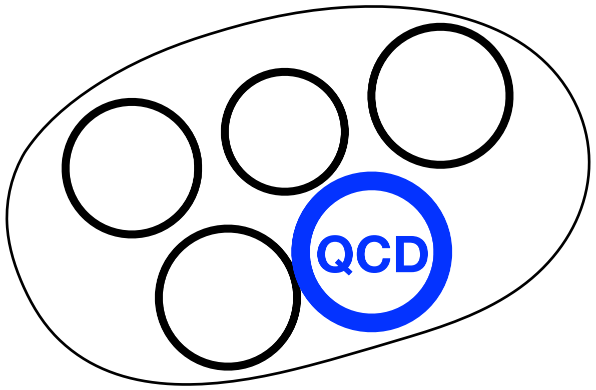

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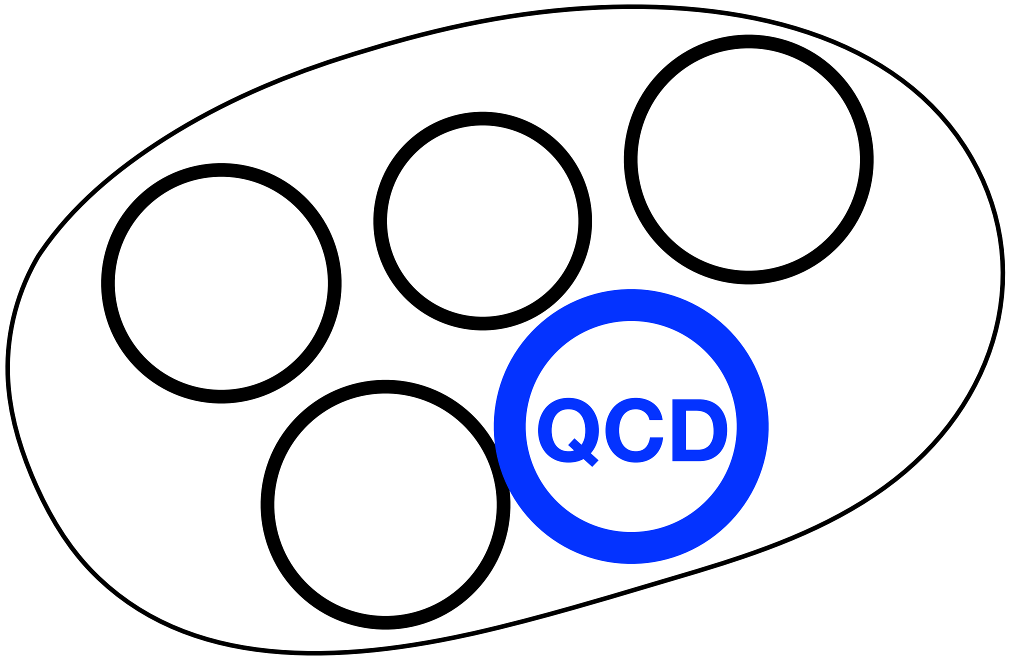

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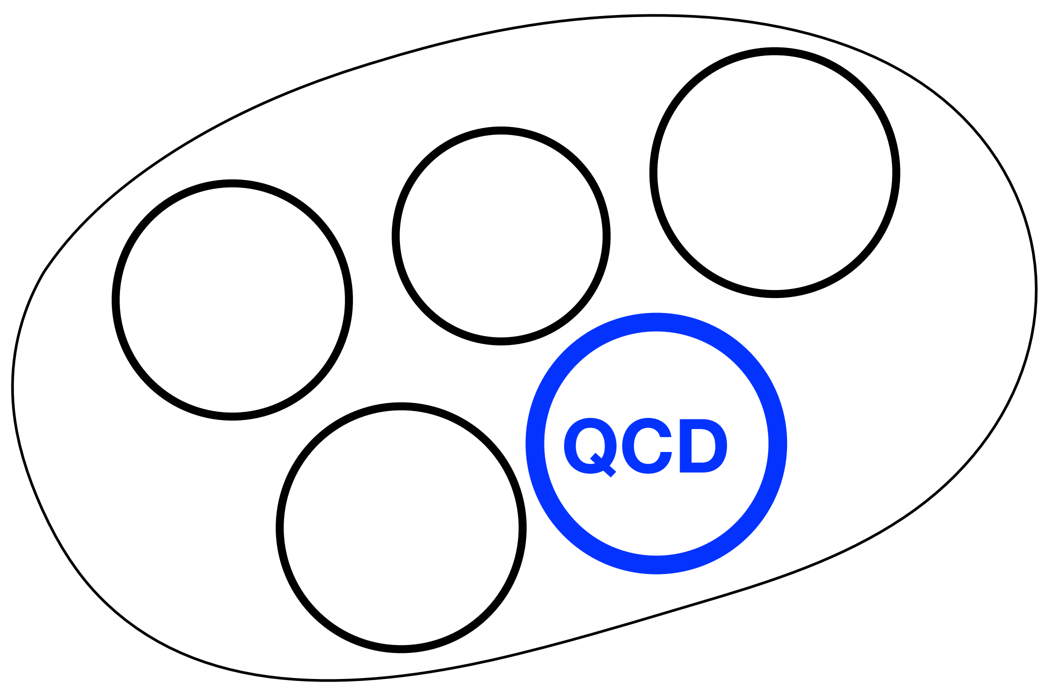

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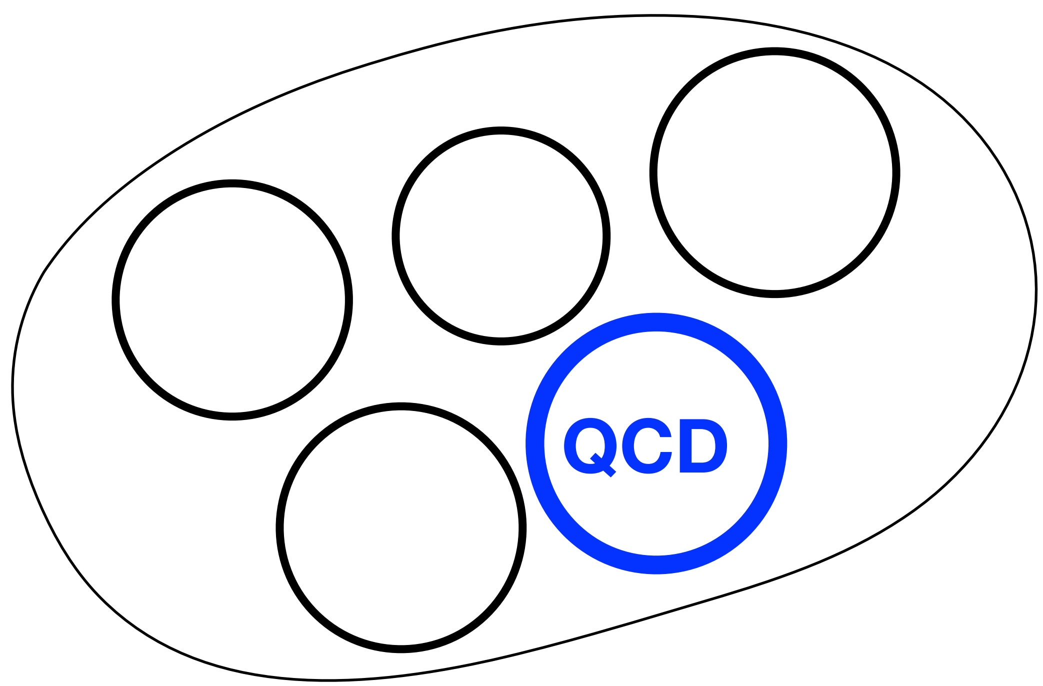

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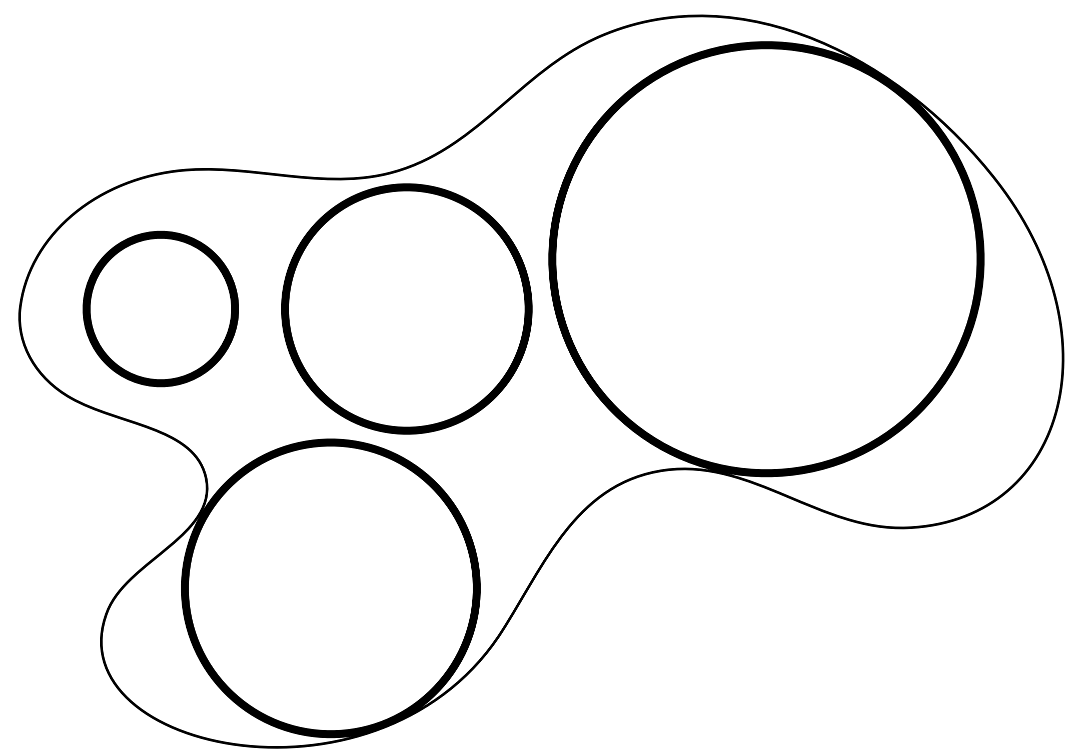

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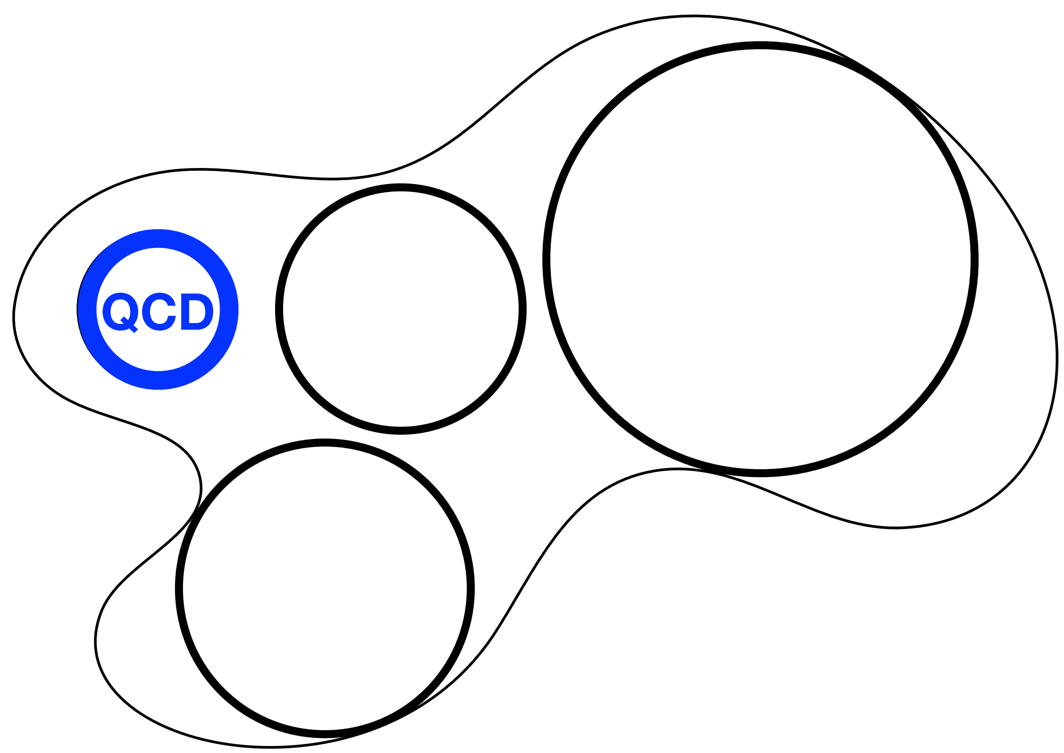

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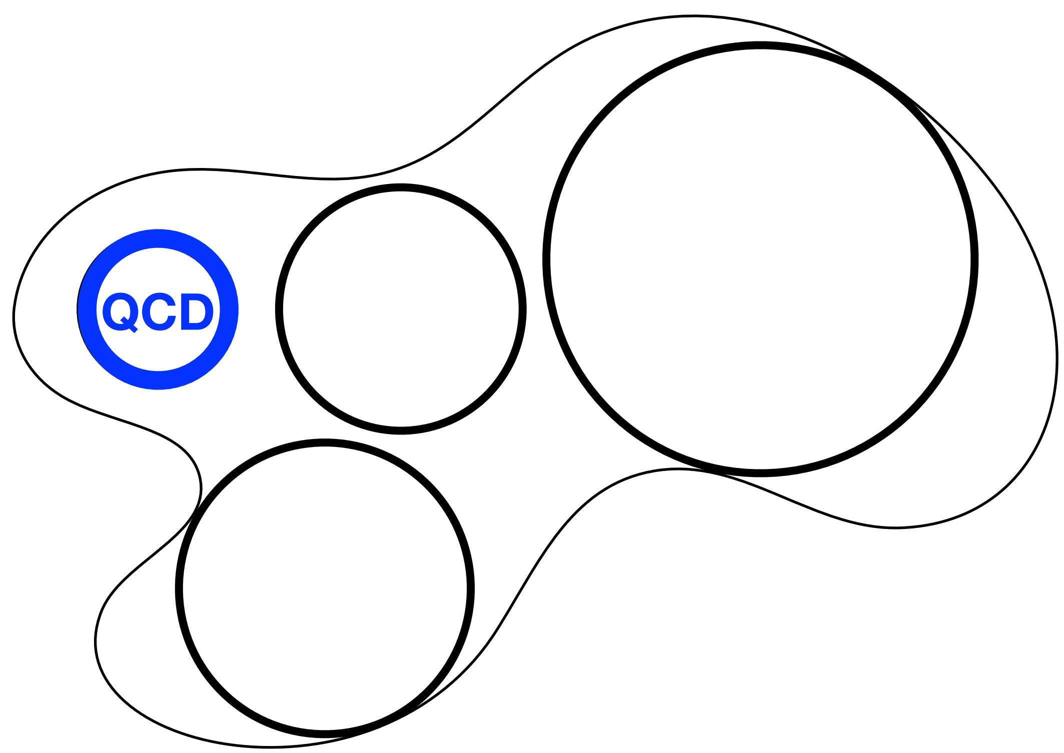

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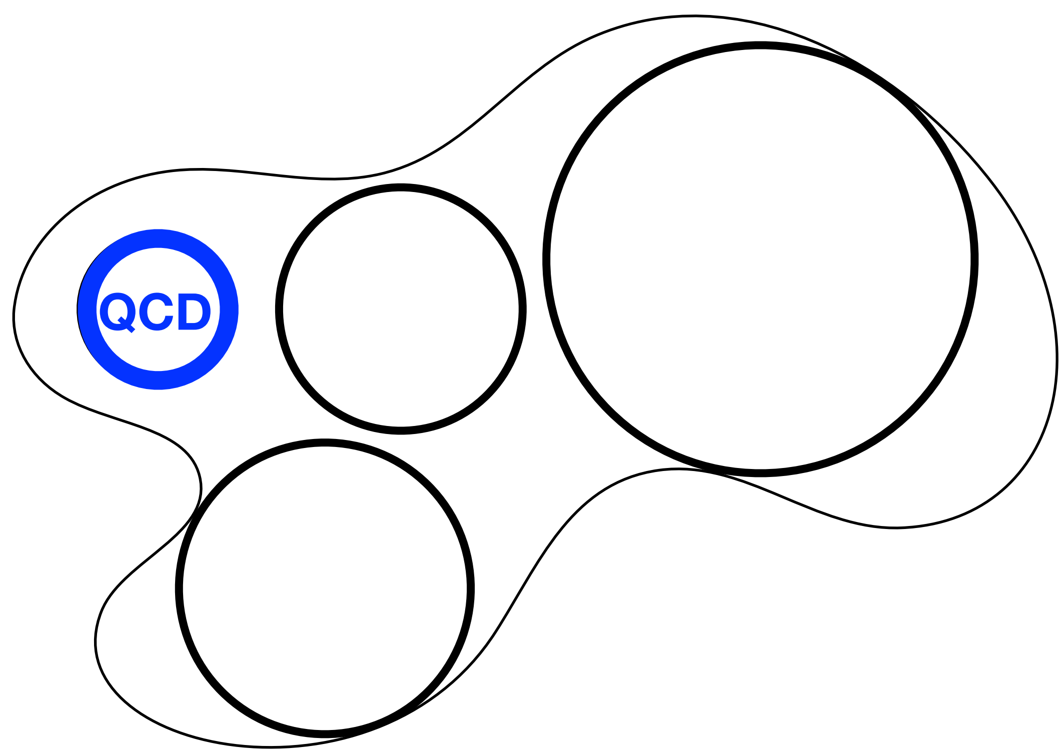

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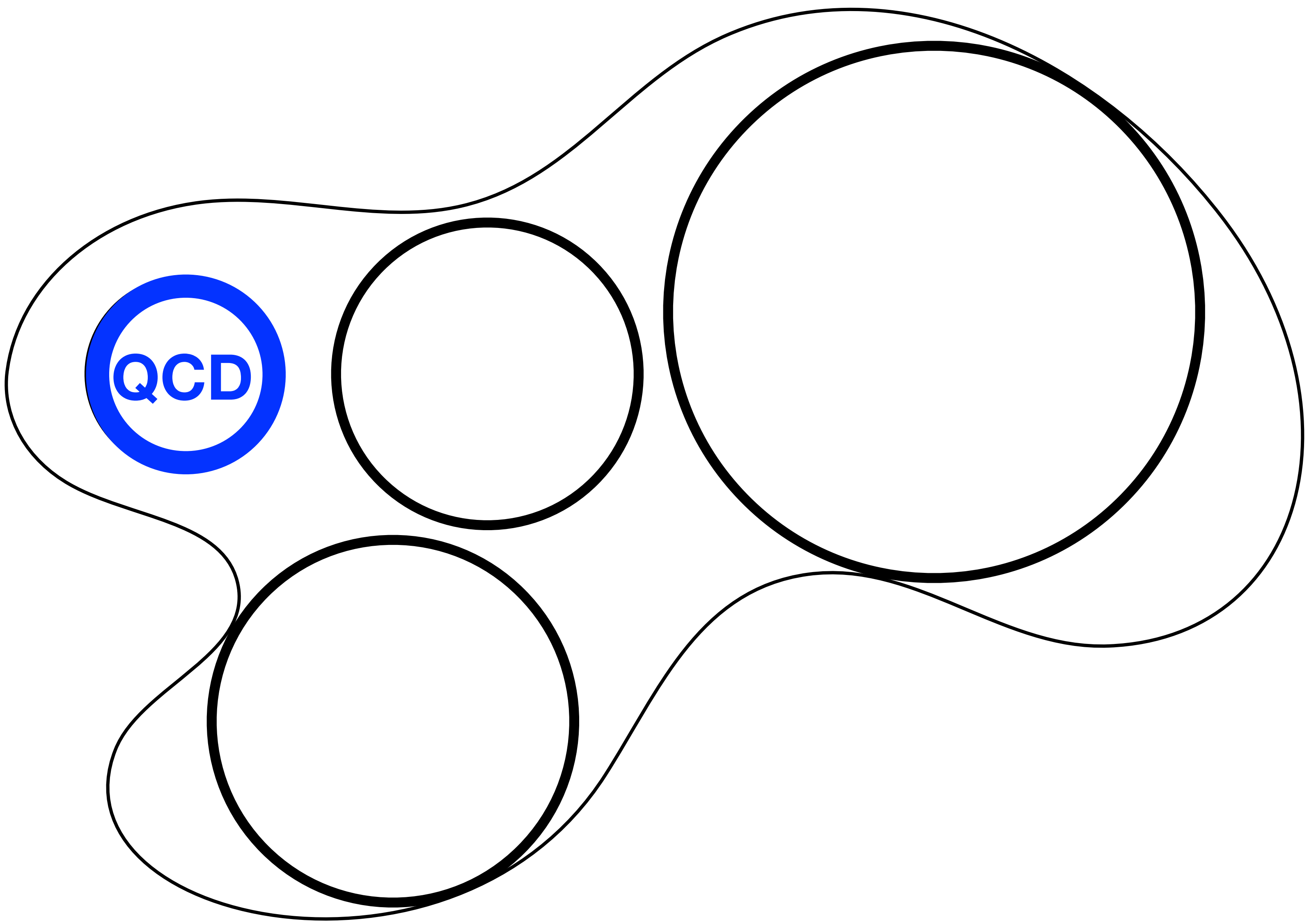

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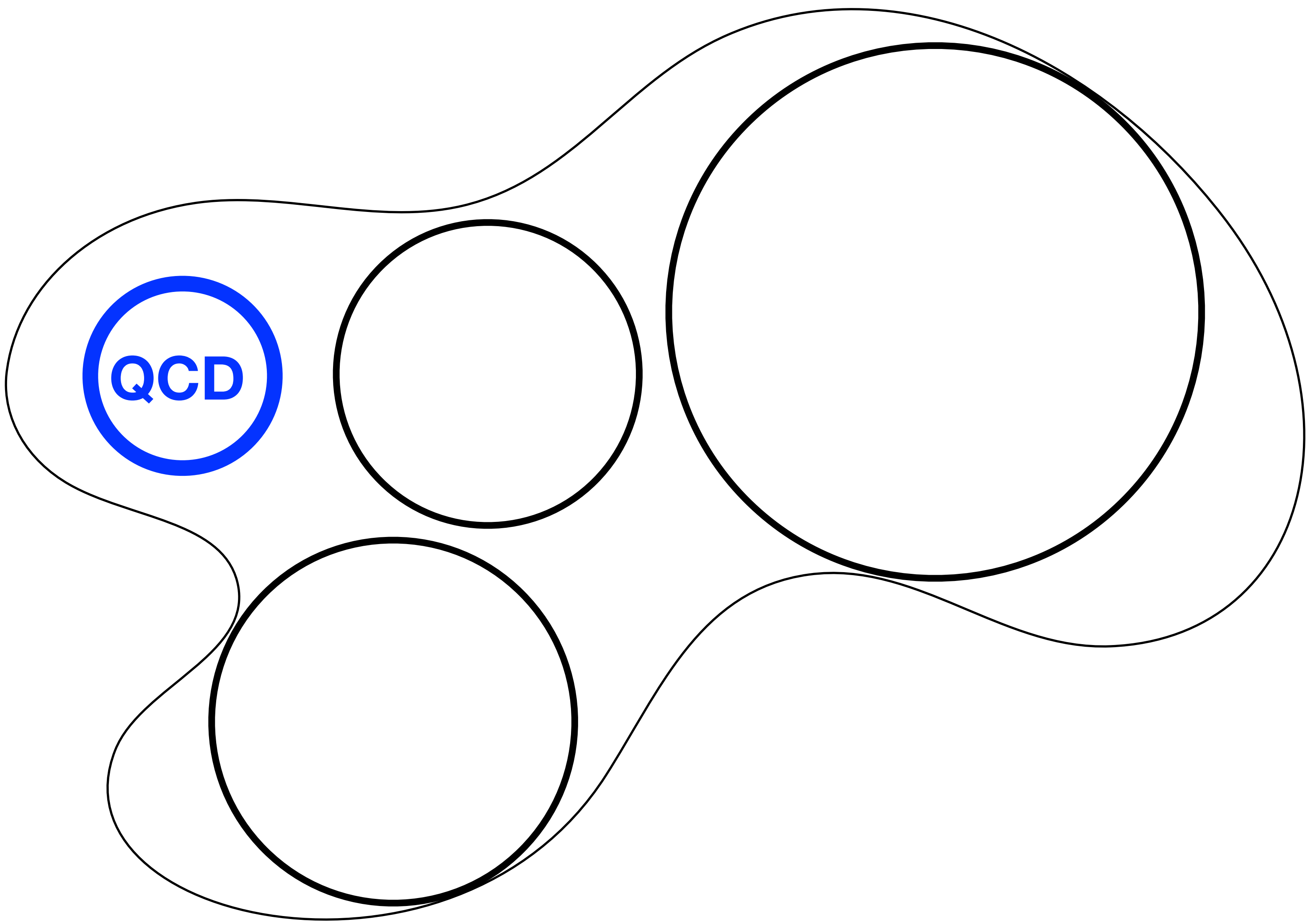

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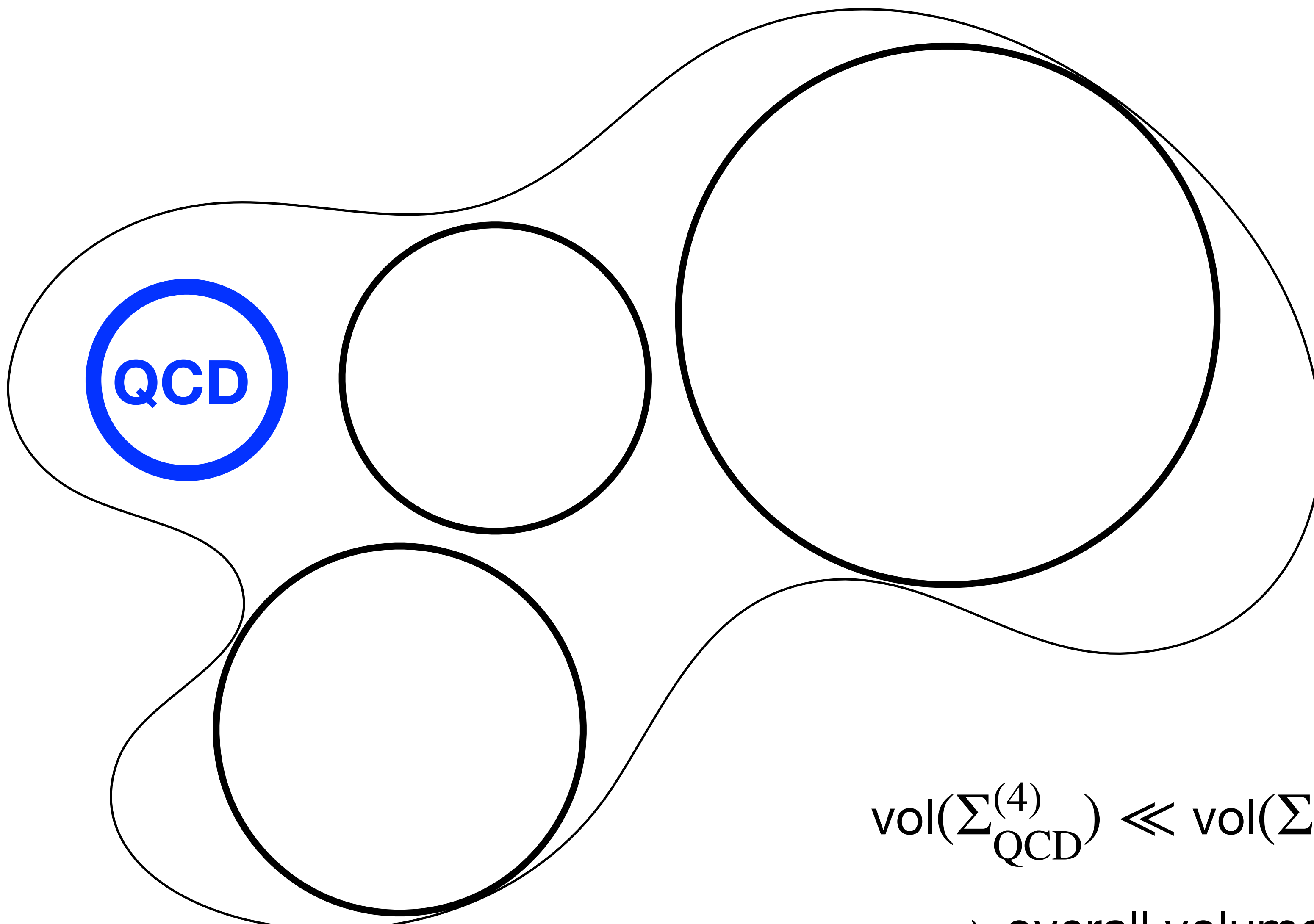

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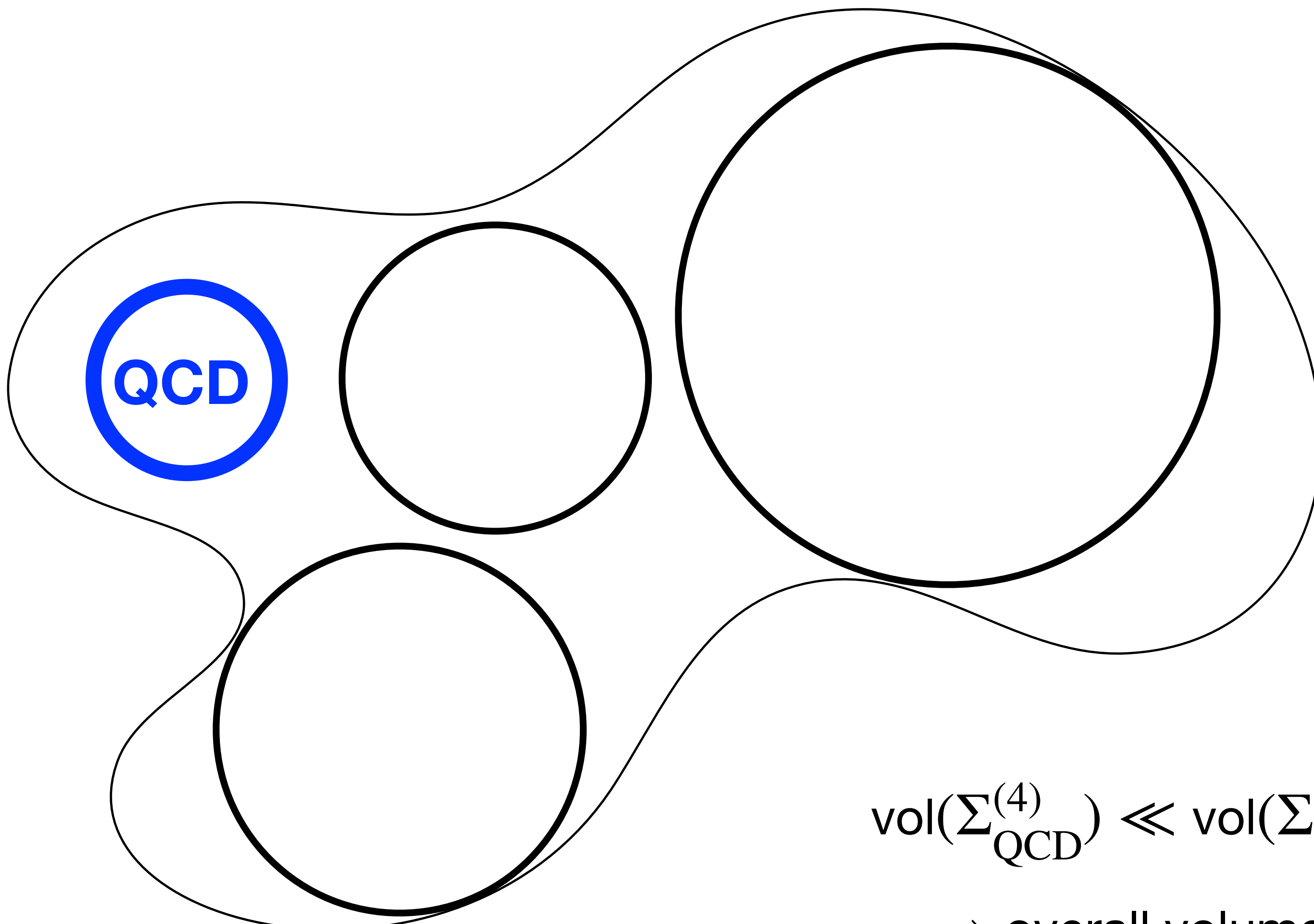

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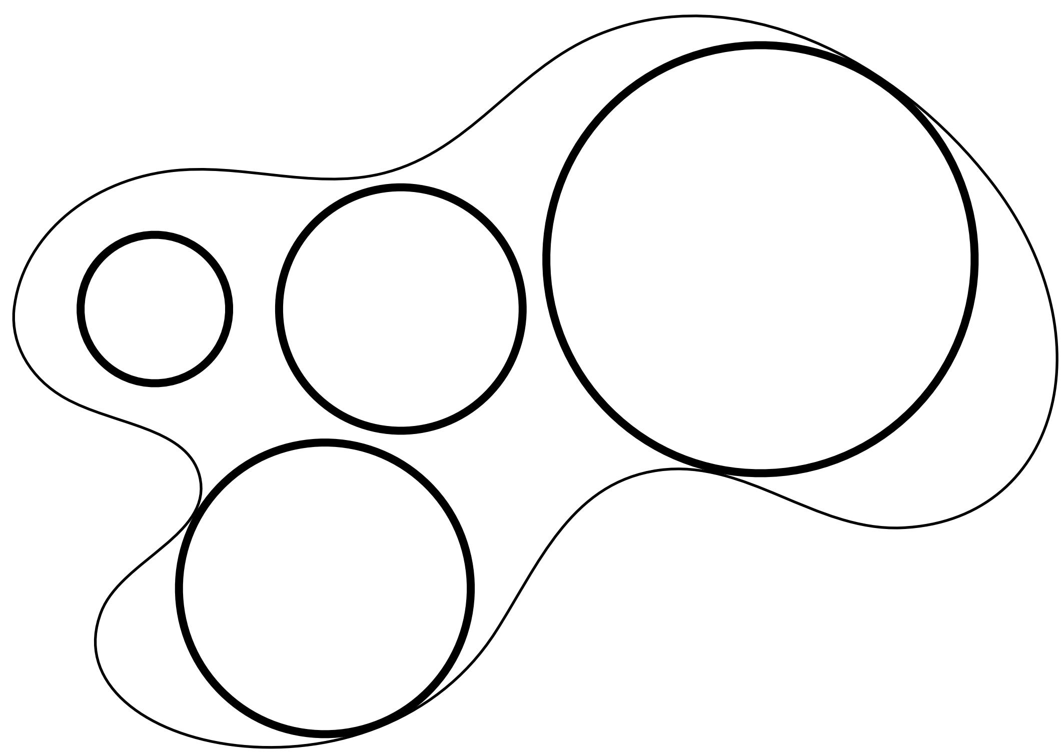

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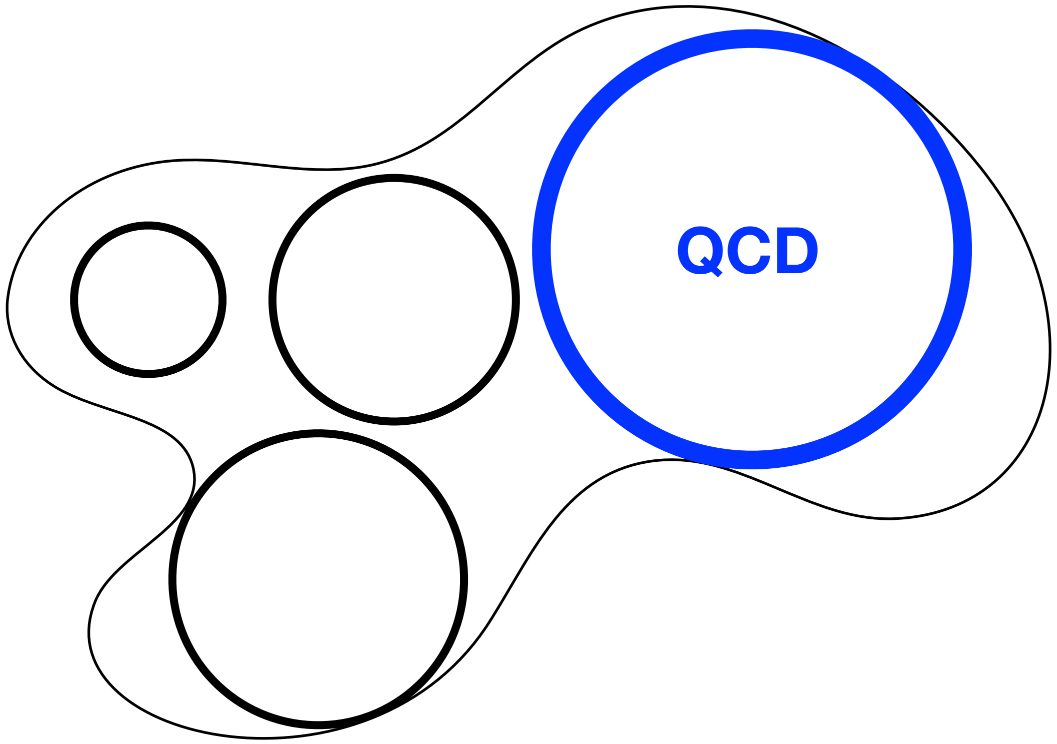

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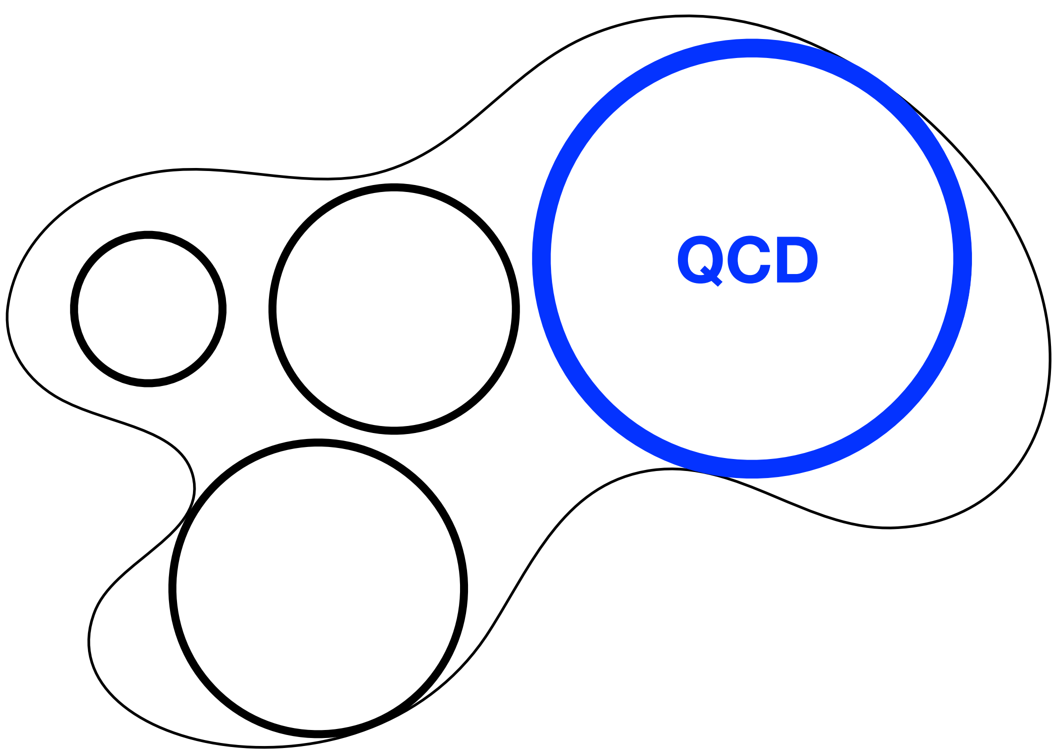

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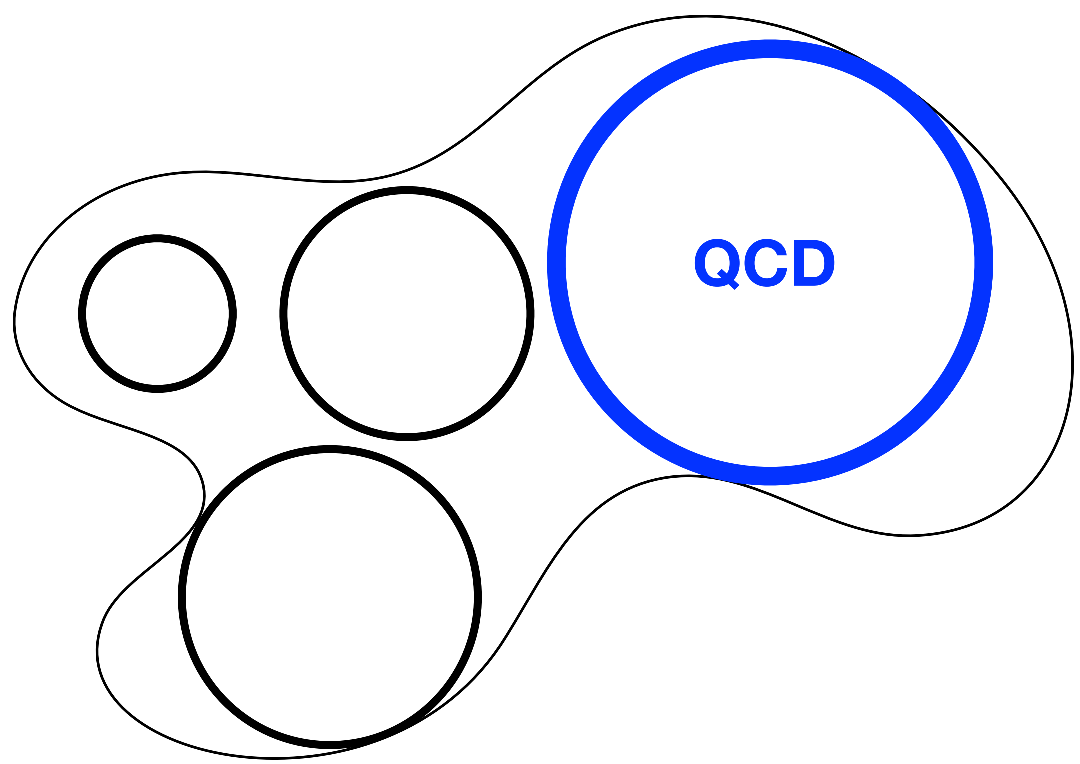

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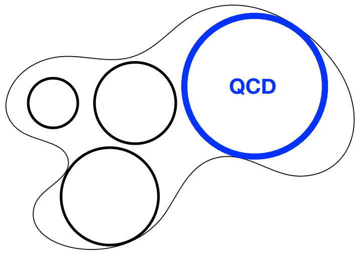

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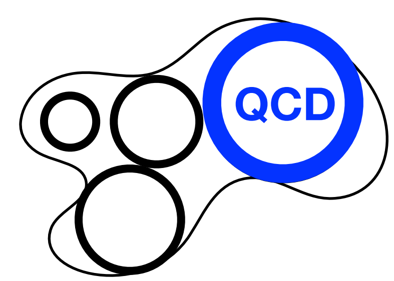

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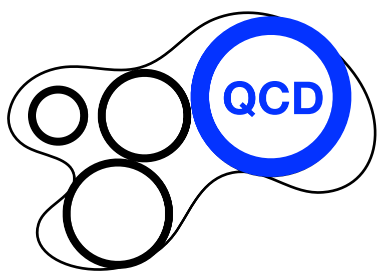

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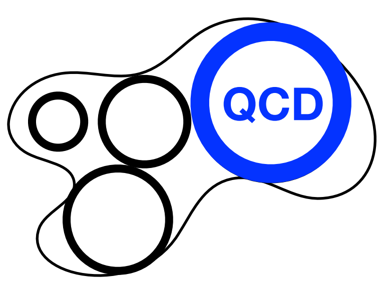

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$\rightarrow$ lose control of the effective theory!

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Question: Could an axion experiment tell us whether we are in a regime of control?

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- In our ensemble, DM experiments are sensitive to the geometry of the string compactification

Thank you!

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- Consider all candidates for $\Sigma^{(4)}_{\mathrm{QCD}}$

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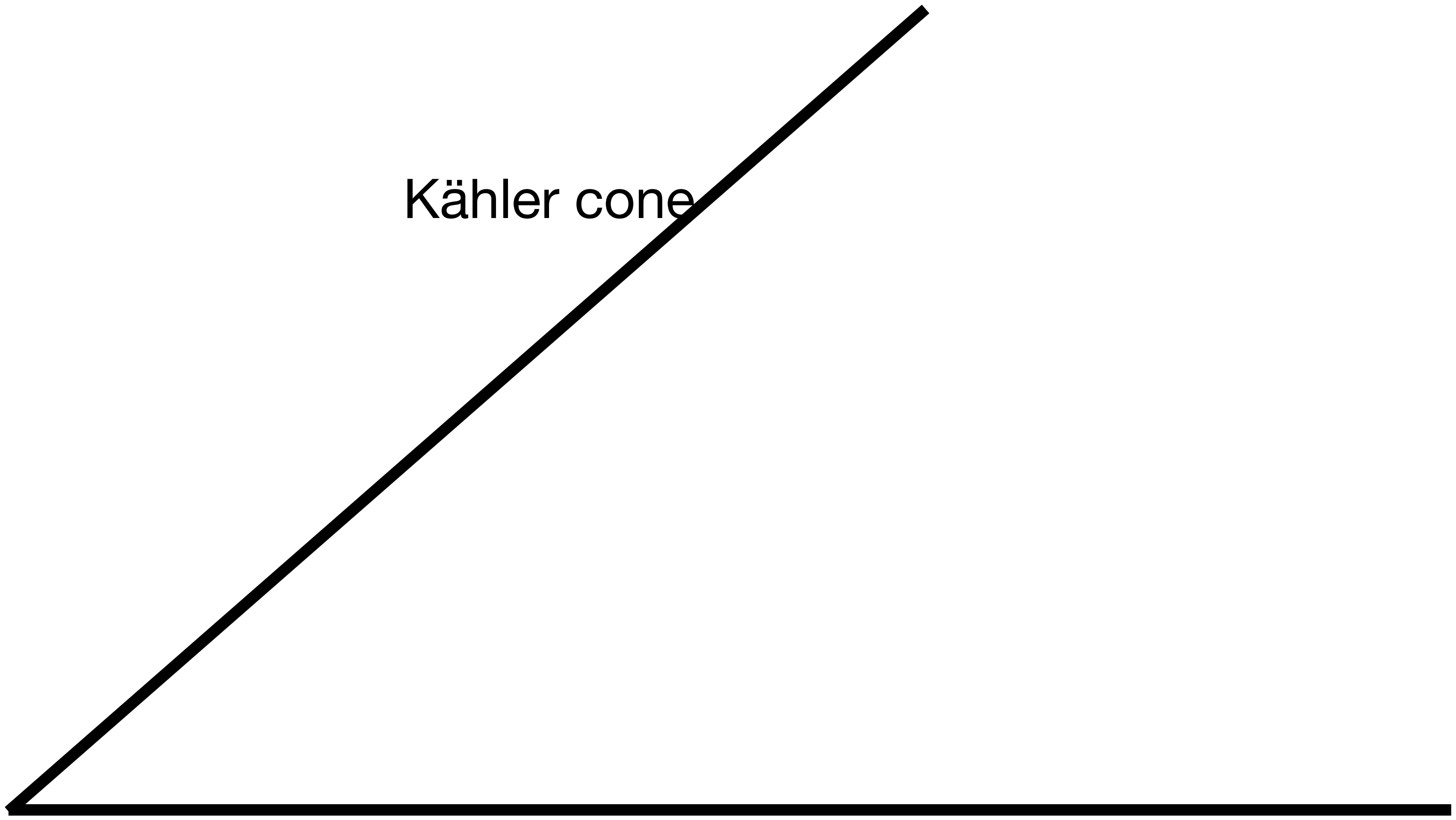

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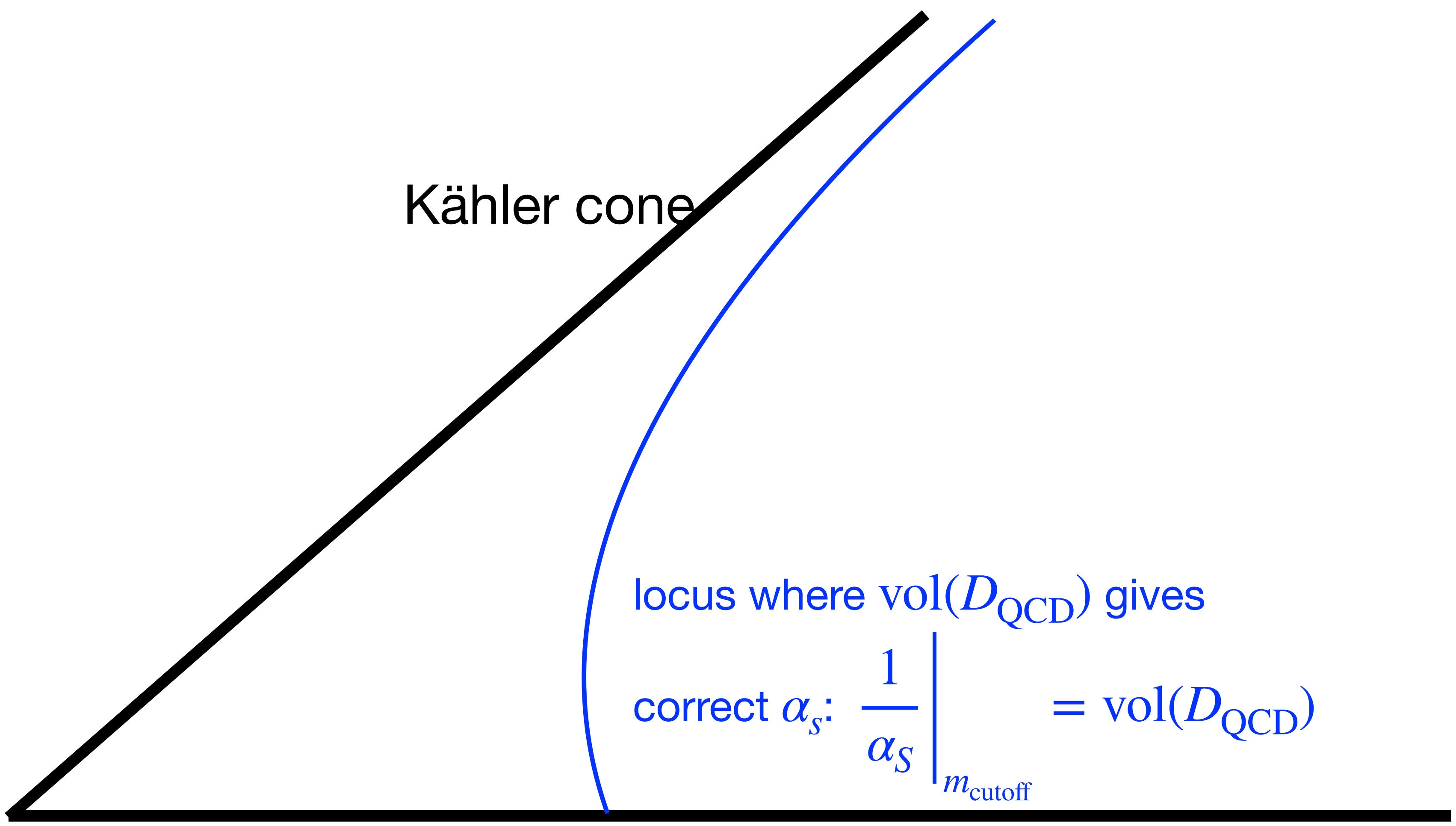

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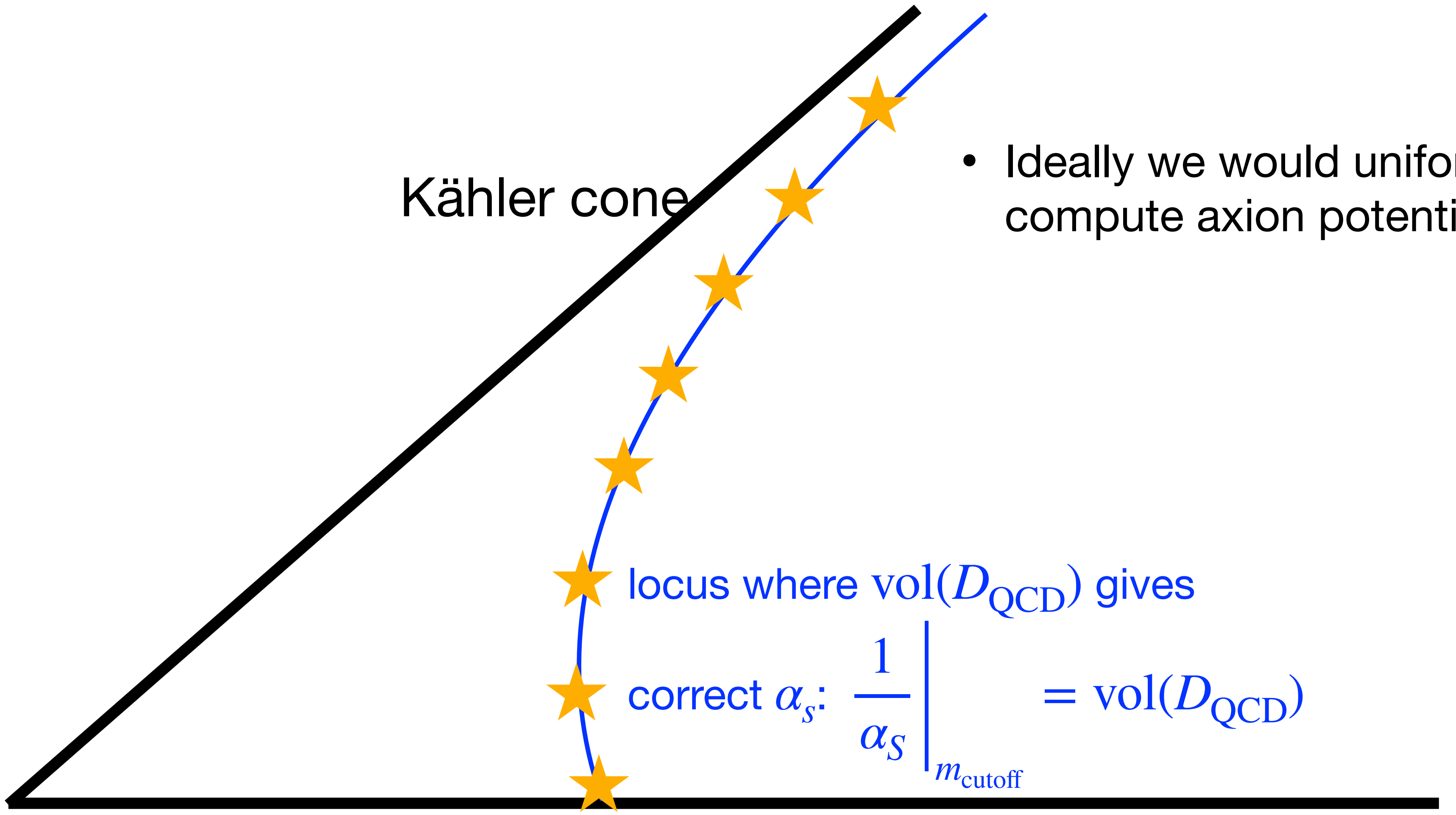

- Ideally we would uniformly sample this locus and compute axion potentials at each point.

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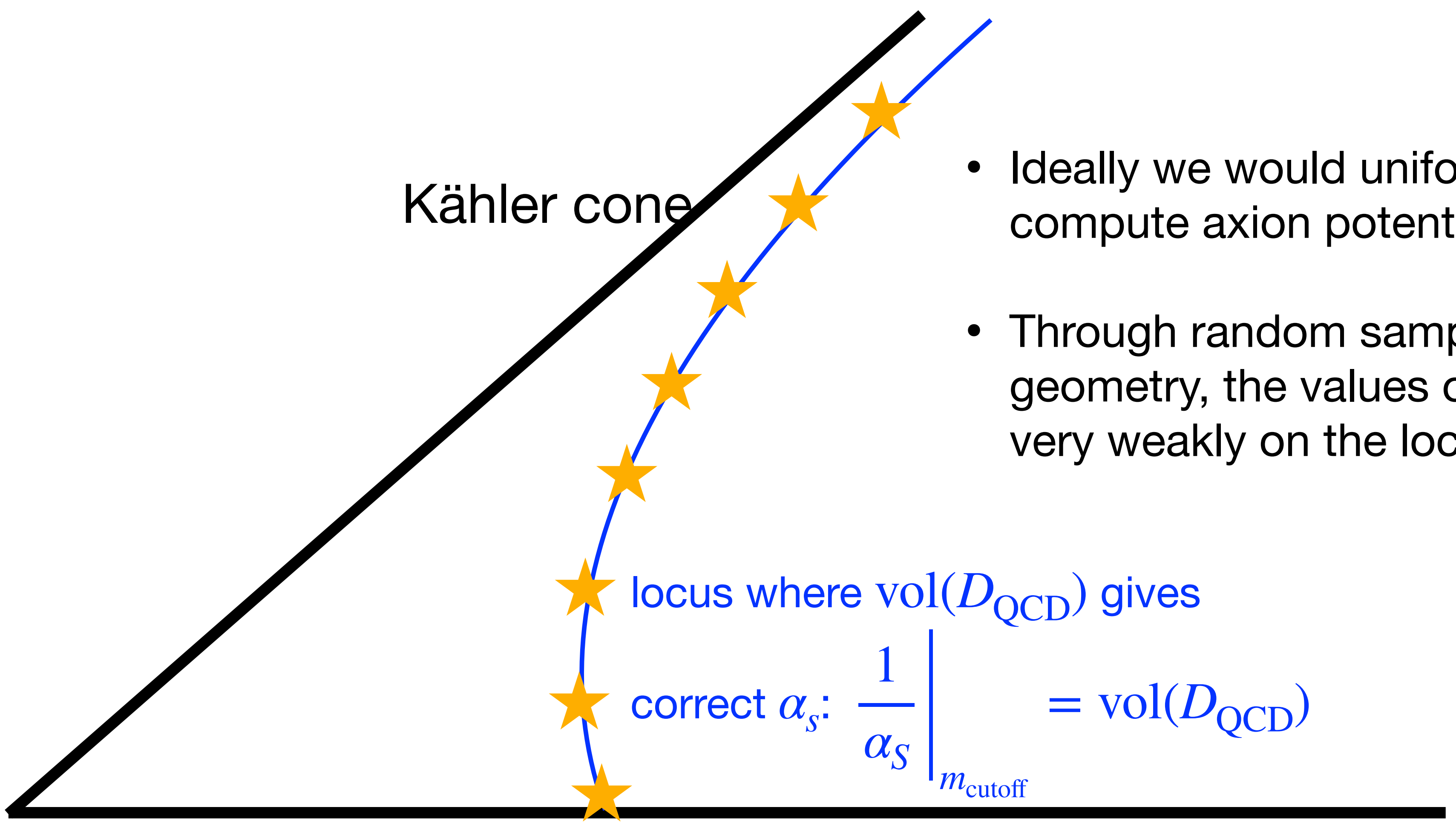

- Ideally we would uniformly sample this locus and compute axion potentials at each point.
- Through random sampling, we found that for a given geometry, the values of the moduli (divisor volumes) depend very weakly on the location on this locus.

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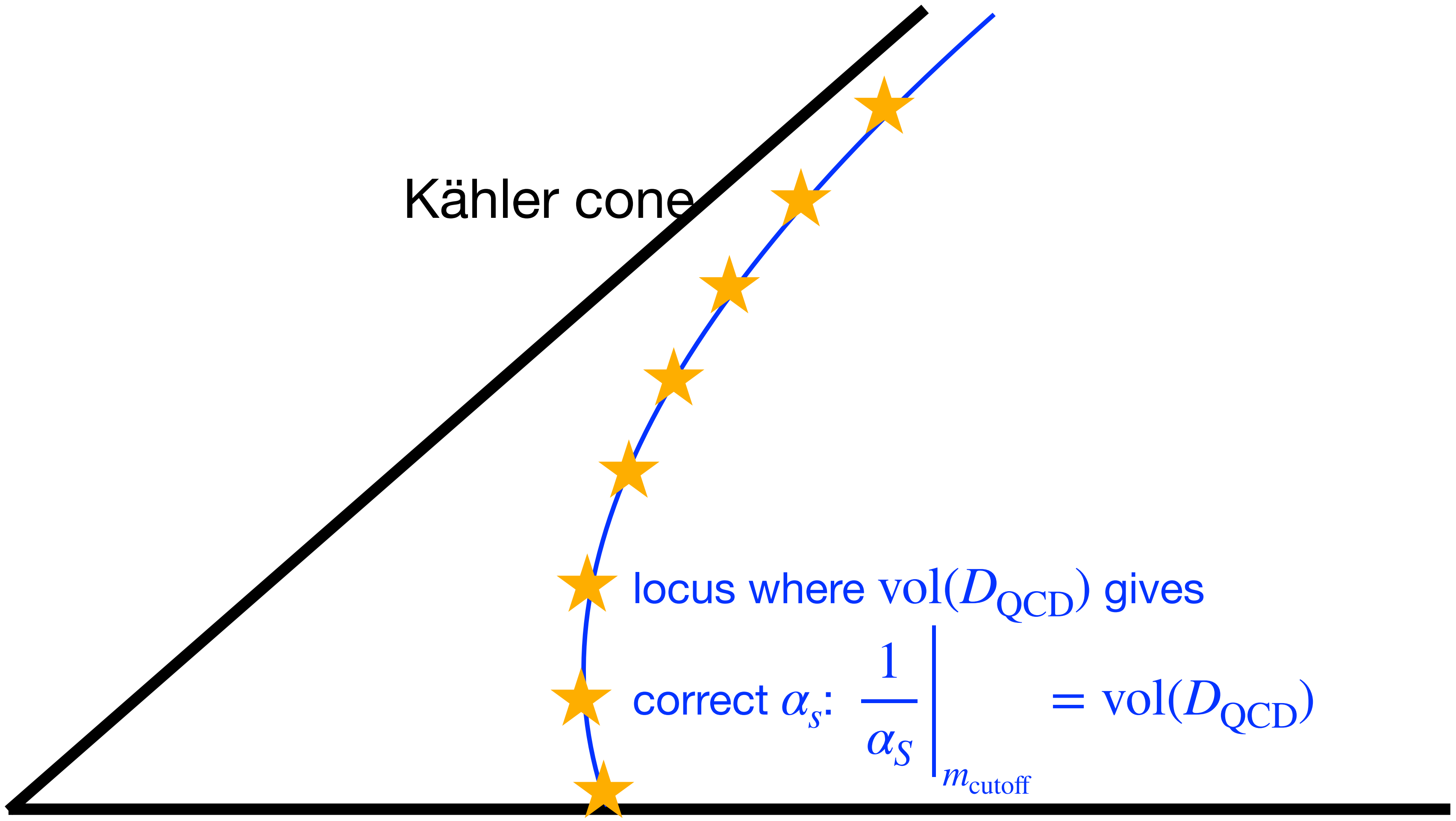

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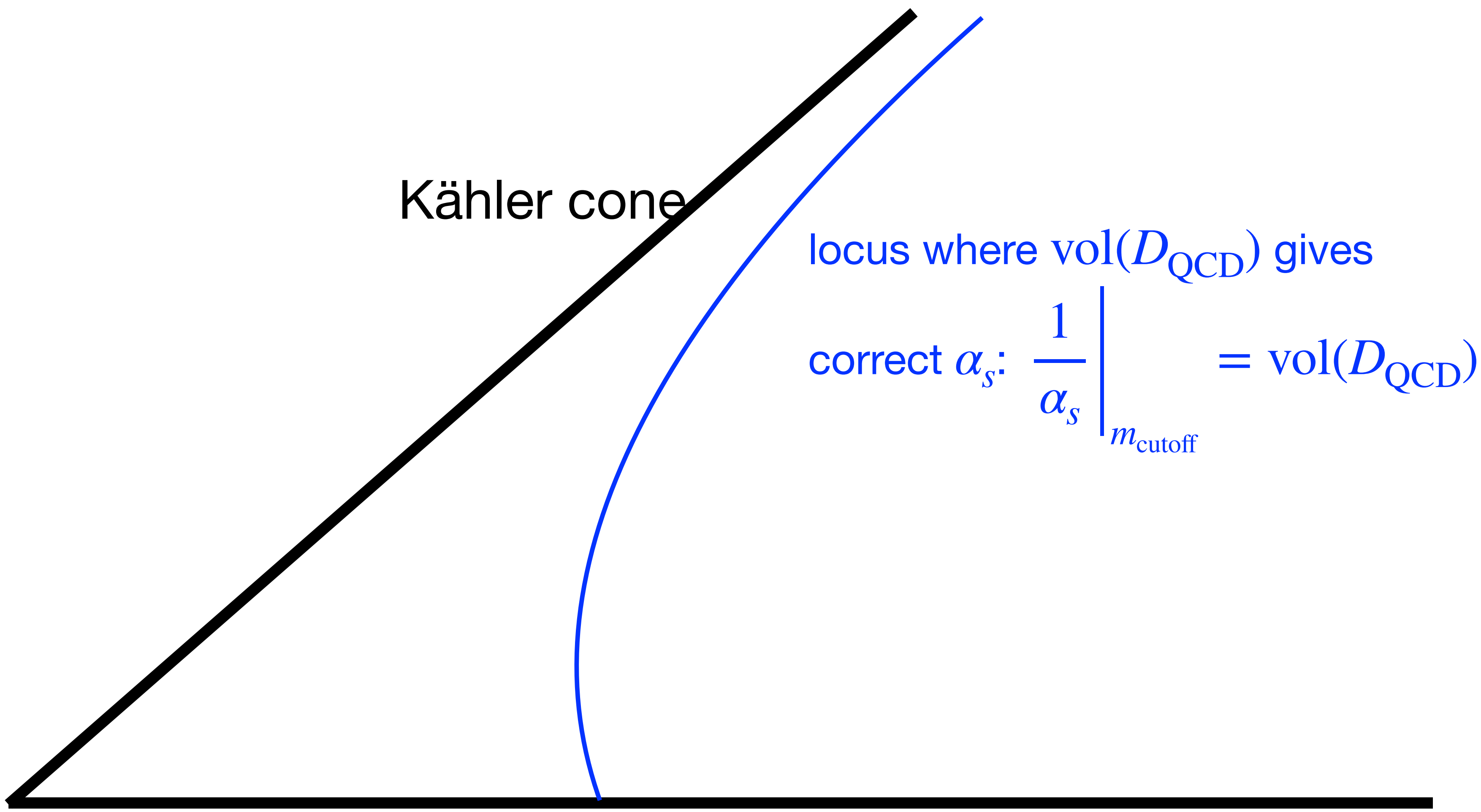

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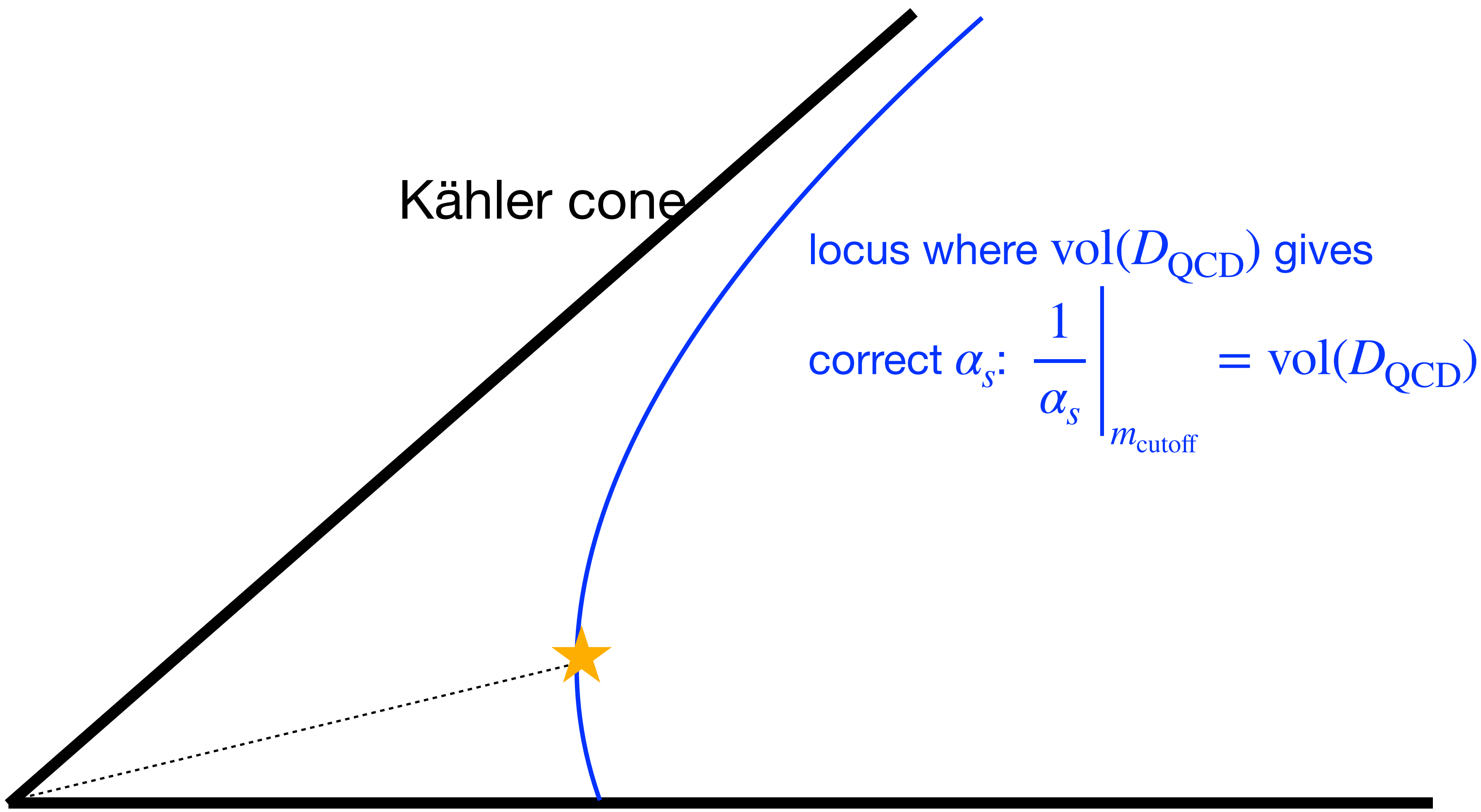

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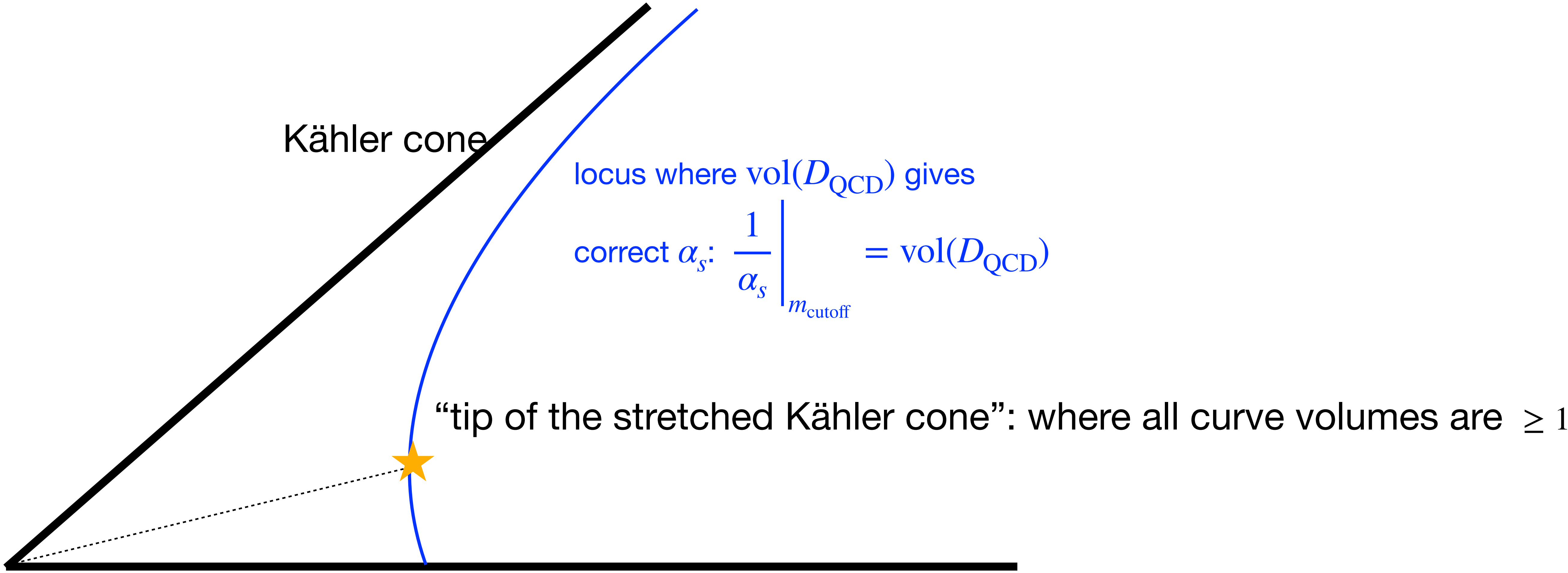

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