Bulk/boundary Modular Quintessence

Marco Scalisi

September 11th, 2025

Corfu Summer Institute

Università di Catania

INFN

Chiara Abramo *"Quintessenza"*

based on

2506.02731 (to be published in **JHEP**)

arXiv:2506.02731v2 [hep-th] 17 Jun 2025

MPP-2025-113
LMU-ASC 15/25

Bulk/boundary Modular Quintessence and DESI

Luis A. Anchordoqui,[a,b,c] **Ignatios Antoniadis,**[d,e] **Niccolò Cribiori,**[f] **Arda Hasar,**[g] **Dieter Lüst,**[h,i] **Joaquin Masias,**[h] **Marco Scalisi**[j,k]

[a] *Department of Physics and Astronomy, Lehman College, City University of New York, NY 10468, USA*
[b] *Department of Physics, Graduate Center, City University of New York, NY 10016, USA*
[c] *Department of Astrophysics, American Museum of Natural History, NY 10024, USA*
[d] *High Energy Physics Research Unit, Faculty of Science, Chulalongkorn University, Bangkok 1030, Thailand*
[e] *Laboratoire de Physique Théorique et Hautes Énergies - LPTHE Sorbonne Université, CNRS, 4 Place Jussieu, 75005 Paris, France*
[f] *KU Leuven, Institute for Theoretical Physics, Celestijnenlaan 200D, B-3001 Leuven, Belgium*
[g] *Department of Physics, Faculty of Arts and Sciences, Middle East Technical University, 06800 Ankara, Türkiye*
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[i] *Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, 80333 München, Germany*
[j] *Department of Physics and Astronomy "Ettore Majorana", University of Catania, Via S. Sofia 64, I-95125 Catania, Italy*
[k] *INFN-Sezione di Catania, Via Santa Sofia 64, I-95123 Catania, Italy*

Abstract: The latest DESI DR2 results, when combined with other independent cosmological data on the Cosmic Microwave Background and supernovas, suggest a preference for dynamical dark energy. We propose a novel cosmological scenario, which features two distinct scalar fields. One governs the magnitude of the present-day dark energy density and is related to the size of extra-dimensions. Accounting for the observed smallness of this energy density requires the scalar to reside near the boundary of field space. The second field, responsible for the time evolution of dark energy and associated with the string coupling, must instead lie in the bulk to remain consistent with the non-observation of light string states. We show that a natural candidate for such dark energy dynamics is a quintessence modular-invariant potential, in which the second scalar field rolls down a negatively curved slope, starting from a self-dual critical point. We find that this scenario is in good agreement with the latest findings by DESI.

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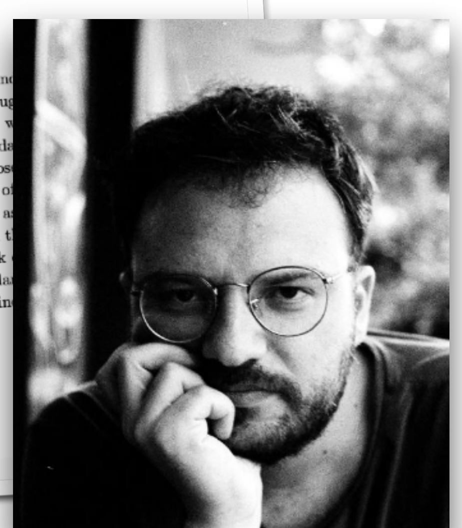

Arda Hasar

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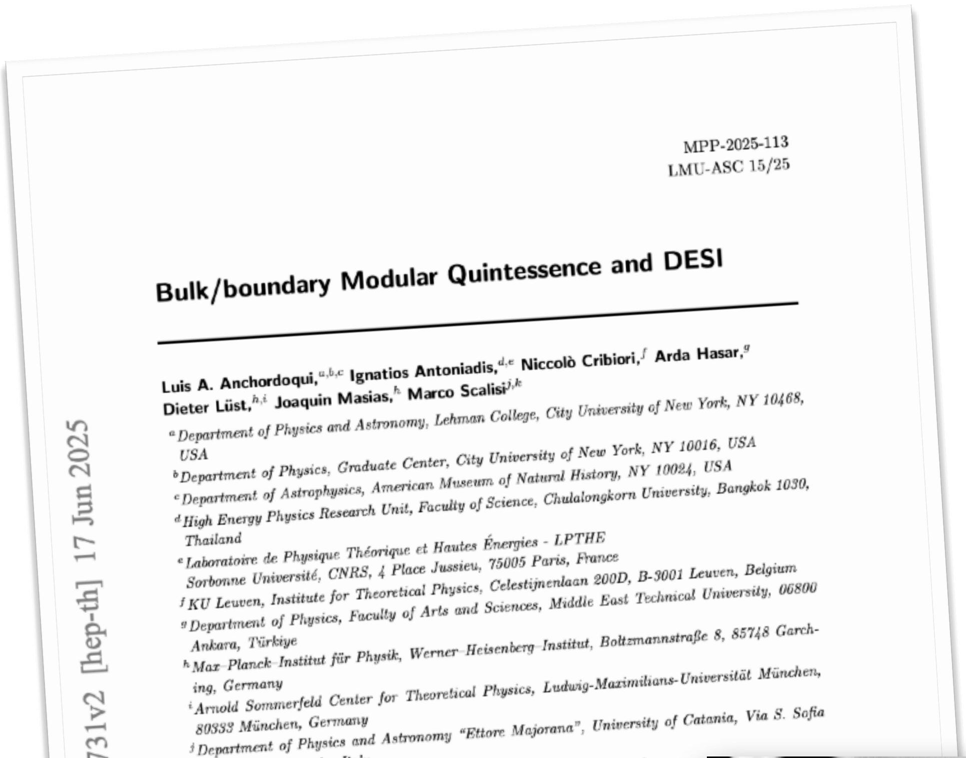

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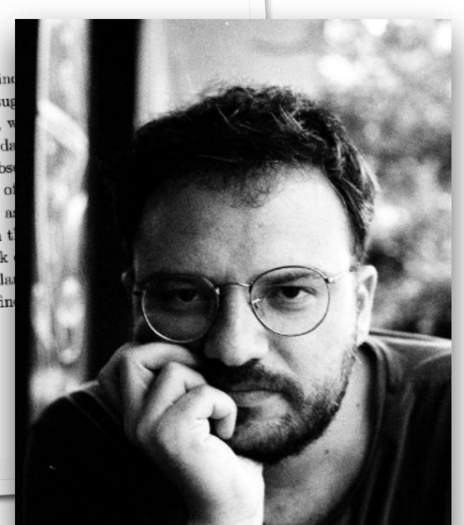


Arda Hasar

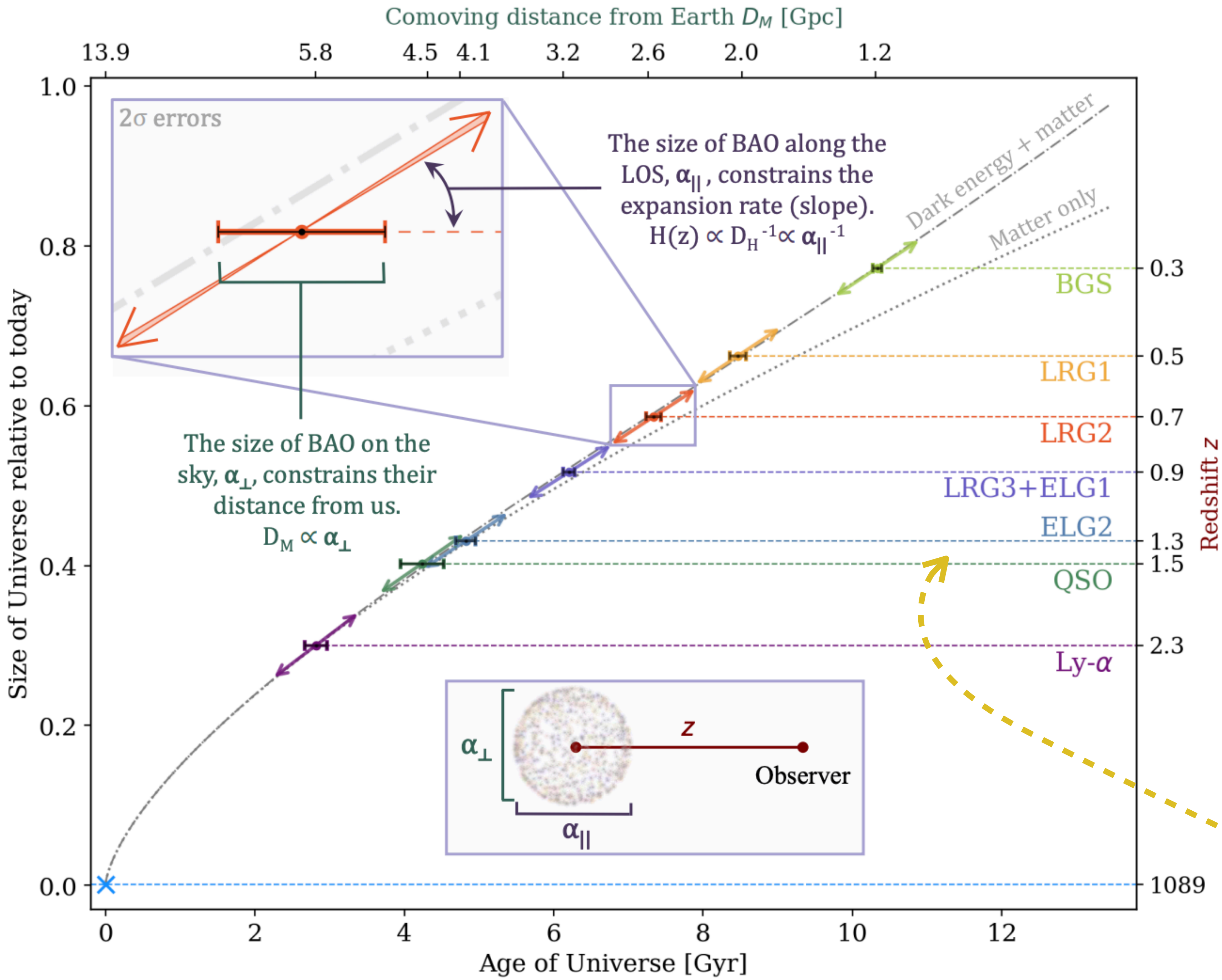
Joaquin Masias

Niccolò Cribiori

DESI = Dark Energy Spectroscopic Instrument

massive multi-object **spectrograph** mounted on
the **Mayall 4-meter telescope** at Kitt Peak National Observatory (Arizona, USA)

DESI



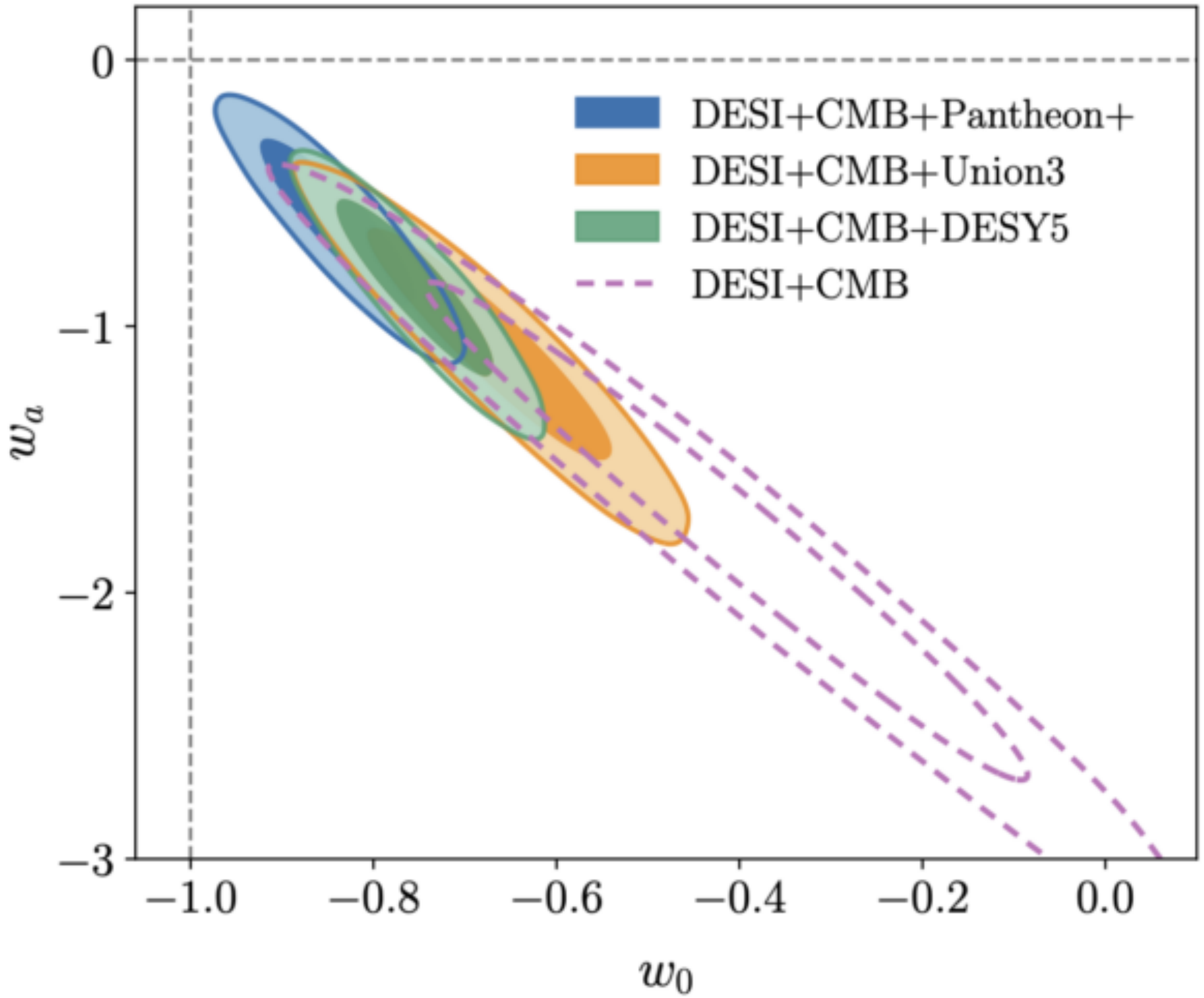
probed **redshifts**

$0.1 \lesssim z \lesssim 3.5$

different **target classes**

~1.5 to **12.5 billion years** after the Big Bang

DESI

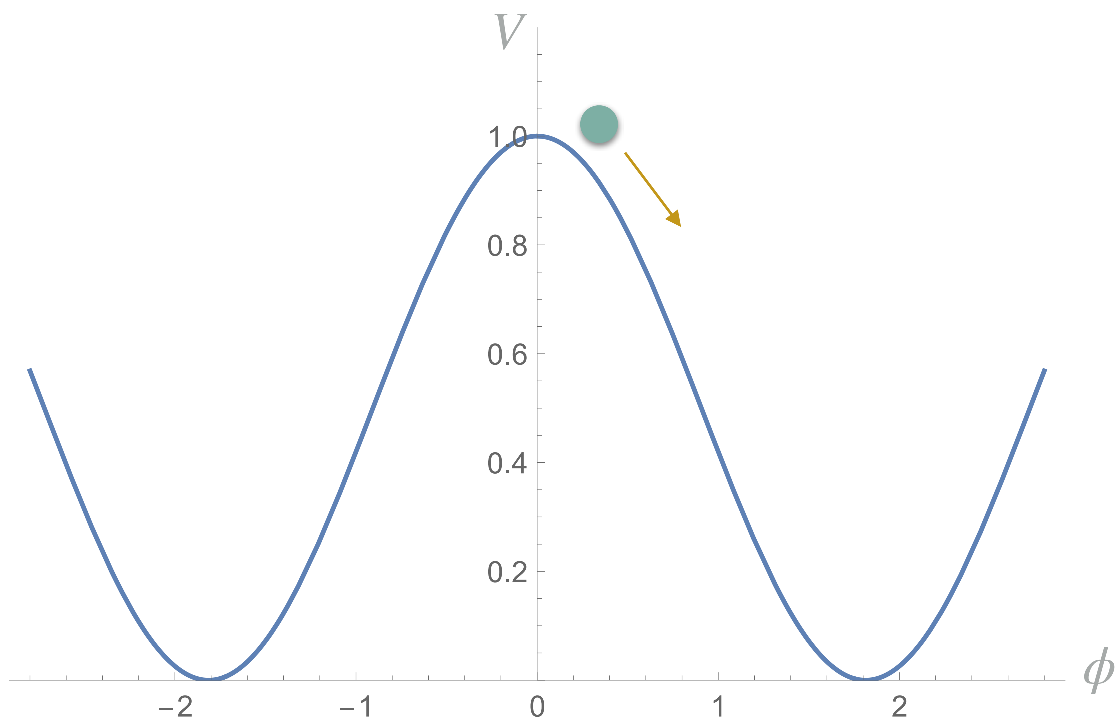


$$w = w_0 + w_a(1-a) = w_0 + w_a\frac{z}{z+1}$$

Chevallier–**P**olarski–**L**inder parametrization

Quintessence

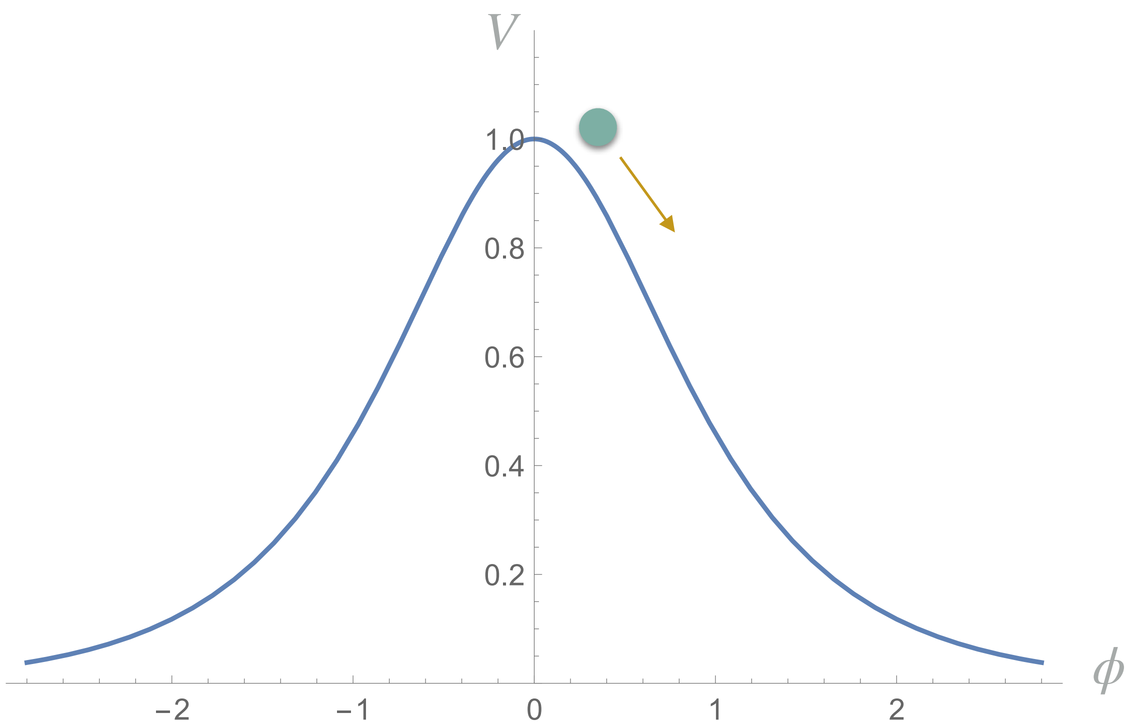
Axion potential



$$V(\phi) = m_a^2\ f_a^2\ [1 + \cos(\phi/f_a)]$$

DESI collaboration ***2503.14743***

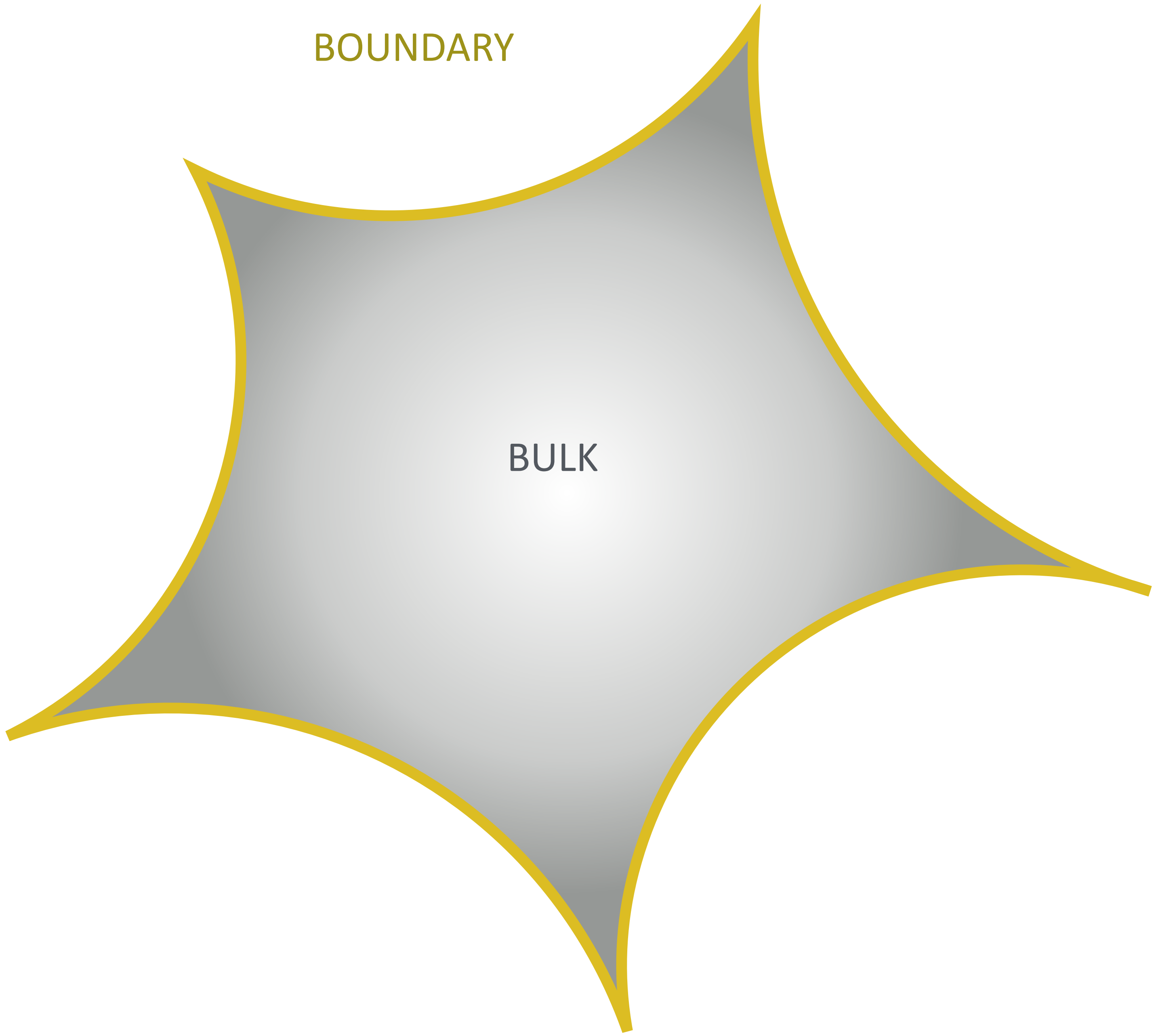
Self-dual potential



$$V = \Lambda\,\mathrm{sech}\left(\sqrt{2}\phi/M_p\right) = \frac{2\ \Lambda}{s + 1/s}$$

Anchordoqui, Antoniadis, Lüst ***2503.19428***

Where in **moduli space**?



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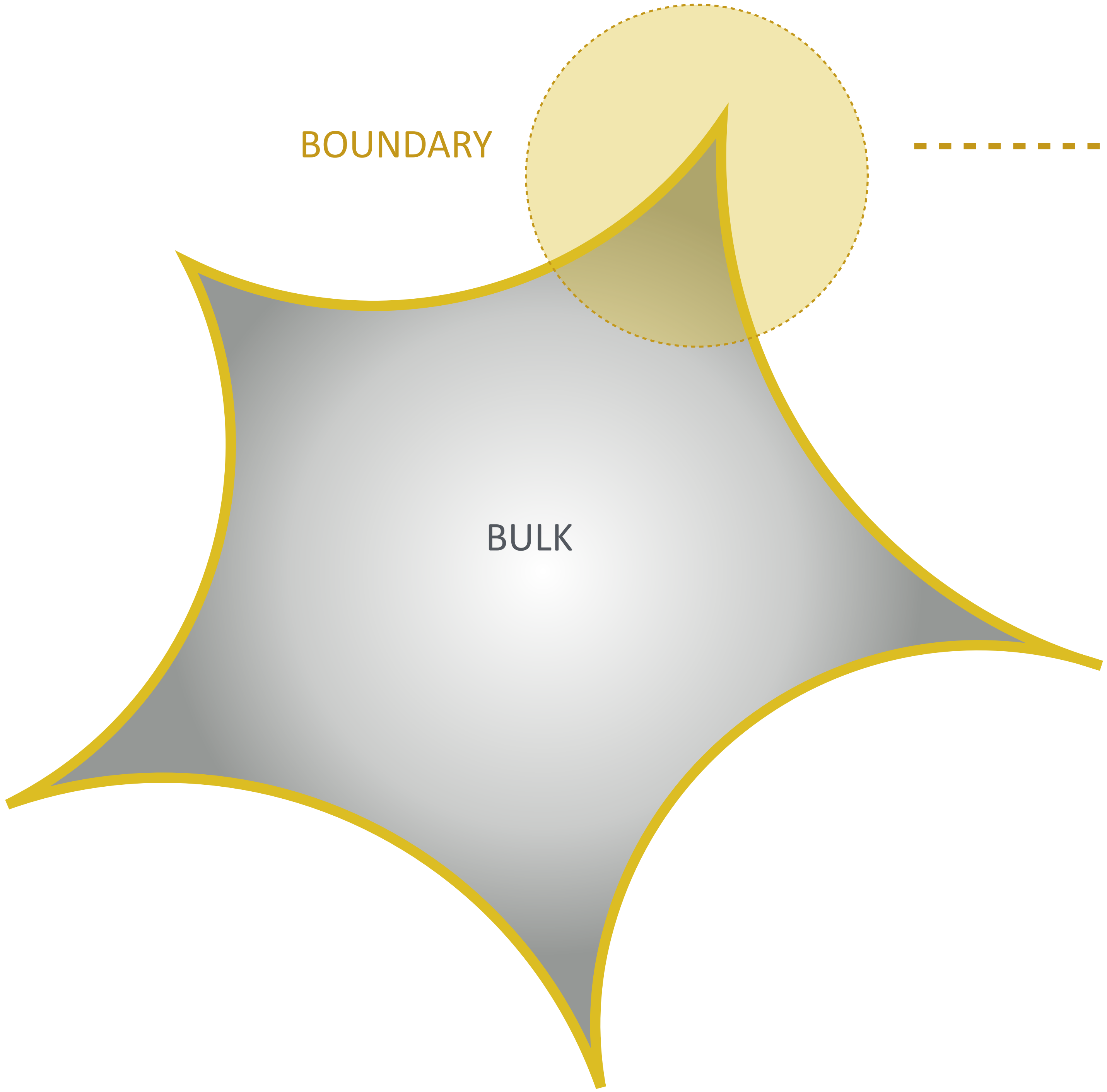


$$V \sim e^{-\lambda\phi}$$

THEORY

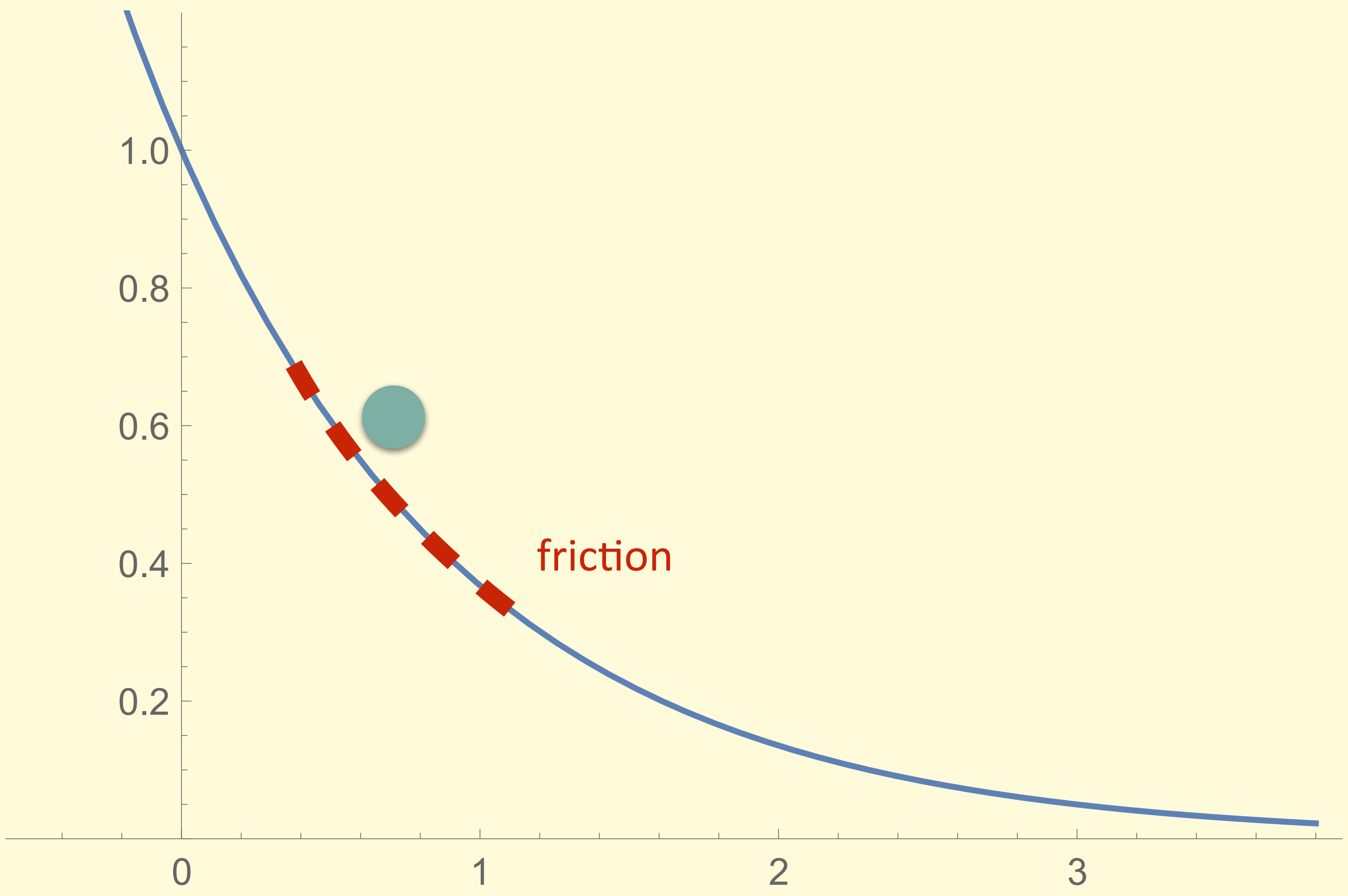
$$\lambda > \sqrt{2}$$

[de Sitter conjecture]
[TCC bound]
[Emergent string conjecture]

OBSERVATIONS

$$\lambda \lesssim 0.5 - 1$$

Coupling to matter = additional friction = effective reduction of w_{DE}



$$V \sim e^{-\lambda\phi}$$

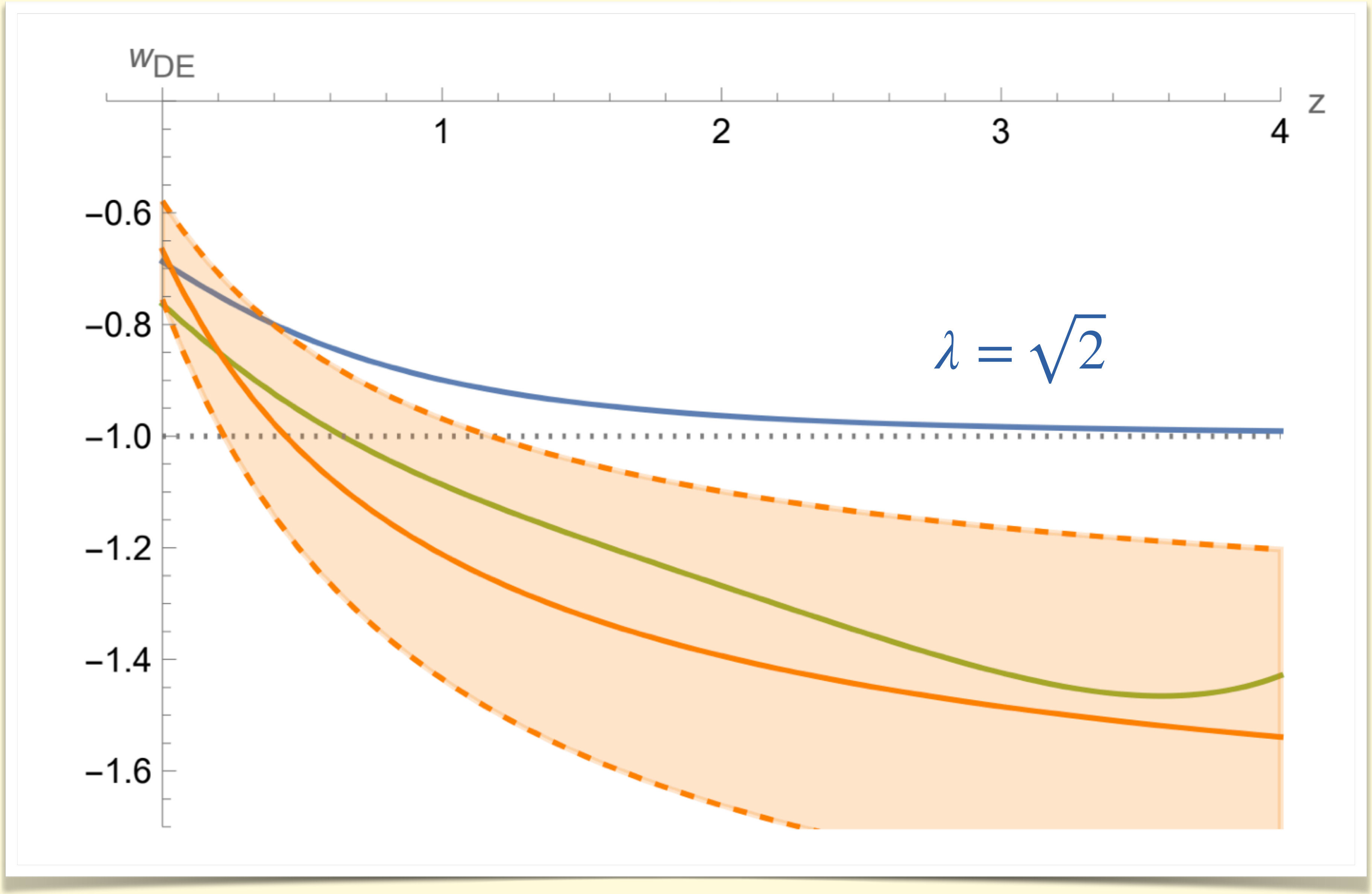
$$\mathscr{L}_m = \mathscr{L}_m(\phi)$$

e.g.

$$m_t \sim e^{-\alpha\phi}$$

David Andriot 2025; Bedroya, Obied, Vafa, Wu 2025

Coupling to matter = additional friction = effective reduction of w_{DE}

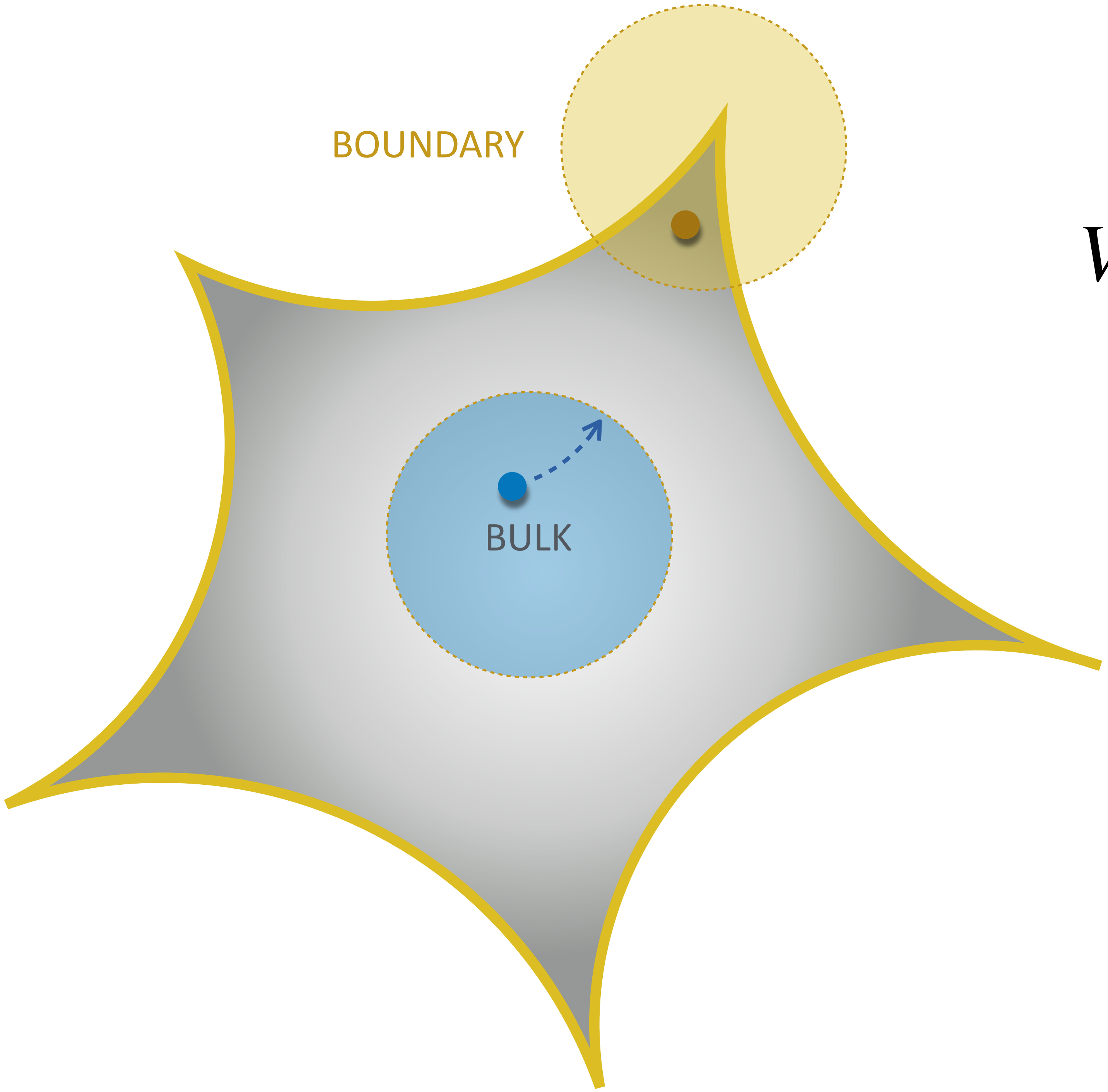


plot taken from D. Andriot ***2505.10410***

Our work

Bulk/boundary scenario

*Anchordoqui, Antoniadis, Cribiori, Hasar, Lüst, Masias, **MS** 2025*



$$V(R, s) = \Lambda(R)\, V_q(s)$$

magnitude
of the present-day
dark energy density

time-evolution
of the present-day
dark energy density

QUINTESSENCE

Dark dimension scenario

$$V(R,s) = \Lambda(R)\, V_q(s)$$

$$\boxed{\Lambda(R) \simeq \frac{\lambda}{R^4}} \simeq 10^{-120} M_p^4$$

if

$$\lambda = \mathcal{O}(10^{-3})$$

Anchordoqui, Antoniadis, Lüst 2022
*Anchordoqui, Antoniadis, Cribiori, Lüst, **MS** 2023*

$$\boxed{R \sim \mathcal{O}(1)\ \mu m}$$

$p = 1$ extra dimension

Montero, Vafa, Valenzuela 2022

$p = 2$ extra dimensions

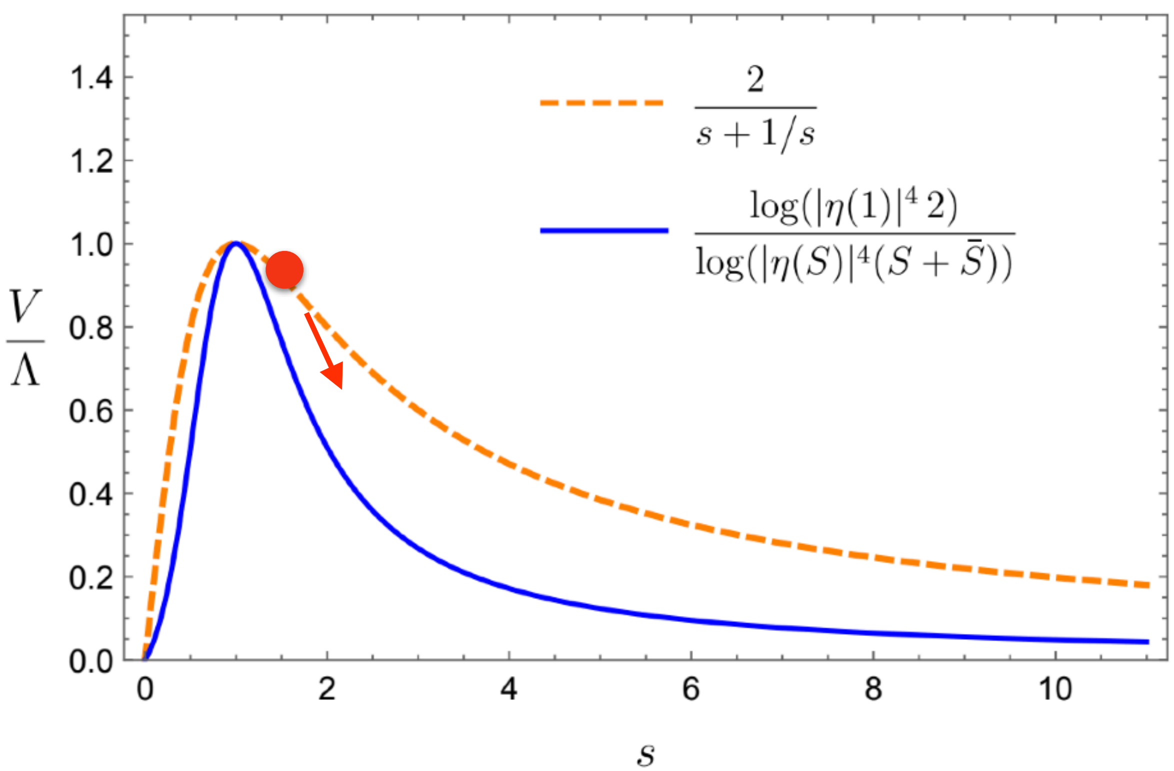
Anchordoqui, Antoniadis, Lüst 2025

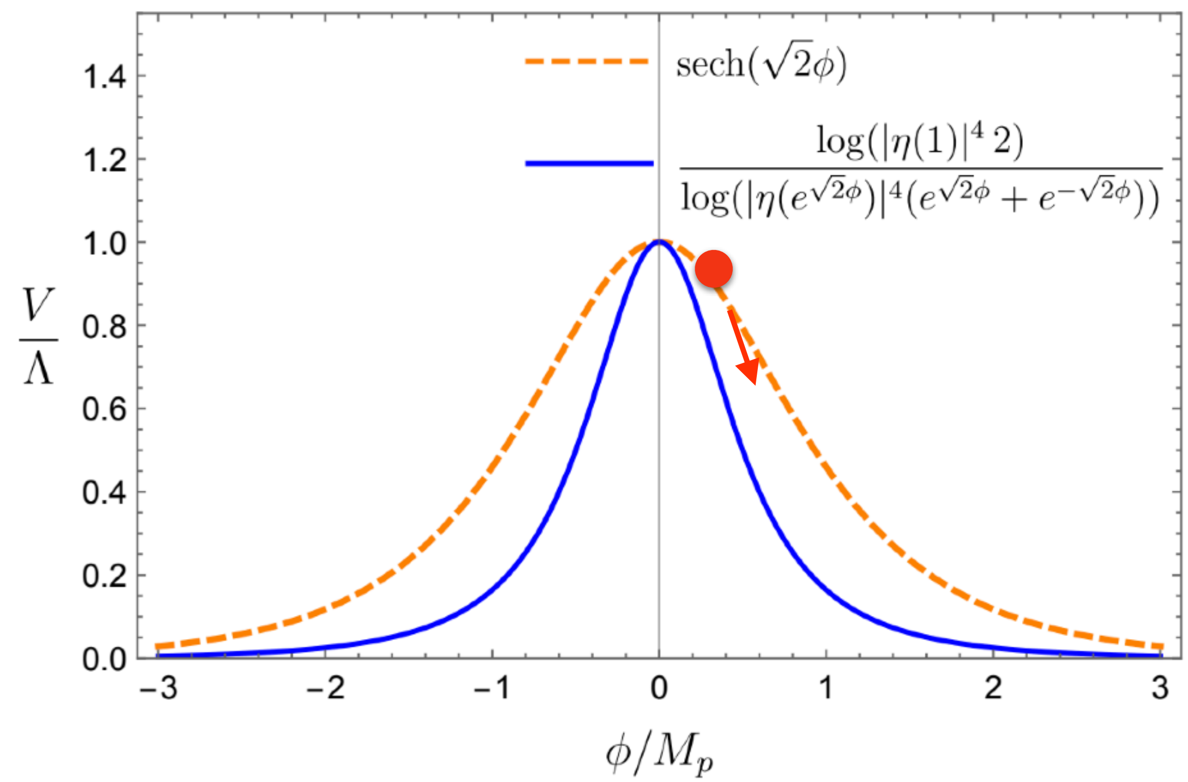
Modular invariant quintessence

$$V(R,s) = \Lambda(R)\, V_q(s)$$

$S = s + ia$ for $S = \bar{S}$

$$V(S,\bar{S}) = -\frac{1}{\log[\,|\eta(S)|^4\,(S+\bar{S})]}$$





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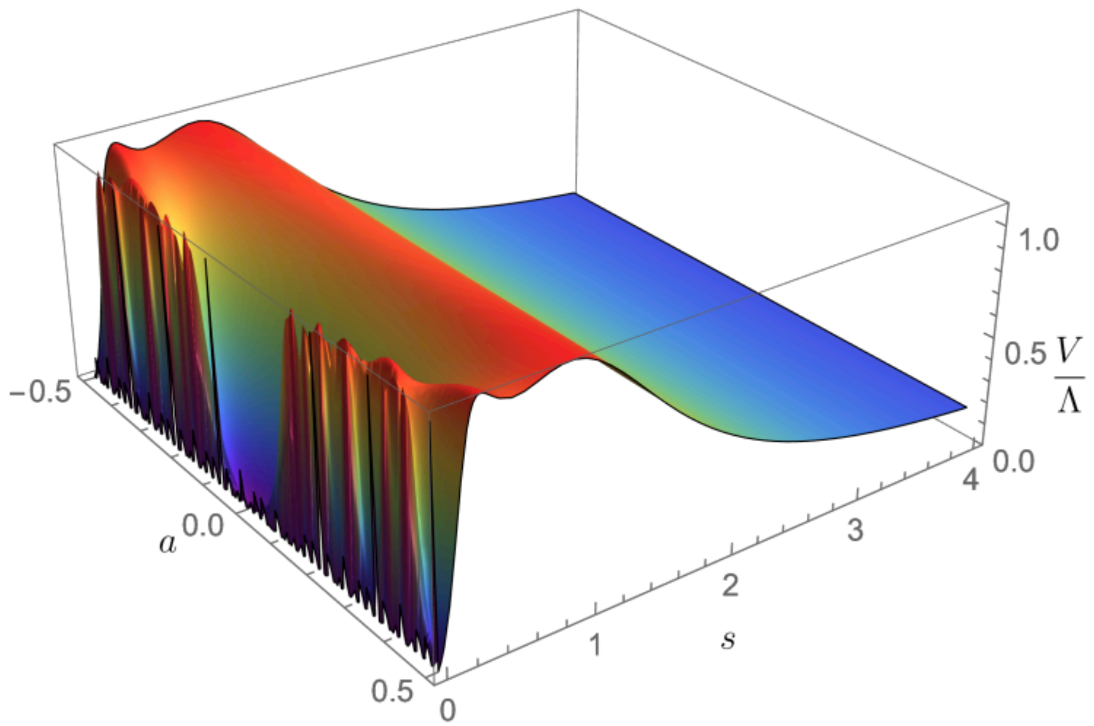
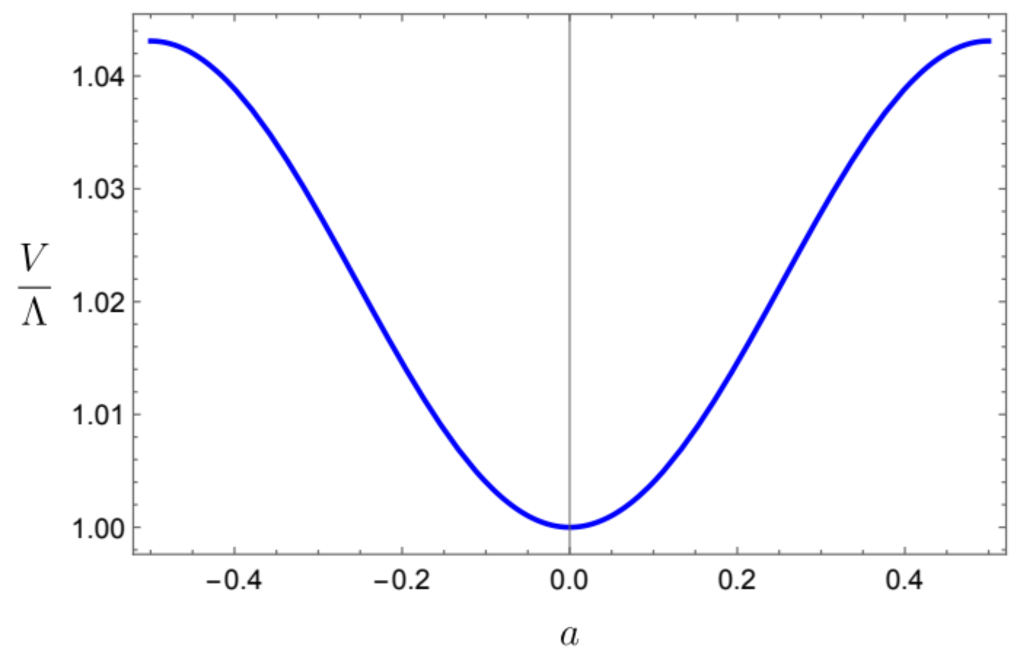




Bulk/boundary scenario and the **species scale**

EFT consistency $V \leq M_p^2 \Lambda_{sp}^2$ *Hebecker, Wrase 2018; **MS**, Valenzuela 2018*

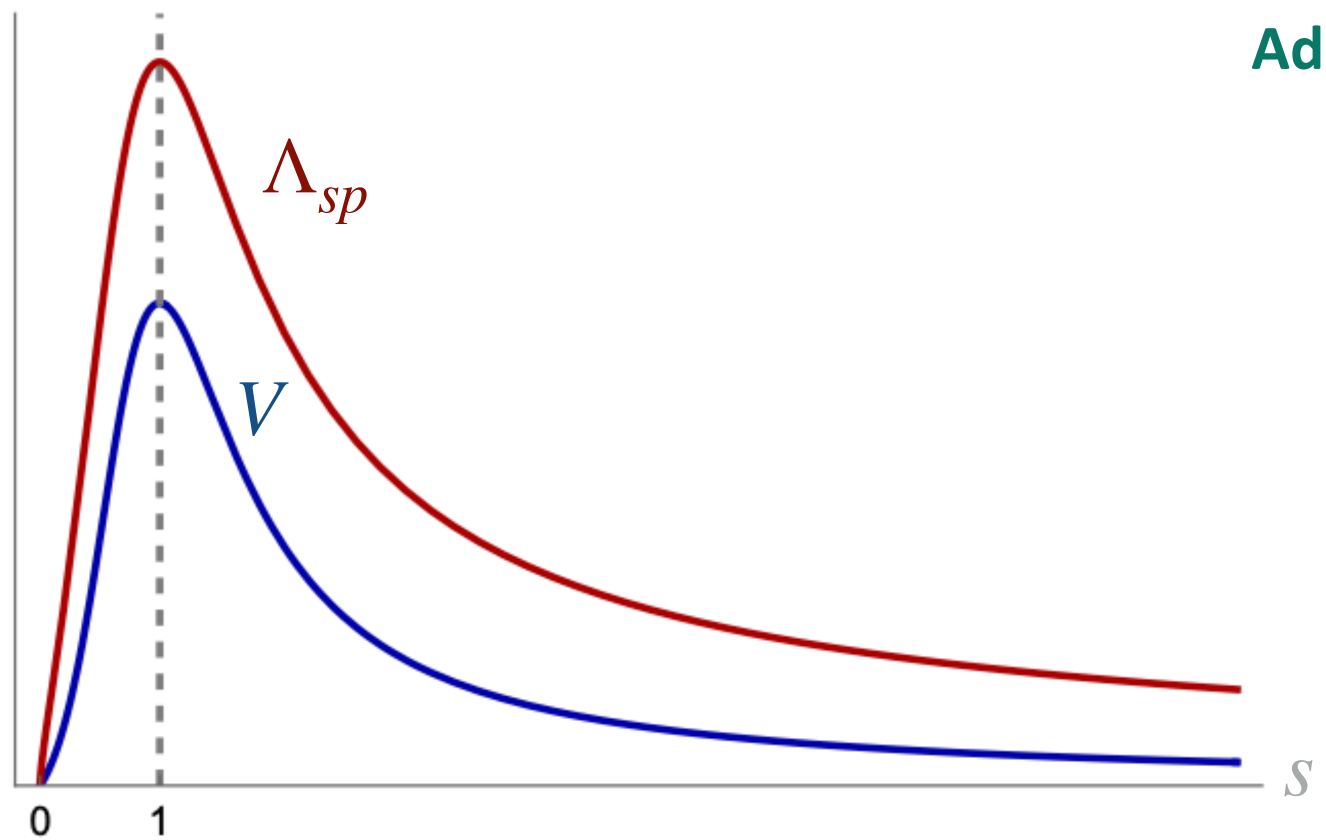
Ansatz
for the potential

$$V = M_p^{4-\alpha} (\Lambda_{sp})^{\alpha}$$

with $\alpha \geq 2$

suggested by the
AdS Distance Conjecture

Lüst, Palti, Vafa 2019



Bulk/boundary scenario and the **species scale**

Emergent String Conjecture *Lee, Lerche, Weigand 2019*

Decompactification limit

$$\Lambda_{sp} \simeq R^{-\frac{p}{d+p-2}} M_p^{\frac{d-2}{d+p-2}} \simeq \frac{M_p}{(M_p R)^{\frac{p}{d+p-2}}} \qquad i.e. \qquad N_{sp} \simeq (M_p R)^{\frac{(d-2)p}{d+p-2}}$$

Emergent string limit

$$\Lambda_{sp} \simeq \hat{g}_s^{\frac{2}{d+p-2}} \hat{M}_p \qquad i.e. \qquad N_{sp} \simeq \hat{g}_s^{-\frac{2(d-2)}{d+p-2}} (M_p R)^{\frac{p(d-2)}{d+p-2}} = g_s^{-2}$$

Bulk/boundary scenario and the **species scale**

Mixed scenario

$$\Lambda_{sp} \simeq g_s^q \frac{M_p}{(M_pR)^{\frac{p}{d+p-2}}} \qquad i.e. \qquad N_{sp} \simeq g_s^{-q(d-2)}(M_pR)^{\frac{p(d-2)}{d+p-2}}$$

$$1/R \leq M_s \leq \Lambda_{sp}$$

$$\frac{1}{M_pR} \leq g_s \leq \frac{1}{(M_pR)^{\xi}}$$

$\xi = 2/5 \qquad p = 1$

$\xi = 2/3 \qquad p = 2$

Bulk/boundary scenario and the **species scale**

Mixed scenario

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⚠

Dark dimension scenario

with $\Lambda \simeq 1/R^4$

valid just when $g_s = \mathcal{O}(1)$

Bulk/boundary scenario and the **species scale**

Modular invariant species scale

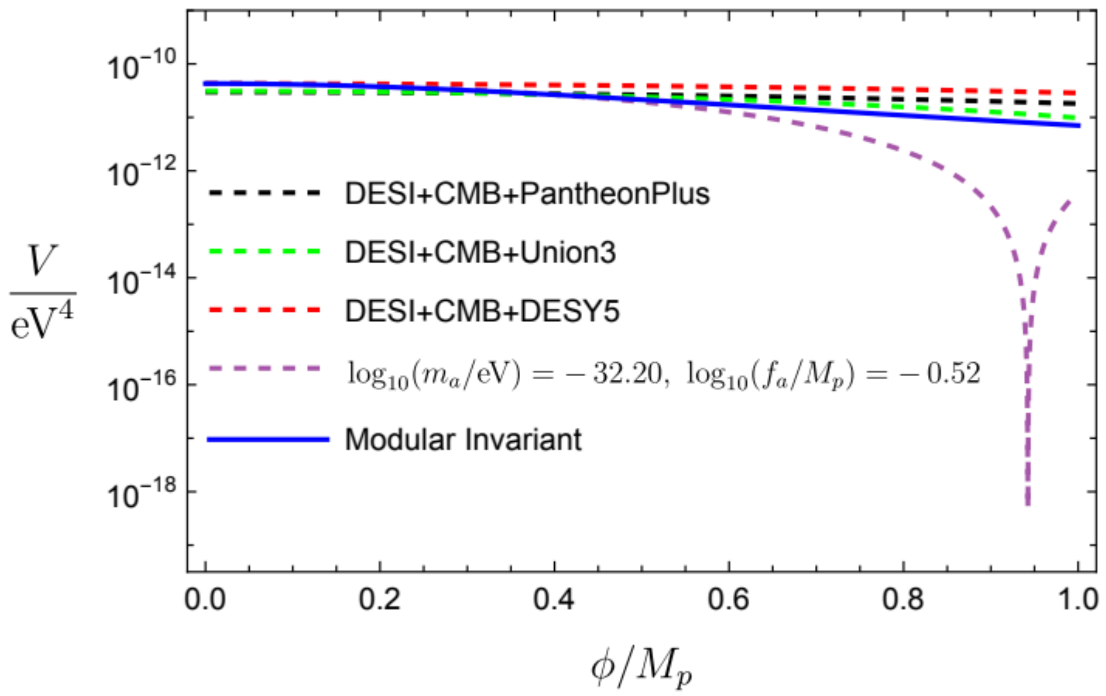
Cribiori, Lüst 2023
*Anchordoqui, Antoniadis, Cribiori, Hasar, Lüst, Masias, **MS** 2025*

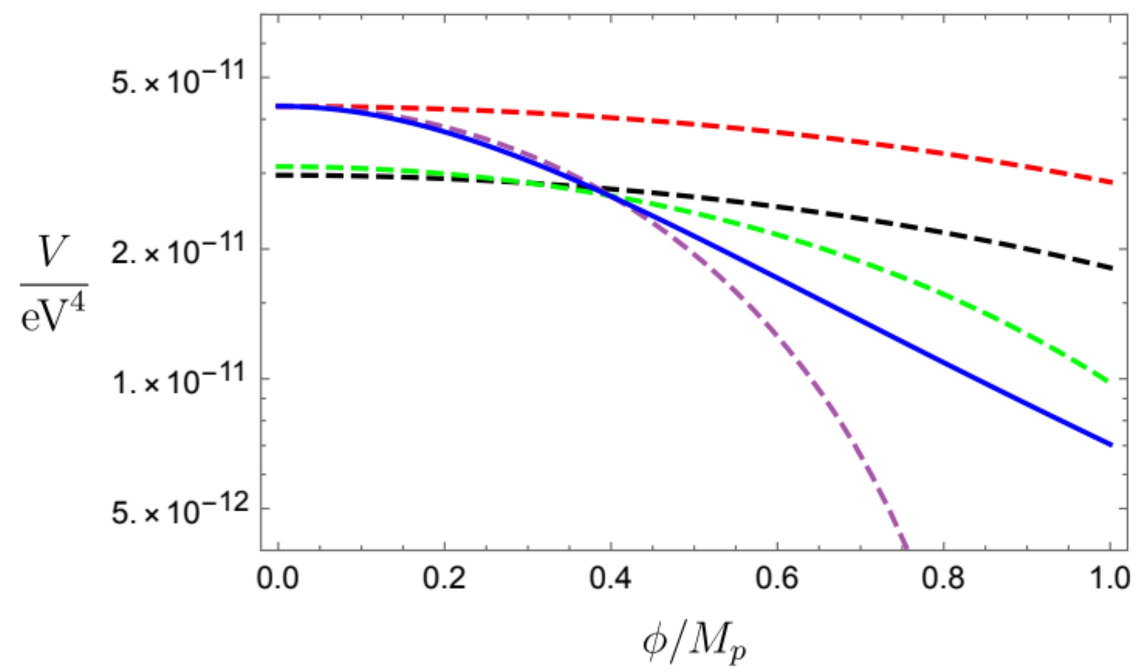
$$\Lambda_{sp} = \frac{M_p}{\left(-\log[\,|\eta(S)\,|^4(S+\bar{S})]\right)^{\frac{q}{2}}(M_pR)^{\frac{p}{p+2}}}$$

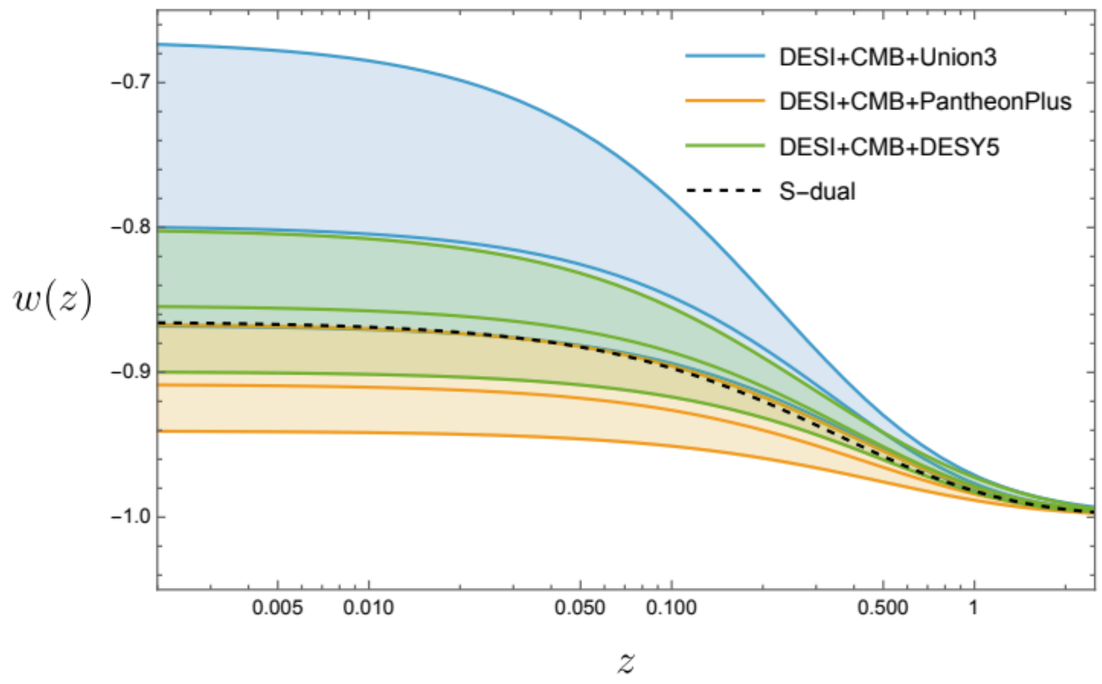
$$V = M_p^{4-\alpha}(\Lambda_{sp})^{\alpha}$$

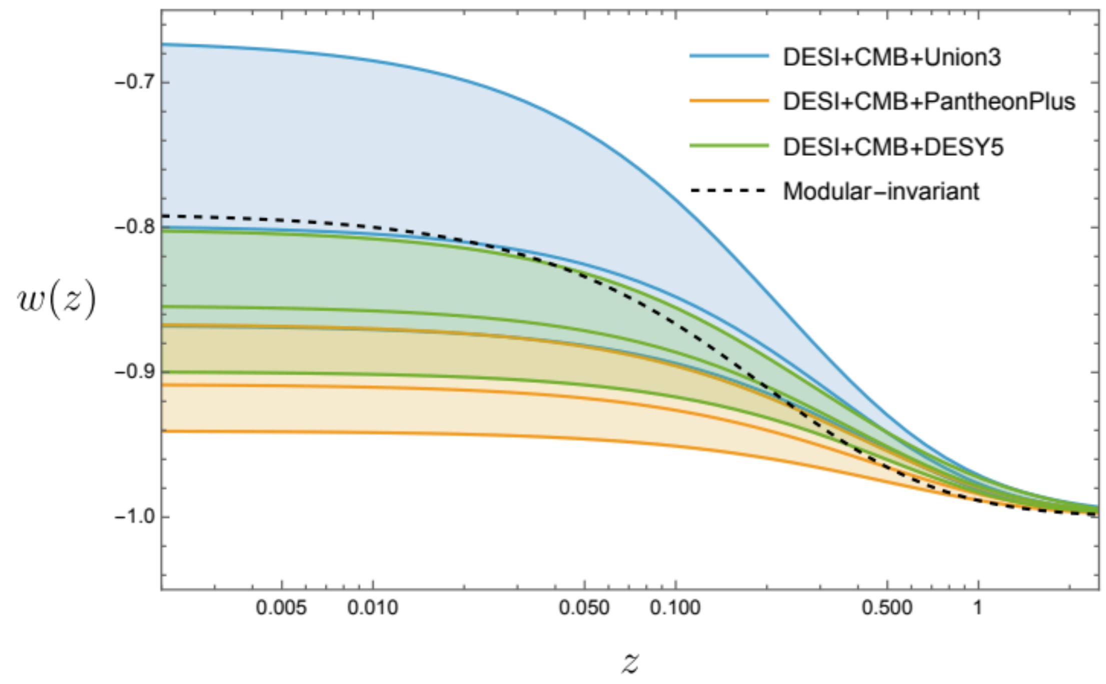
$$V(S,\bar{S},R) = -\frac{1}{\log[\,|\eta(S)\,|^4(S+\bar{S})]}\frac{1}{R^4}\,.$$

Match with **DESI DR2** data

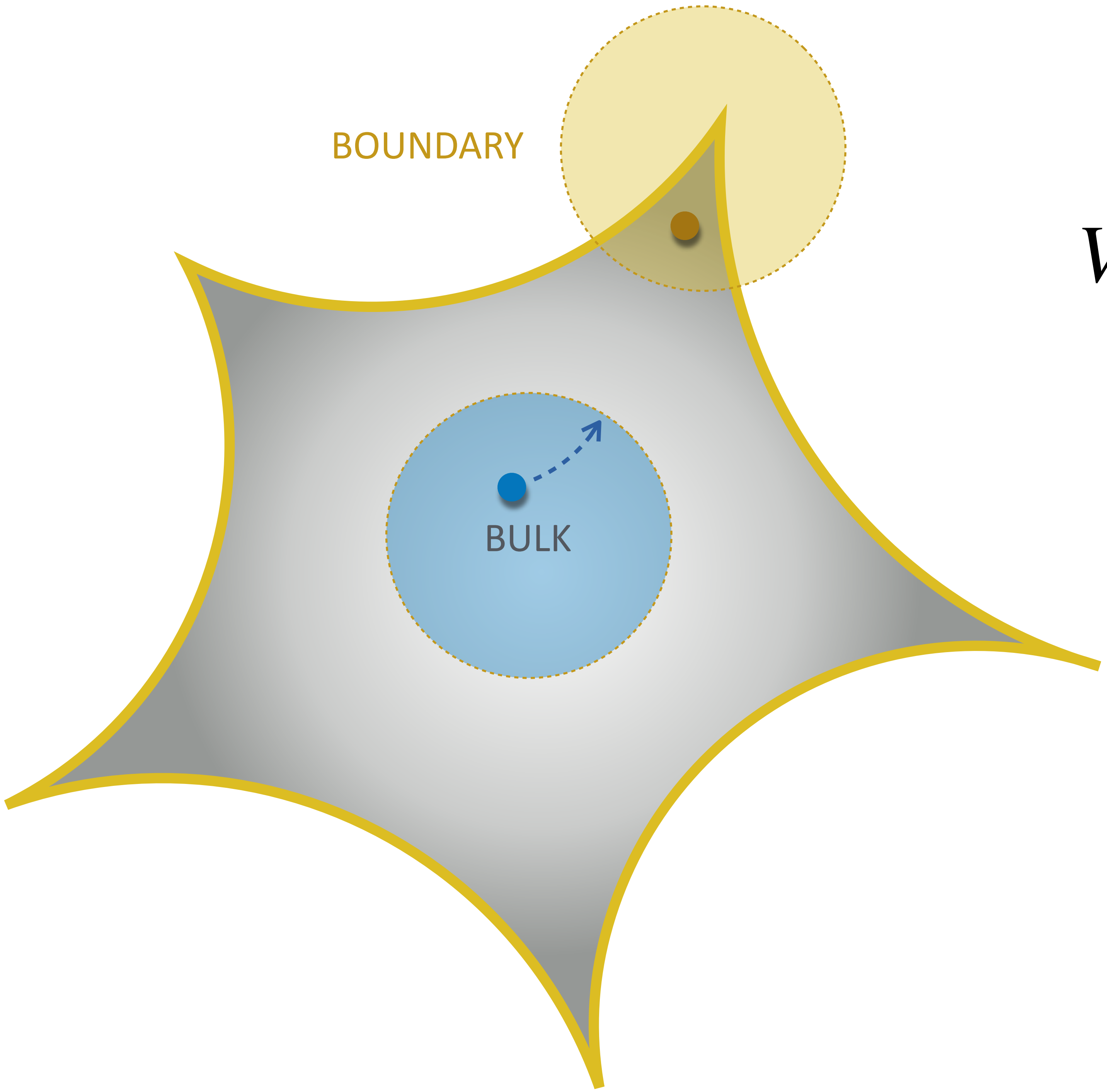








Conclusions



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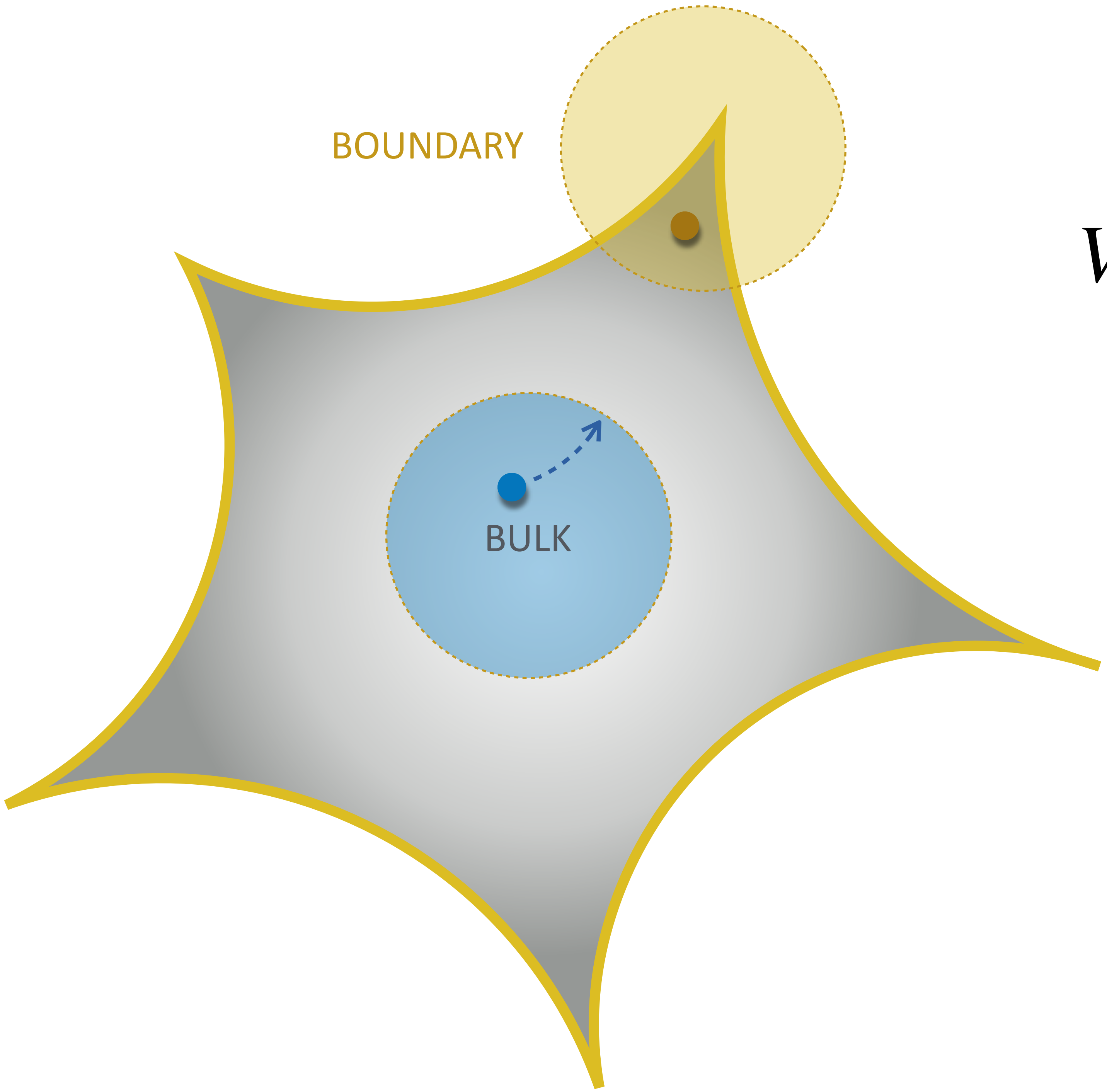


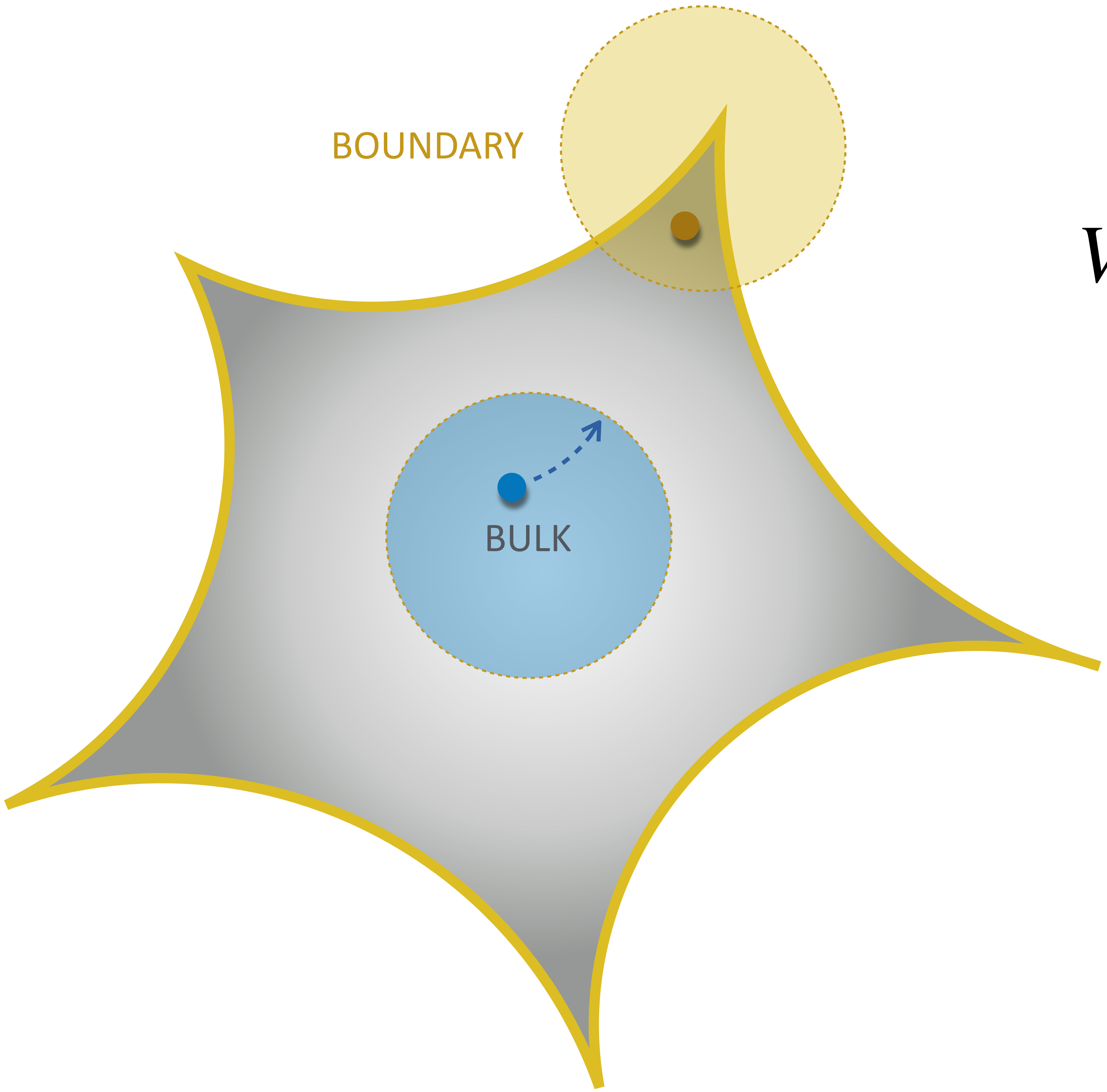
$$V(R, s) = \Lambda(R)\; V_q(s)$$

Dark dimension scenario

$$\Lambda(R) \simeq R^{-4}$$

Modular invariant quintessence

$$V_q(s) = -\frac{1}{\log[\,|\eta(s)|^4\ (s)]}$$



THANK YOU

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de Sitter


W2
HAUPTAUSGANG


bon appetit