Acceleration: Then & Now

Inflation 2025

IAP

CPB @ PI

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

McMaster University

Outline

Acceleration Then

Open EFTs and Their Uses

Minimal Primordial Decoherence

Acceleration Now

The Supersymmetric Dark

Natural Relaxation

Yoga Fitness

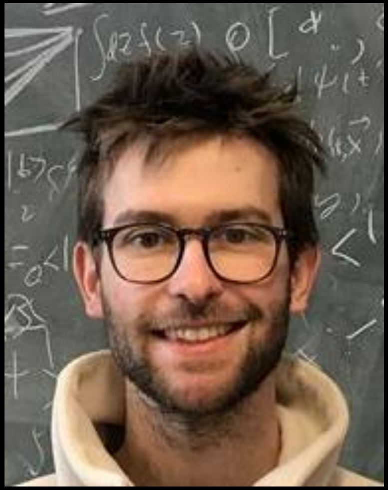
Acceleration: Then

V. Vennin

R. Holman

G. Kaplanek

J. Martin



T. Colas

Minimal Primordial Decoherence

2211.11046 2509.07769

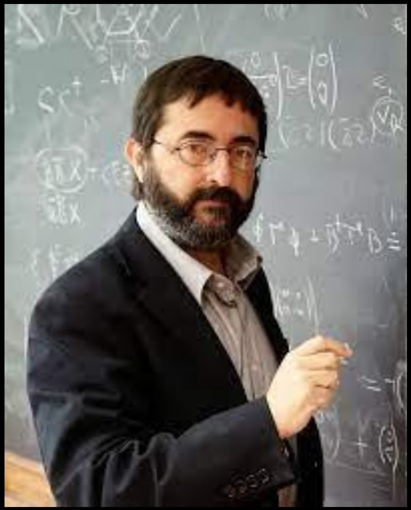
Resummation

2403.12240

Decoupling

2411.09000

Acceleration: Now



F. Quevedo

D. Dineen

P. Brax

E. Di Valentino

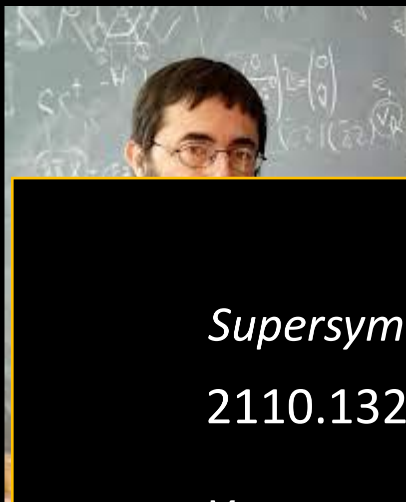
M. Mylova

A. Smith

A. Davis

C. van de Bruck

Acceleration: Now




Supersymmetric Dark
2110.13275

Yoga models
2111.07286

RG stabilization
2202.05344

dS & inflation
2408.03852

Axio-dilatons & solar system tests

2110.10352

2212.14870

2310.02092

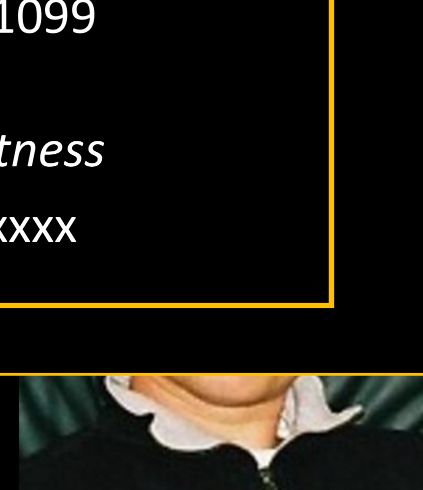
CMB & LSS
2408.10820

2505.05450

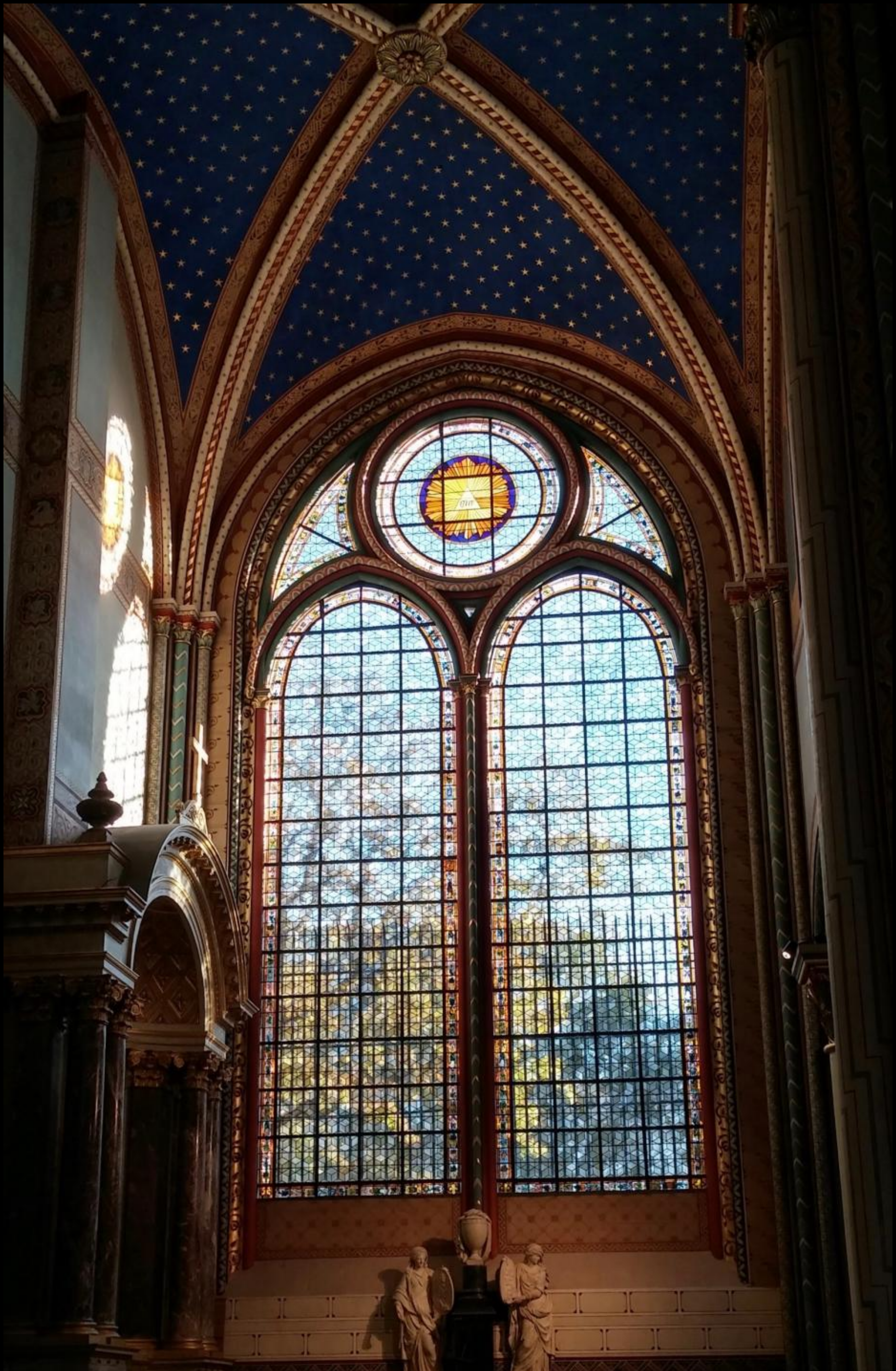
Axio-dilaton DM DE
2410.11099

Yoga Fitness
2512.xxxxx



M. Mylova A. Smith A. Davis C. van de Bruck



Acceleration Then

A decoherent overview

Acceleration Then

Quantum Primordial Fluctuations

EFTs and Theoretical Error

Late-time Pitfalls and Open EFTs

Decoherence and Decoupling

Many Roads to Inflationary Classicality

Decoherence from UV Environments

Minimal Decoherence

Scalar Fluctuations, Tensor Fluctuations

Review:
2212.09157

Late-time Breakdown of Perturbation Theory

Perturbation Theory Always Fails at Late Times

$$\exp[-i(H_0 + H_{\rm int})t] \neq \exp[-iH_0 t]\Big(1 - iH_{\rm int}t\Big)$$

This can be a problem in cosmology or BH physics, where late times are of interest and `secular growth' is observed

Good News: secular growth can sometimes be resummed to give reliable results at late times without giving up perturbative methods

$$\text{e.g.} \quad N(t) = N_0 \, \exp(-\lambda t)$$

which we trust because its differential version has a broader domain of validity

$$\frac{\mathrm{d}N}{\mathrm{d}t} = -\lambda N$$

Open EFTs Can Sometimes Help

Evolution of reduced density matrix usually complicated

$$H = H_{\rm sys} + H_{\rm env} + H_{\rm int} \qquad \varrho_{\rm sys}(t) = {\rm Tr}_{\rm env}\Big[\rho_{\rm tot}(t)\Big]$$

$$\text{e.g. if} \quad H_{\rm int}(t) = A(t) \otimes B(t)$$

$$\partial_t \varrho_{\rm sys}(t) = -i\Big[A\,,\varrho_{\rm sys}(t)\Big]\langle B\rangle_{\rm env}$$

$$+\int_{t_0}^t {\rm d}s \Big\{ C(s,t)\Big[A(t)\,,\varrho_{\rm sys}(s)A(s)\Big] - C(t,s)\Big[A(t)\,,A(s)\varrho_{\rm sys}(s)\Big]\Big\}$$

$$\text{where} \quad C(s,t) := \langle \delta B(s)\,\delta B(t)\rangle_{\rm env}$$

In general evolution depends on entire previous history

Open EFTs Can Sometimes Help

Evolution of reduced density matrix sometimes simplifies in a way that allows late-time resummation

For instance, if evolution is Markovian in a way that does not depend on initial conditions then evolution can forget its history

$$\partial_t \varrho_{\rm sys}(t) \simeq -i\Big[A\,,\varrho_{\rm sys}(t)\Big]\langle B\rangle_{\rm env}$$

$$+\Big\{F(t_0,t)\Big[A(t)\,,\varrho_{\rm sys}(t)A(t)\Big] - F(t,t_0)\Big[A(t)\,,A(t)\varrho_{\rm sys}(t)\Big]\Big\}$$

$$\text{where}\quad F(t,t_0) := \int_{t_0}^{t} {\rm d}s\; C(s,t)$$

Late time resummation can be possible if F depends just on t

Application to single clock metric fluctuations

For simplest models a single field controls
breaking of de Sitter symmetries near horizon exit

$$\mathcal{L} = -\sqrt{-g}\Big[M_p^2 \mathcal{R} + (\partial\phi)^2 + V(\phi)\Big]$$

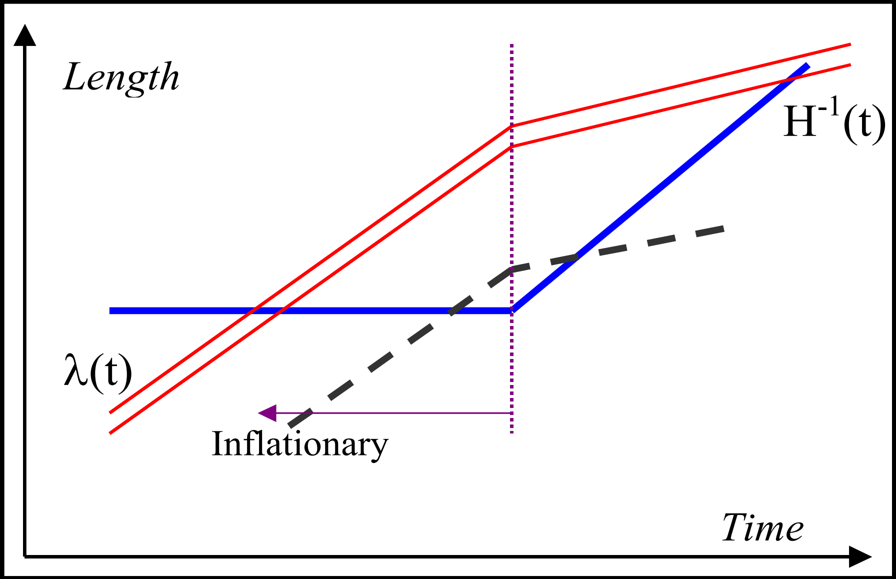
$$\phi = \varphi(t) + \delta\phi(x,t)$$

$$\text{and} \quad \mathrm{d}s^2 = a^2\Big[-(1+2\psi)\mathrm{d}\eta^2 + (1-2\psi)\mathrm{d}x^2\Big]$$

Lovely story in which late time primordial fluctuations start life as quantum fluctuations. Can use Open EFTs to compute and resum decoherence rate at very late times.

Cosmic Decoherence?

Define environment to be the unobserved (in particular shorter wavelength) modes



$$v = v_{\rm sys}(k < k_*) + v_{\rm env}(k > k_*)$$

Possibilities & Pitfalls

Secular growth causes perturbative predictions to break down well before inflation ends

If super-Hubble evolution is Markovian can sometimes resum to get reliable late-time predictions

Short wavelength physics should be describable by an effective action. If so, how can it ever decohere longer wavelengths?

Field redefinitions and ‘boundary’ contributions confuse things and can lead to mistaken decoherence rates. Ordering of limits when dealing with regularized quantities matters very much.

Equivalence principle makes scalars, tensors and ghosts all contribute similarly to long-wavelength decoherence. Watch this space….


Adventure Sports Magazine
Acceleration Now
Why Gravity Makes it Hard to Do So Gracefully

Acceleration Now

Can UV usefully inform tests of gravity?

EFTs & Decoupling (Two are Better than One)

Axiodilaton Benchmark

The Highland Program

Potentials as Low-Energy Poison

Scaling the Supersymmetric Dark

Natural Relaxation (Yoga) Models

Axiodilaton Dark Sector

Yoga Fitness

Review:
2509.00688

A Light Scalar Surprise

Particle physicists usually argue that light scalar fields
are NOT generic at low energies

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A technically natural Dark Energy density makes them *more* likely rather than less likely

astro-ph/0107573

A Light Scalar Surprise

Particle physicists usually argue that light scalar fields are NOT generic at low energies

A technically natural Dark Energy density makes them *more* likely rather than less likely

BUT we are likely looking for them in the wrong way (should be exploring 2-derivative interactions).

$$S = \int d^4x \sqrt{-g} \Big[V(\vartheta) + \mathcal{G}_{ab}(\vartheta)\, \partial_\mu \vartheta^a \partial^\mu \vartheta^b + M_p^2 \mathcal{R} + (\partial^4 \text{ terms}) \Big]$$

The derivative expansion is the loop expansion and so is what justifies the classical analysis we all do

A Light Scalar Surprise

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$$\mathcal{G}_{ab}\,\mathrm{d}\vartheta^a \mathrm{d}\vartheta^b = Z^2(\tau)\Big[\mathrm{d}\tau^2 + \mathrm{d}a^2\Big]$$

Axial symmetry

$$= \mathrm{d}\chi^2 + W^2(\chi)\mathrm{d}a^2$$

Requires at least two scalars. Axio-dilatons can provide a useful minimal example of what is possible

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Supersymmetry (generic in the UV) pairs dilaton with axion.

Susy usually better approximation in dark sector.

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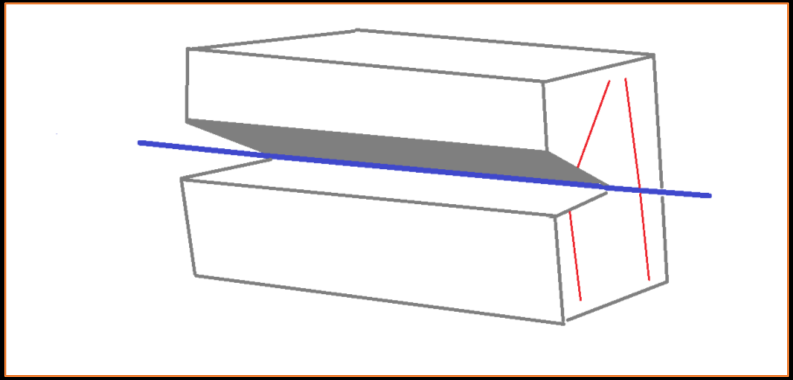
Axion + Dilaton = DM + DE?

Supersymmetric Dark

How can susy be relevant for cosmology?

Supersymmetry of the gravity sector

Attempts to understand DE size in technically natural way point to the low-energy world involving a gravitationally coupled but supersymmetric dark sector (containing a dilaton) coupled to non-supersymmetric matter.



Vilenkin 81

$$\delta = \frac{\kappa^2 T}{2\pi}$$

Idea is based on gravitation field of a line-distribution of mass: the geometry transverse to the string is a cone – only the transverse dimensions actually curve.

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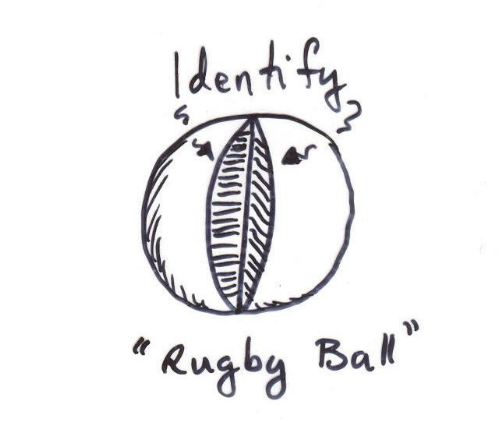


SLED Models

$$r \sim 1\ \mu\text{m} \quad r^{-1} \sim 0.1\ \text{eV}$$

Do the same in 2 extra dimensions.

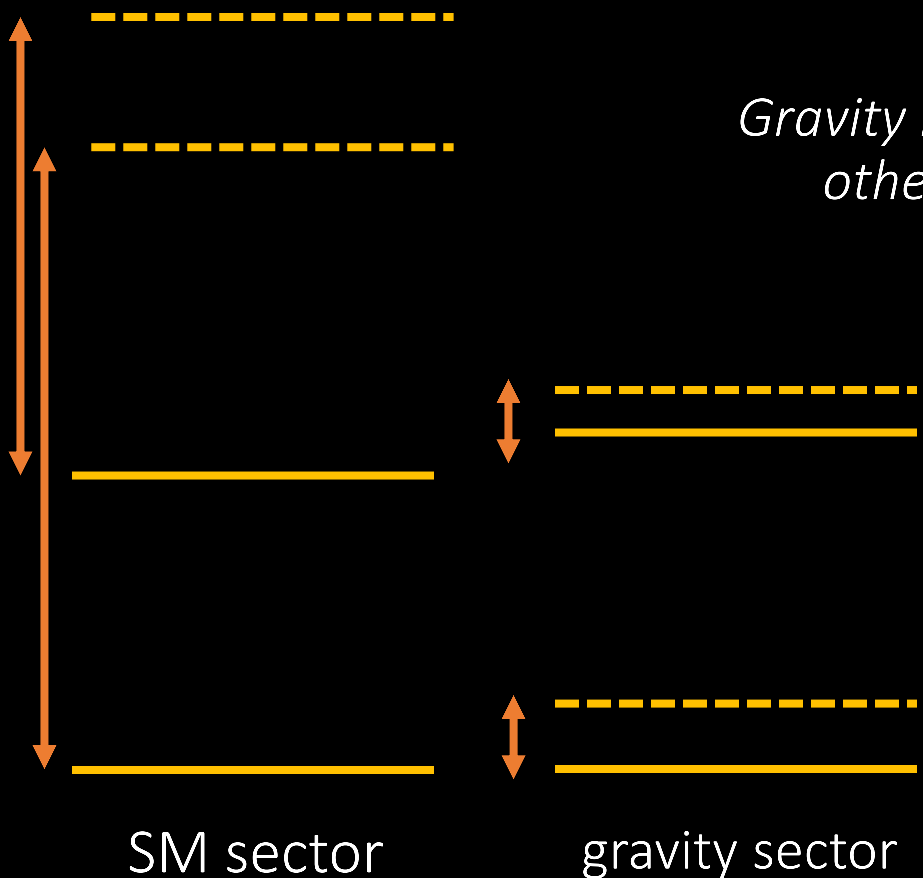
Carroll & Guica 03

Crucially: require supersymmetry in extra dimensions to remove extra-dimensional cosmological constant. Brane need not be supersymmetric.

Aghababaie et al 03

Supersymmetry of the gravity sector

Supersymmetric gravity sectors are generic in UV theories



Gravity multiplet typically split by less than others because gravity is weakest force

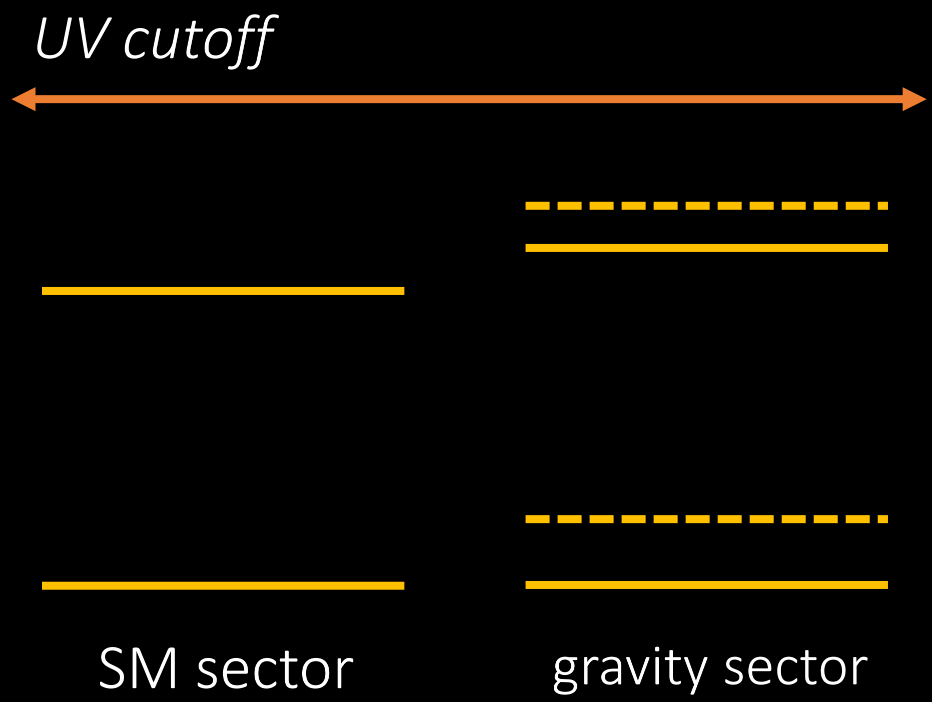
$$\Delta m^2 = m_B^2 - m_F^2 \sim gF$$

Supersymmetry of the gravity sector

How can supersymmetry play a role at low energies when LHC finds no evidence for supersymmetry?

ph/0404135

2110.13275



Should expect gravity sector to be more supersymmetric at low energies than particle physics sector

We now know how to couple supergravity to matter that is not supersymmetric

Komargodsky & Seiberg 09
Bergshoeff et al 15
Dallagata & Farakos 15
Schillo et al 15
Antoniadis et al 21
Dudas et al 21

Generic Approximate Symmetries from the UV

Supersymmetry (especially of the gravity sector)

Rigid scaling symmetries

Usual approach (for which dS is hard to obtain):
SCALE BREAKING >> susy breaking

KKLT 03
LVS 05

More promising approach:
SUSY BREAKING >> scale breaking

2202.05344

Symmetry Insights into suppressing size of V

Berg, Haack & Kors 05
Berg, Haack & Pajer 07
Cicoli, Conlon & Quevedo 08

Supersymmetry (especially

Rigid scaling symmetries

Scale invariant with a flat scalar potential

Not scale invariant but still with a flat scalar potential

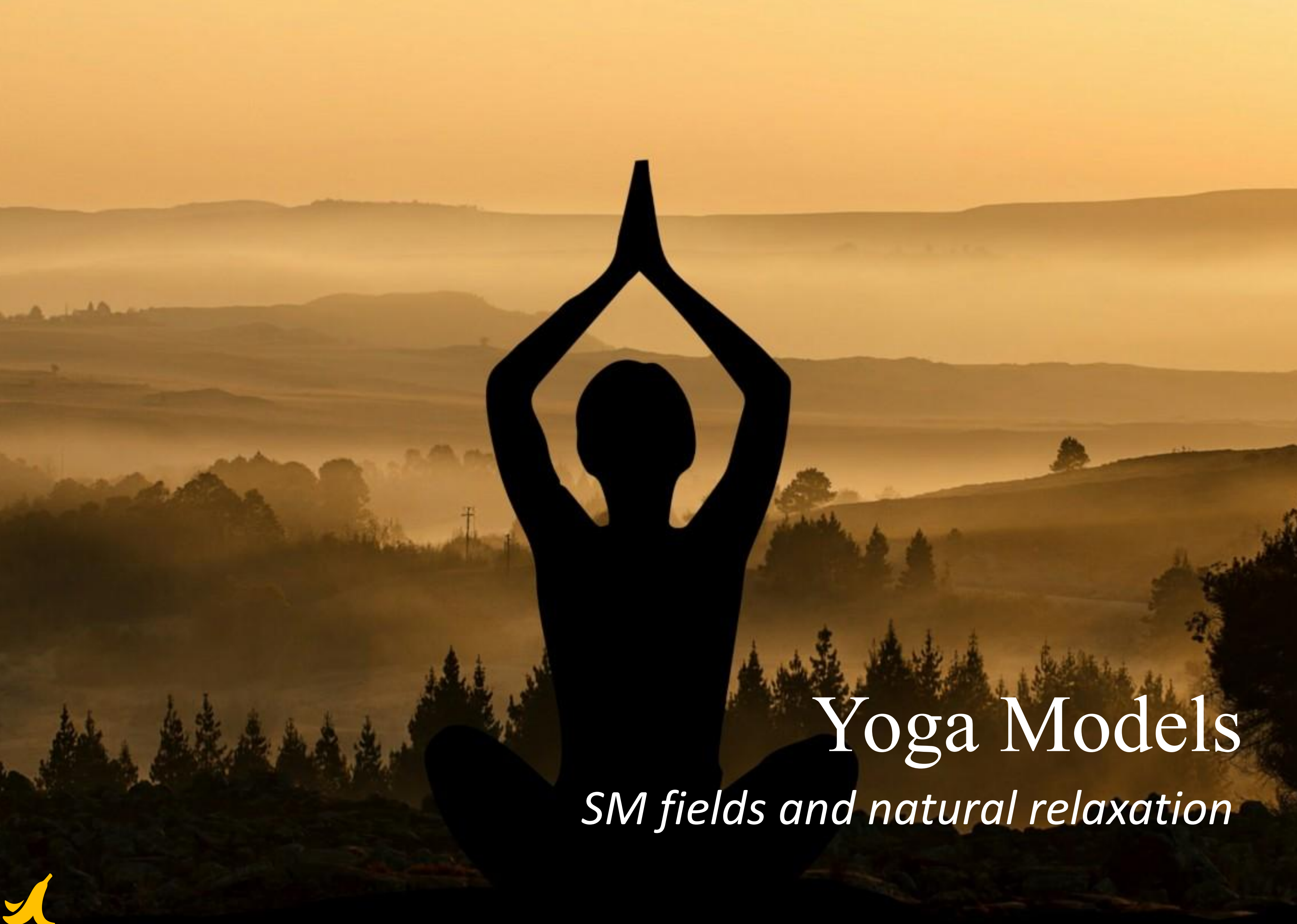
Not scale invariant & flatness of scalar potential is lifted

MECHANISM FOR SUPPRESSING V:

Together these can be more than the sum of their parts…

Interplay of scaling and supersymmetry provides a new mechanism for suppressing vacuum energies:

$$e^{-K(\tau)/3} = A\tau + B + \frac{C}{\tau} + \cdots$$


Yoga Models
SM fields and natural relaxation

An example Low-energy framework

Yoga Models

2111.07286

2212.14870

Low-energy dynamics involves matter coupled to gravity and axio-dilaton (plus possible relaxon field)

axio-dilaton: $T = \tau + i\, a$

$$e^{-K(\tau)/3} = A\tau + B + \frac{C}{\tau} + \cdots$$

Coefficients B, C depend on SM fields and possibly log τ

An example Low-energy framework

Yoga Models

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2212.14870

Low-energy dynamics involves matter coupled to gravity and axio-dilaton (plus possible relaxon field)

axio-dilaton: $T = \tau + i\, a$

$$\mathcal{L}_{\rm ad} \sim M_p^2 \left[\mathcal{R} + \frac{(\partial\tau)^2 + (\partial a)^2}{\tau^2} \right] + V(\tau) + \mathcal{L}_m(\tilde{g}_{\mu\nu}, \psi)$$

$$\tilde{g}_{\mu\nu} = e^{K/3} g_{\mu\nu} \simeq \frac{g_{\mu\nu}}{\tau}$$

$$m_{sm} \propto \frac{M_p}{\sqrt{\tau}} \qquad m_\nu \propto \frac{M_p}{\tau}$$

This works if

$$\tau_{\rm min} \sim 10^{28}$$

Scalar Potential

Yoga Models

2111.07286

2212.14870

$$V(\tau) \simeq M_p^4 \left[\frac{w_X^2}{\tau^2} + \frac{A w_X}{\tau^3} + \frac{B}{\tau^4} + \cdots \right]$$

w_X, A, B functions of other fields and $\ln \tau$

Scalar Potential

Yoga Models

2111.07286

2212.14870

$$V(\tau) \simeq M_p^4 \left[\frac{w_X^2}{\tau^2} + \frac{A w_X}{\tau^3} + \frac{B}{\tau^4} + \cdots \right]$$

$\mathcal{O}(m_{sm}^4)$ NOT SMALL, BUT POSITIVE

$$m_{sm} \propto \frac{M_p}{\sqrt{\tau}}$$

Scalar Potential

Yoga Models

2111.07286

2212.14870

$$V(\tau) \simeq M_p^4 \left[\frac{w_X^2}{\tau^2} + \frac{A w_X}{\tau^3} + \frac{B}{\tau^4} + \cdots \right]$$

Introduce 'relaxation' field that seeks minimum of w_X terms

$$V(\tau) \simeq \frac{M_p^4}{\tau^4} U(\ln \tau)$$

Scalar Potential

Yoga Models

2111.07286

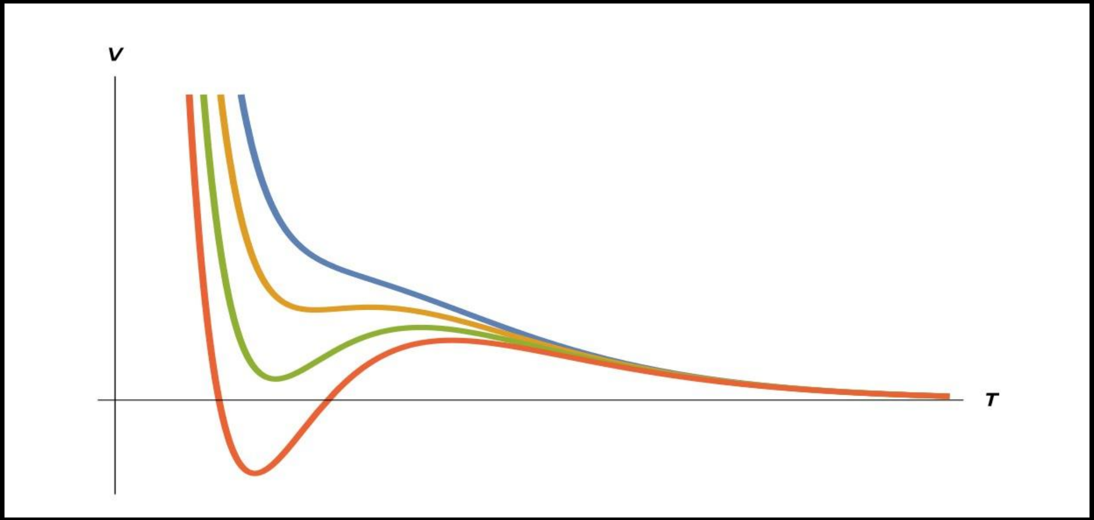
2212.14870

$$V(\tau) \simeq \frac{M_p^4}{\tau^4} U(\ln \tau)$$

$$\ln \tau_{\min} \sim 65$$

$$\tau_{\min} \sim 10^{28}$$

1/τ expansion still under control



Scalar Potential

Yoga Models

2111.07286

2212.14870

$$V(\tau) \simeq \frac{M_p^4}{\tau^4} U(\ln \tau)$$

$$m_{sm} \propto \frac{M_p}{\sqrt{\tau}}$$

$$V_{\min} \propto \frac{M_p^4}{\tau_{\min}^4} \propto \left(\frac{m_{sm}^2}{M_p}\right)^4$$ 👀

Scalar Potential

Yoga Models

2111.07286

2212.14870

$$V(\tau) \simeq \frac{M_p^4}{\tau^4} U(\ln \tau)$$

$$V_{\rm min} \sim \frac{\epsilon^5}{\tau_{\rm min}} F^* F \qquad F > (10\ \mathrm{TeV})^2$$

$$\epsilon \sim 1/(\log \tau_{\rm min})$$

Out of the box: $V_{min} = 10^{-91}\, M_p^{\,4}$ (not *quite* 10^{-120}*, but…)*

These model cry out for tests of GR

Yoga Models
2111.07286
2212.14870

Both axions and dilatons are pseudo-Goldstone bosons and so can naturally be in low-energy theory

Any progress on the cosmological constant problem generically makes at least one dilaton extremely light

$$m^2 \sim V_{\rm min}/M_p^2 \sim H^2$$

Technically natural: astro-ph/0107573

Unlike axions, low energy dilaton mass and coupling tends to be model-independent: a Brans-Dicke scalar coupling with gravitational strength (a problem since they are light enough to mediate macroscopic forces)

Not yet known whether screening mechanisms can allow them to have escaped detection (multiple scalars allow new possibilities)


Preliminary phenomenology

Implications for low energy gravity

$$\mathcal{L} = \mathcal{L}_{\rm ad}(g_{\mu\nu}, \chi, a) + \mathcal{L}_m(\tilde{g}_{\mu\nu}, a, \psi)$$

$$\mathcal{L}_{\rm ad} = M_p^2\Big[\mathcal{R} + (\partial\chi)^2 + e^{-2\zeta\chi}(\partial a)^2\Big] + U(a,\chi)e^{-4\zeta\chi}$$

$$\tilde{g}_{\mu\nu} = e^{-2g\chi}g_{\mu\nu}$$

Dilaton couples to matter like a very light Brans-Dicke scalar:
(solar system tests require $g < 0.001$)

All ordinary particle masses acquire a universal dependence on the dilaton through the Higgs vev

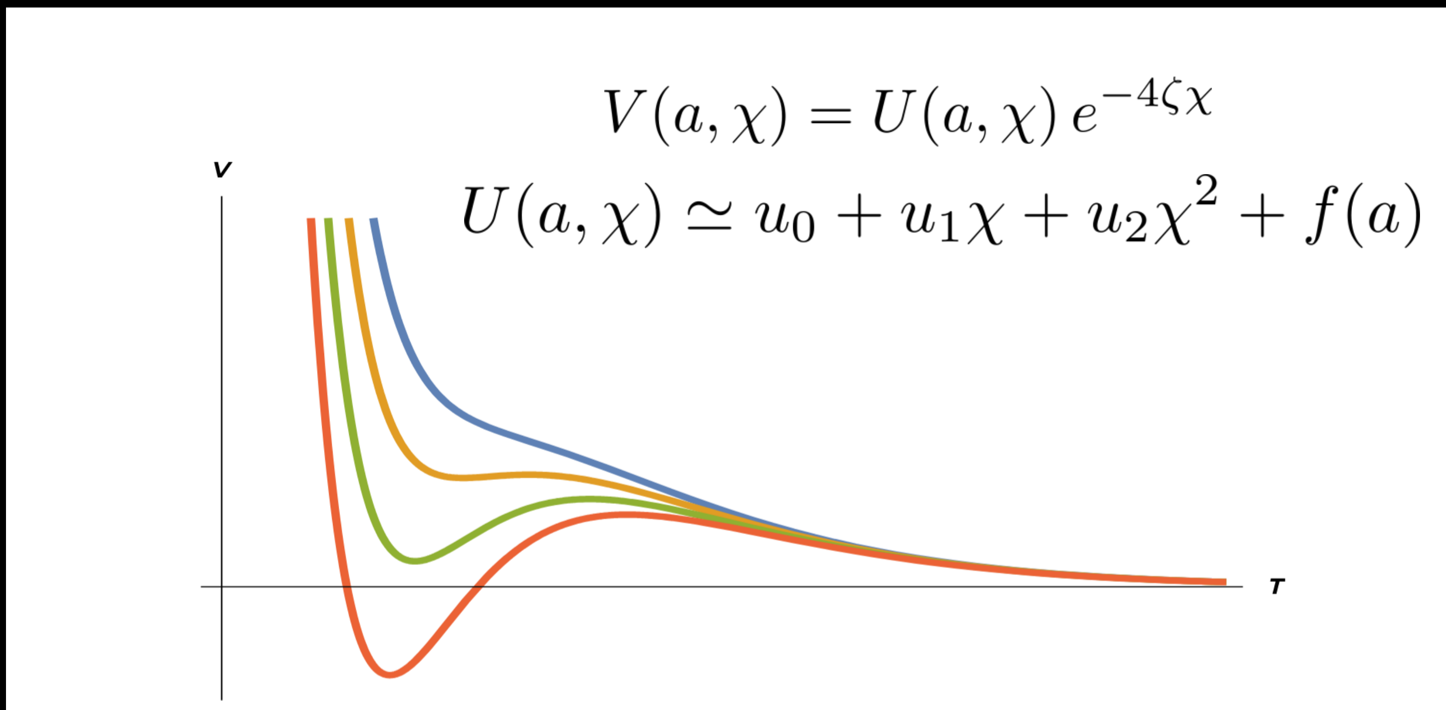
$$m_{SM} \sim M_p\, e^{-g\chi} \qquad m_\nu \sim M_p\, e^{-2g\chi} \qquad (\text{successful if } g\chi \sim 32)$$

Axion also has a dilaton-dependent mass (though depends on ζ not g)

Can axiodilaton be both the DM and DE?

Can arrange potential to have local minimum consistent with Dark Energy

Can easily arrange $g\chi = 32$ using only parameters in potential that are O(10)



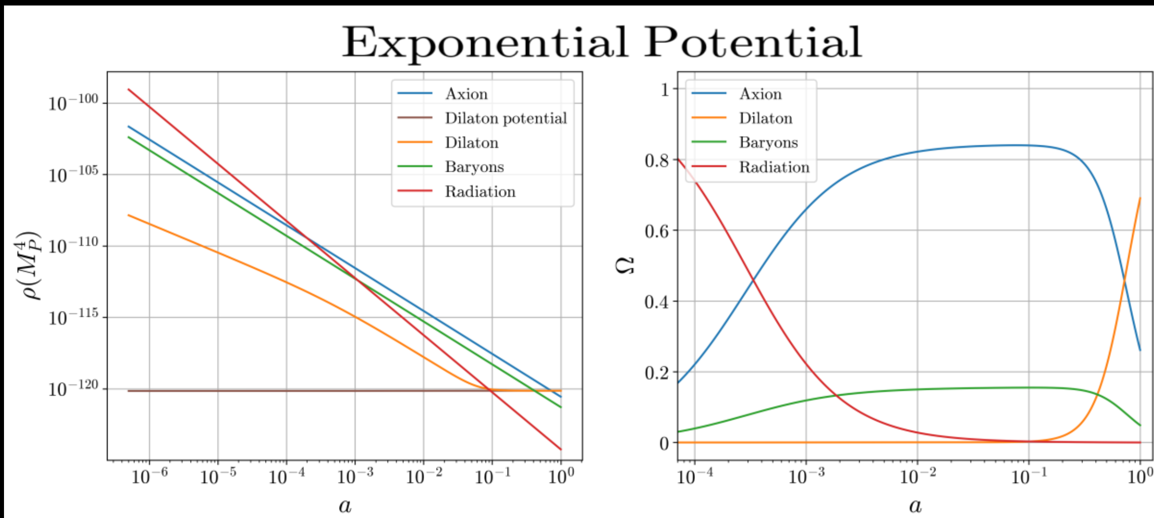
Dilaton mediated forces also change how matter clusters

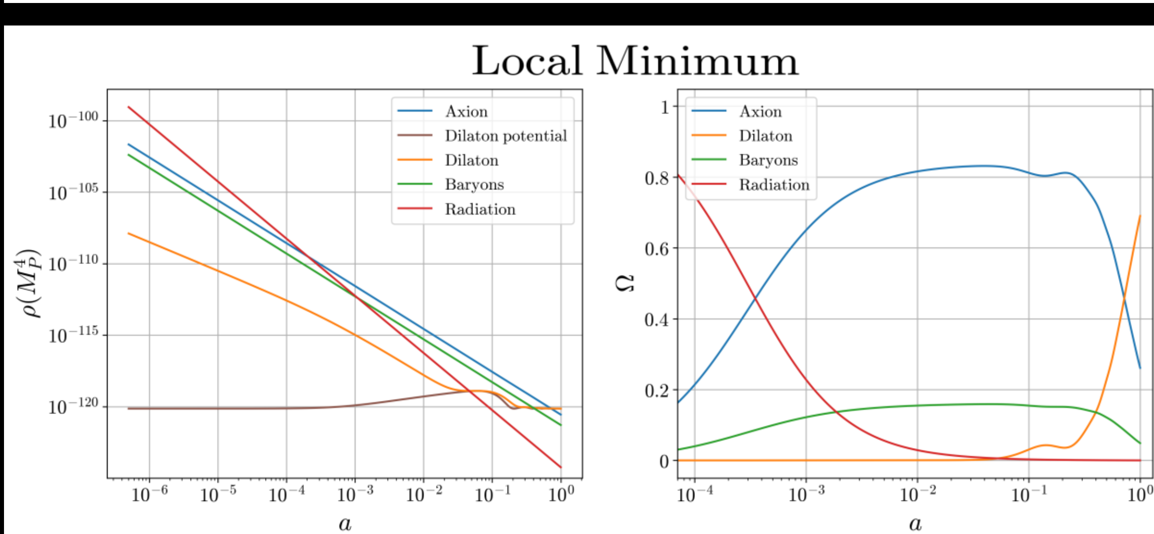
Can this describe cosmological observations?

2410.11099

Can axiodilaton be both the DM and DE?

Background cosmology can be reasonable





Density evolution for cosmic fluid components

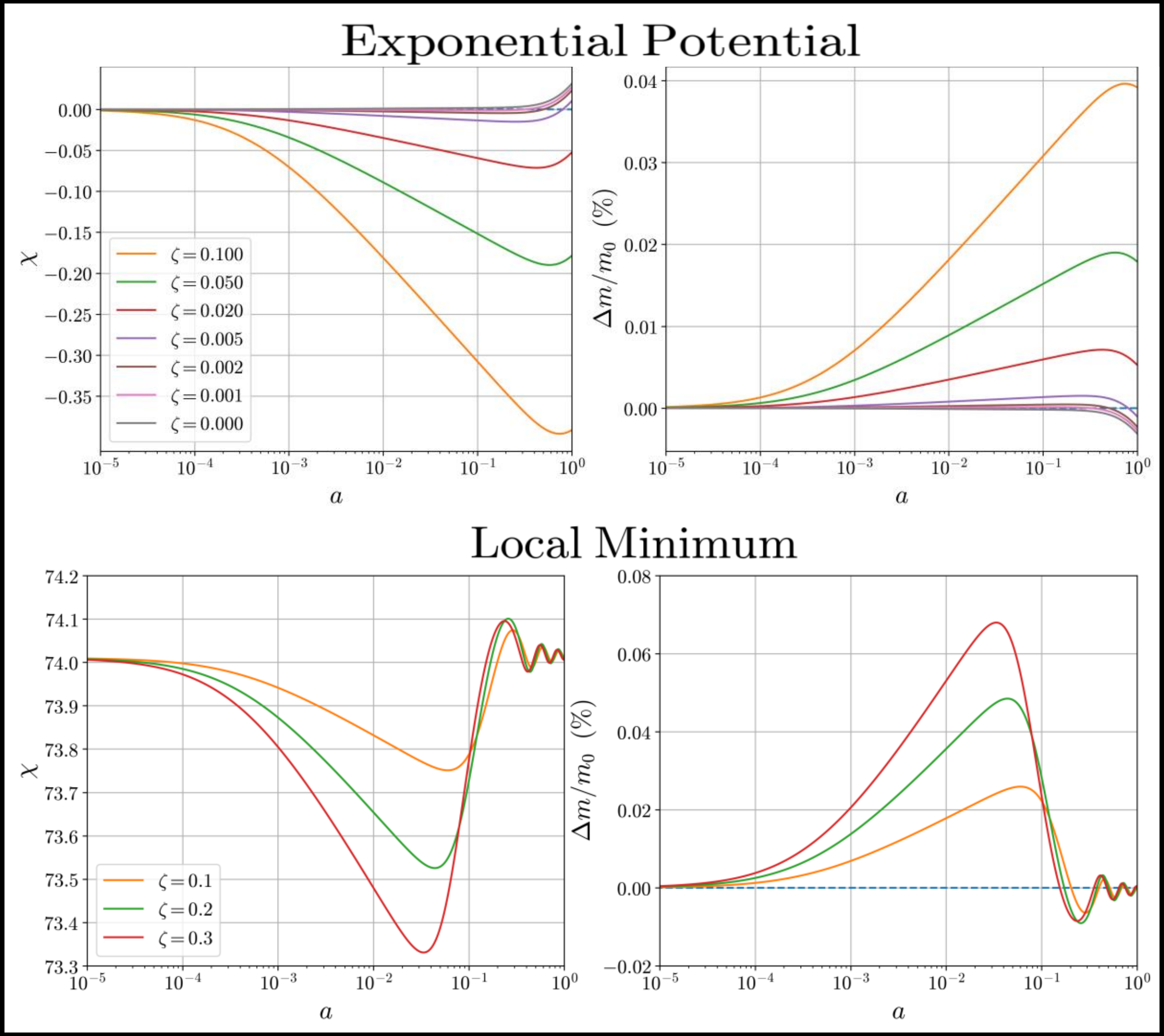
$$W = W_0 \, e^{-\zeta \chi / M_p}$$

$$V(\chi) = U(\chi) \, e^{-4\zeta \chi / M_p}$$

2410.11099

Can axiodilaton be both the DM and DE?

Dilaton evolves in tracker solutions: always excursion at radiation-matter equality *implying masses at recombination differ from those at BBN and now*.



Evolution of dilaton and particle masses for various ζ

$$W = W_0\, e^{-\zeta\chi/M_p}$$

$$V(\chi) = U(\chi)\, e^{-4\zeta\chi/M_p}$$

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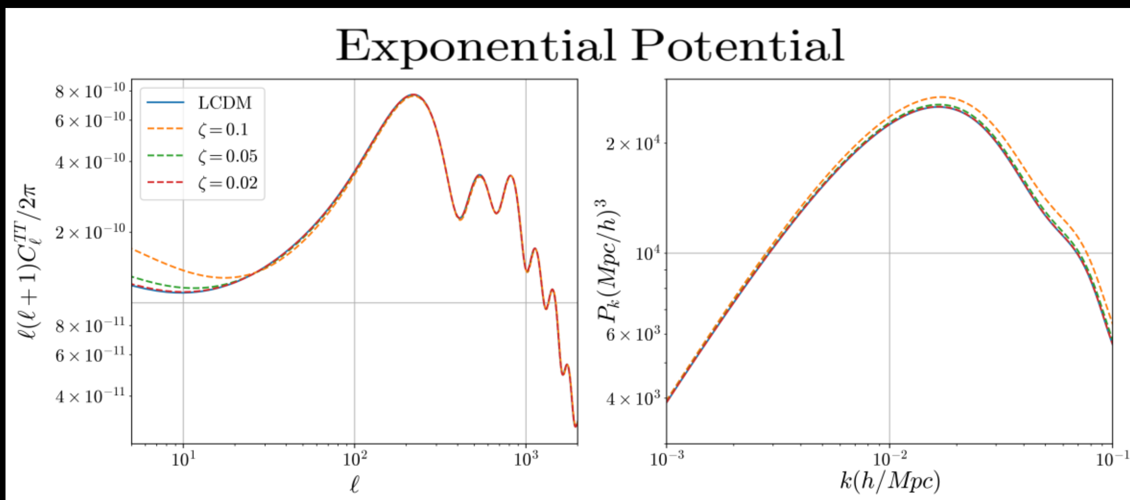
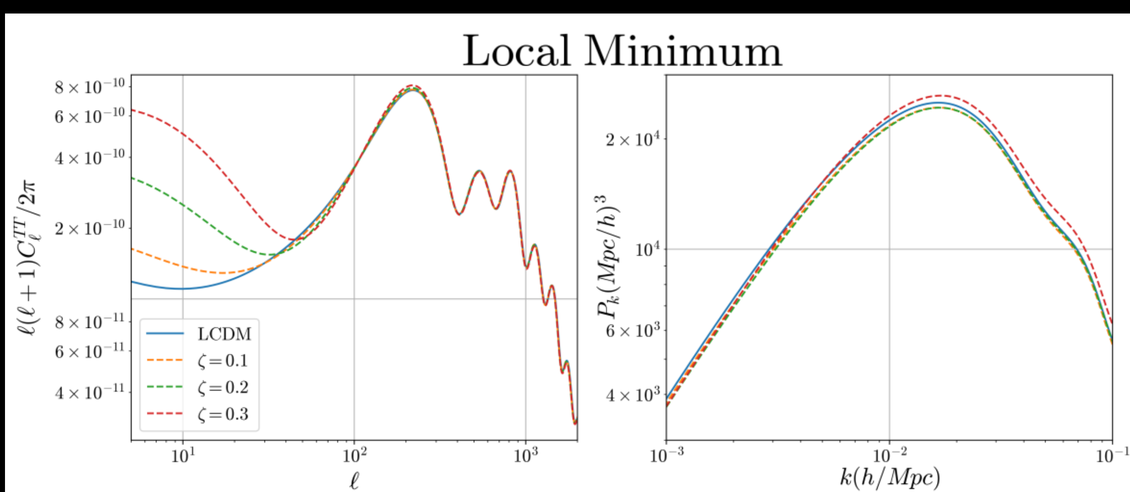
Can axiodilaton be both the DM and DE?

Fluctuations in CMB and Power spectrum can be reasonable





CMB and Power Spectrum for various choices for ζ

$$W = W_0\, e^{-\zeta\chi/M_p}$$

$$V(\chi) = U(\chi)\, e^{-4\zeta\chi/M_p}$$

2410.11099

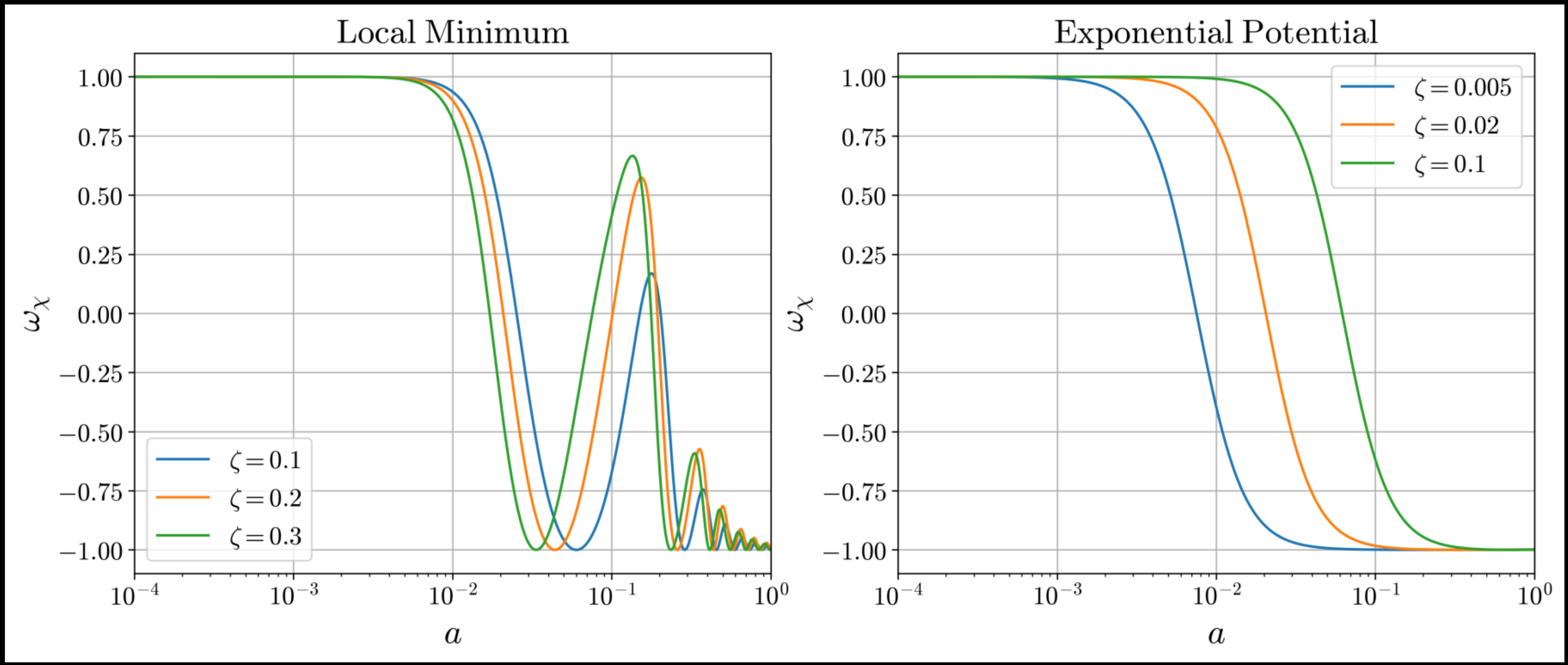
Can axiodilaton be both the DM and DE?

Evolution can fake *w < -1* because DM mass does *not* evolve like *1/a³*

Evolution of actual DE equation of state parameter with z

$$W = W_0 \, e^{-\zeta\chi/M_p}$$

$$V(\chi) = U(\chi) \, e^{-4\zeta\chi/M_p}$$



2410.11099

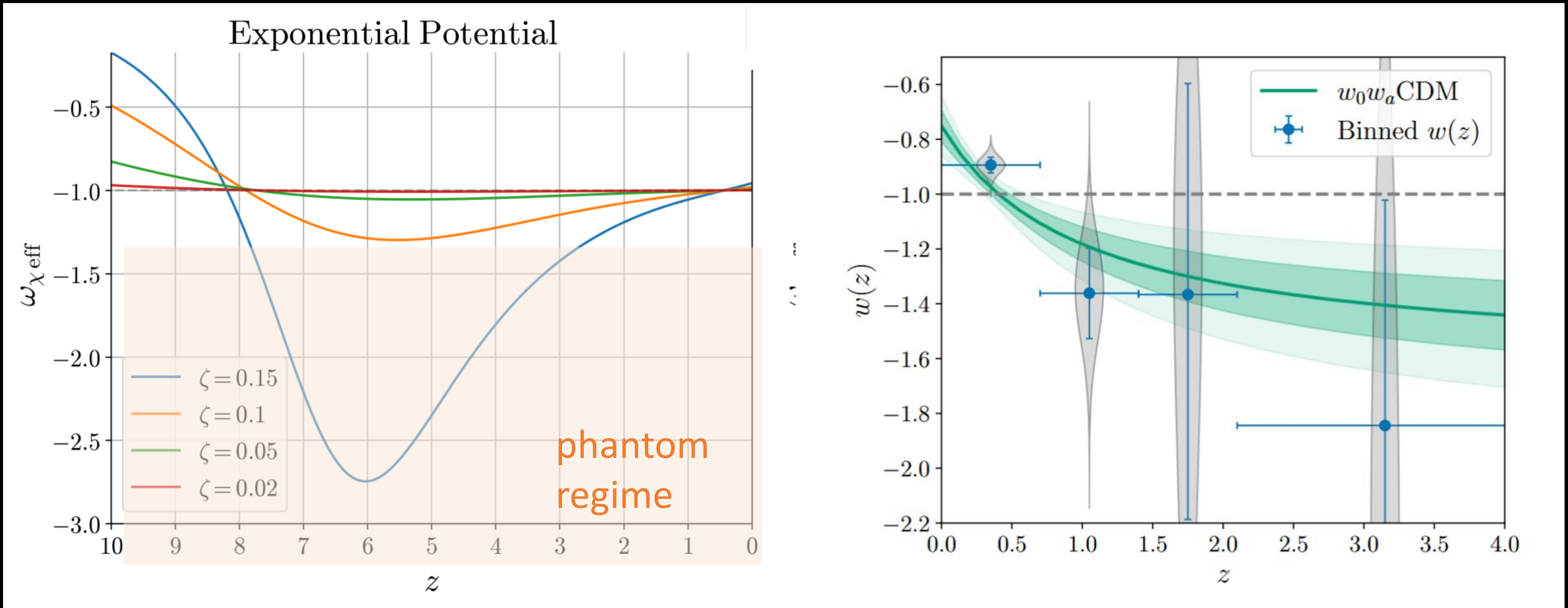
Can axiodilaton be both the DM and DE?

The effective equation of state inferred by eg DESI *assumes* vanilla DM: $\hat{\rho}_{\rm dm} \propto a^{-3}$

Evolution of *effective* DE equation of state parameter as seen by DESI

$$\omega_{\chi\,\rm eff} = \frac{\omega_\chi}{1+(\rho_{\rm ax}-\hat{\rho}_{\rm dm})/\rho_\chi}$$

DESI Collaboration



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Comparison to Cosmological Data

Model provides a passable fit to CMB-B DESI and PP datasets

But best-fit value of Hubble scale rises relative to LCDM due to mass evolution, bringing the SH0ES range to within 3σ, and so permitting combining datasets

Model	Dataset	H_0	$\mathbf{g}$	ζ	χ_i	$R-1$	$\Delta\chi^2$
Yoga-VI	CMB-B DESI PP	$69.17^{+0.66}_{-0.76}$ (69.13)	-0.001 ± 0.095 (-0.052)	0.003 ± 0.050 (-0.003)	74.010 ± 0.150 (73.844)	0.102	-7.2
	CMB-B DESI	69.42 ± 0.72 (69.58)	-0.011 ± 0.097 (0.102)	-0.002 ± 0.049 (-0.039)	$73.98^{+0.18}_{-0.15}$ (74.142)	0.195	-6.3
EXP	CMB-B DESI PP	69.17 ± 0.67 (69.99)	0.002 ± 0.093 (0.104)	-0.001 ± 0.044 (-0.022)	–	0.338	-7.3
	CMB-B DESI	69.37 ± 0.72 (69.12)	0.000 ± 0.093 (-0.023)	-0.003 ± 0.045 (-0.038)	–	0.885	-6.1
	CMB-B	$67.50^{+0.68}_{-1.2}$ (67.78)	-0.005 ± 0.074 (0.041)	0.002 ± 0.047 (-0.002)	–	0.029	–
w0-wa + me	CMB-B DESI PP	68.32 ± 0.83 (67.95)	–	–	–	0.098	-12.1
	CMB-B DESI	$64.2^{+1.9}_{-2.6}$ (63.78)	–	–	–	0.041	-10.5
w0-wa	CMB-B DESI PP	67.65 ± 0.59 (67.52)	–	–	–	0.010	-9.6
Λ CDM	CMB-B DESI PP	68.04 ± 0.26 (68.25)	–	–	–	0.007	0.0
	CMB-B DESI	68.13 ± 0.26 (68.23)	–	–	–	0.006	0.0

TABLE V: Posterior means with quoted 1σ marginal uncertainties and best-fit values in parentheses for all models fit to the CMB-B dataset combinations including SPT-3G. Columns list the inferred Hubble constant, the dilaton coupling $\mathbf{g}$, the axion CDM kinetic coupling ζ, the initial dilaton value χ_i when present, and the change in best-fit $\Delta\chi^2$ relative to the corresponding ΛCDM run.

Goodness of fit comparison using CMB-B DESI PP datasets

2512.xxxxx

Comparison to Cosmological Data

Model resolves (to smaller than 3 sigma) the Hubble tension in the CMB-B DESI and PP datasets including a SH0ES prior on H_0

Comparable to the combined $w_0 w_a + m_e$ model (though is a real theory and so predicts correlations between properties at recombination and later epochs)

Model	Dataset	H_0	g	ζ	χ_i	$R-1$	$\Delta\chi^2$
Yoga VI	CMB-A DESI PPSH0ES	70.85 ± 0.58 (71.11)	$0.03^{+0.17}_{-0.20}$ (-0.214)	-0.012 ± 0.060 (0.082)	$74.03^{+0.20}_{-0.23}$ (73.903)	10.313	-19.7
EXP	CMB-A DESI PPSH0ES	70.79 ± 0.59 (71.03)	0.000 ± 0.160 (0.161)	-0.003 ± 0.062 (-0.058)	–	68.516	-18.9
w0-wa + me	CMB-A DESI PPSH0ES	70.51 ± 0.73 (70.37)	–	–	–	0.005	-19.4
Λ CDM+me	CMB-A DESI PPSH0ES	70.97 ± 0.57 (71.34)	–	–	–	0.006	-19.2
Λ CDM	CMB-A DESI PPSH0ES	68.72 ± 0.28 (68.77)	–	–	–	0.006	0.0

TABLE VI: Posterior means ($\pm 1\sigma$) with best-fit values in parentheses, and $\Delta\chi^2$ relative to the ΛCDM run with the same dataset (CMB-A DESI PPSH0ES).

Goodness of fit comparison using CMB-B DESI PP datasets including a SH0ES prior on H_0

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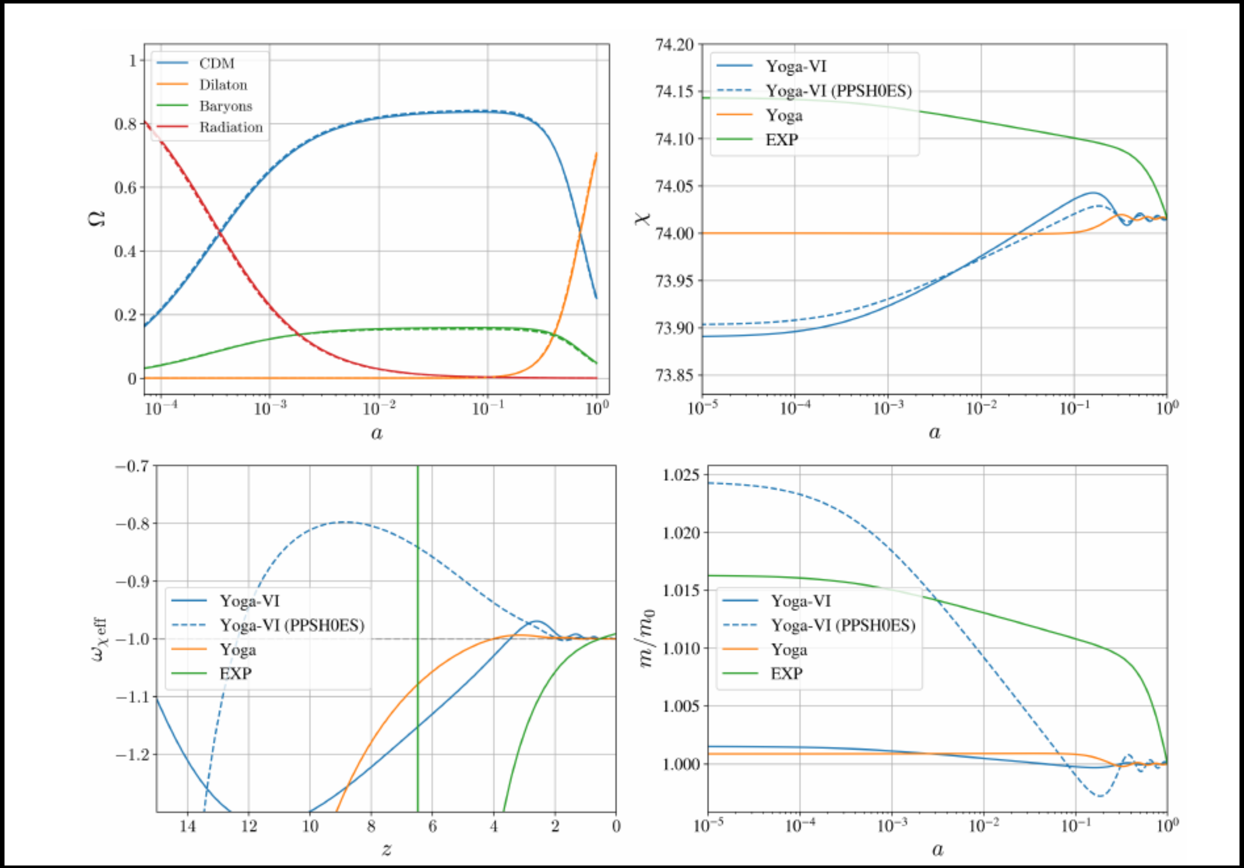
Comparison to Cosmological Data

Improvement of fit occurs because masses differ at recombination.

Unlike in models where this is done by hand can predict why variation happens (recombination is not long after radiation-matter equality) and why this need not cause problems for BBN



Evolution of key model parameters with redshift

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Comparison to Cosmological Data

Improvement of fit occurs because masses differ at recombination.

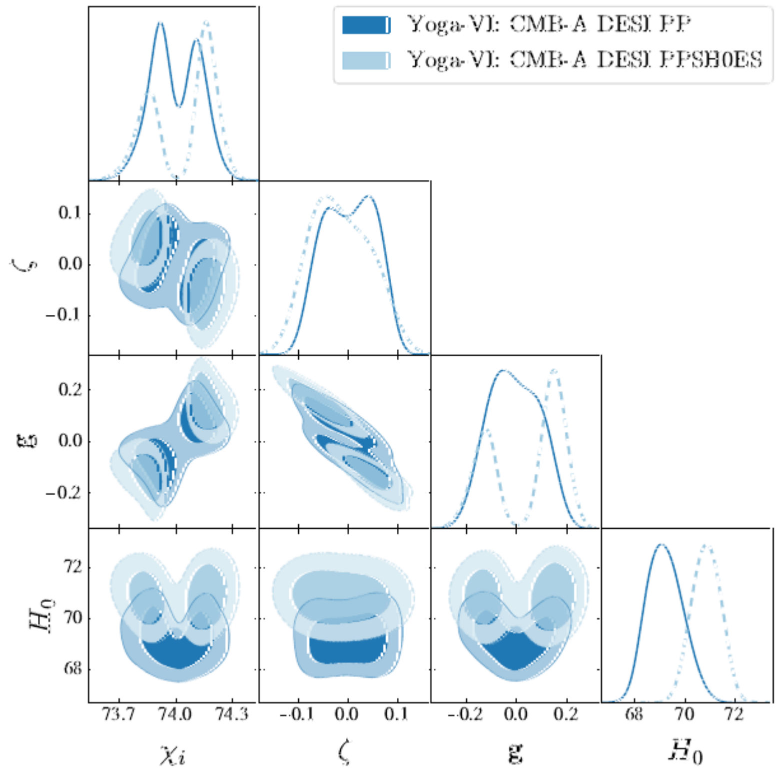

FIG. 5: Triangle plot showing constraints on the minimal Yoga-VI model with and without the SH0ES prior calibration with CMB-A DESI PP datasets. Imposing the SH0ES prior amplifies the existing correlations among **g**, ζ and H_0, with much larger couplings and initial dilaton displacements being preferred.

Triangle plot for $\Omega_c h^2$, $\Omega_b h^2$, H_0 and g for the exponential potential with and without the SH0ES prior

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Conclusions

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High road to UV properties can be predictive

But it is robust properties like accidental scale invariance and supersymmetric gravity sector that are informative

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But it is robust properties like accidental scale invariance and supersymmetric gravity sector that are informative

Remarkably rich physics possible at very low energies

EFT arguments are restrictive but not prohibitive for predicting things to be tested in GW (and other gravity) tests.

Two scalars are better than one

Conclusions

High road to UV properties can be predictive

But it is robust properties like accidental scale invariance and supersymmetric gravity sector that are informative

Remarkably rich physics possible at very low energies

EFT arguments are restrictive but not prohibitive for predicting things to be tested in GW (and other gravity) tests.

Two scalars are better than one

Axiodilatons as a minimal Dark Sector fit cosmological data well

Resolution of H tension seems to require big dilaton-matter g

Multiple types of tests: mass variations in space/time; polarization in CMB; DE EOS variations; structure formation changes; GWs; Solar system tests; …

Conclusions

High road to UV properties can be predictive

But it is robust properties like accidental scale invariance and supersymmetric gravity sector that are informative

Remarkably rich physics possible at very low energies

EFT arguments are restrictive but not prohibitive for predicting things to be tested in GW (and other gravity) tests.

Two scalars are better than one

Much to explore

Axiodilatons provide a minimal picture of Dark Matter

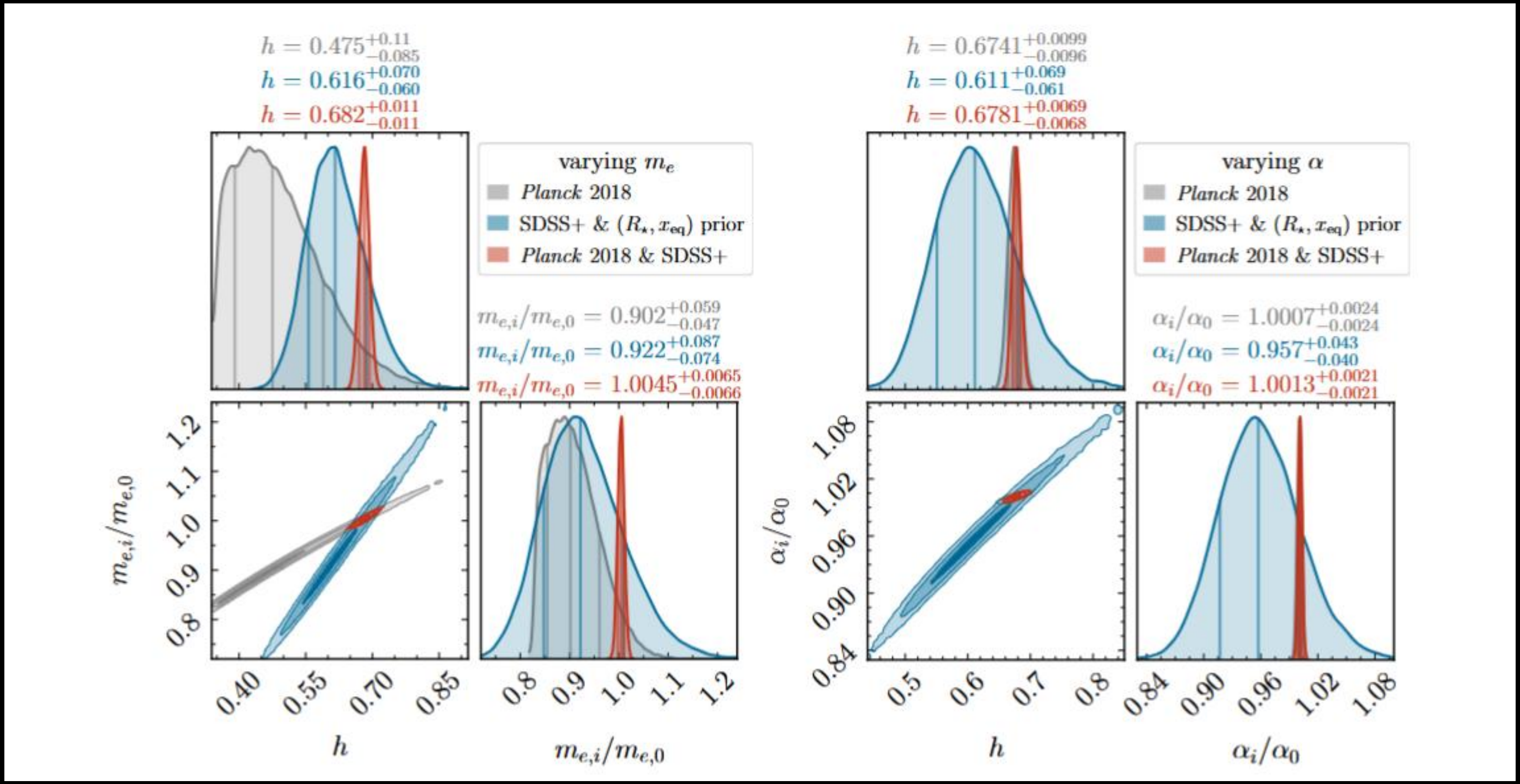
Multiple types of tests: mass variations in space/time; polarization in CMB; DE EOS variations; structure formation changes; GWs; Solar system tests; …

Thanks for your time & attention!

Extra Slides

Dangers and Opportunities?

See related recent studies: Baryakhtar et al 2405.10358



Relevance to inflation

Practical consequences for inflationary models

Two kinds of low-energy pseudo-Goldstone bosons with which to build technically natural inflationary string potentials, one class of which arises due to approximate scale invariances

Axions	Dilatons

Practical consequences for inflationary models

Axions Dilatons

Axionic inflationary models

- axions are ubiquitous
- axions have protected masses

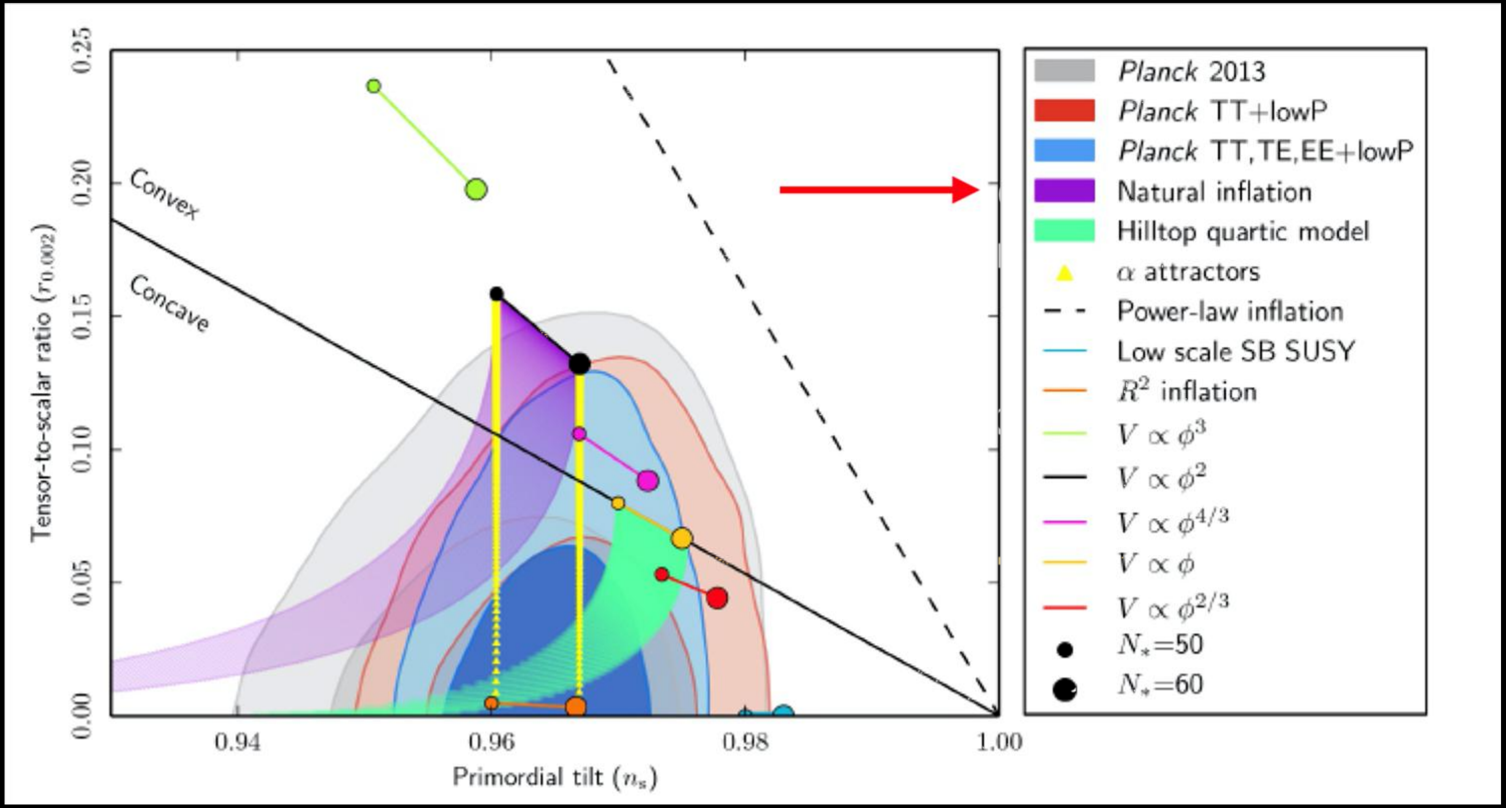
$$V(a) = A + B\cos\left(\frac{a}{f}\right)$$

Freese et.al. 90; Kachru et.al. 03;
Silverstein & Westphal 08 and more

Practical consequences for inflationary models

But: need $f \gg M_p$ disfavoured by data

Axions Dilatons



Planck collaboration

Practical consequences for inflationary models

Axions *Dilatons*

Scaling inflationary models

- Fibre moduli are ubiquitous
- F. mod have protected masses

$$V(a) = A - B\, e^{-a/f}$$

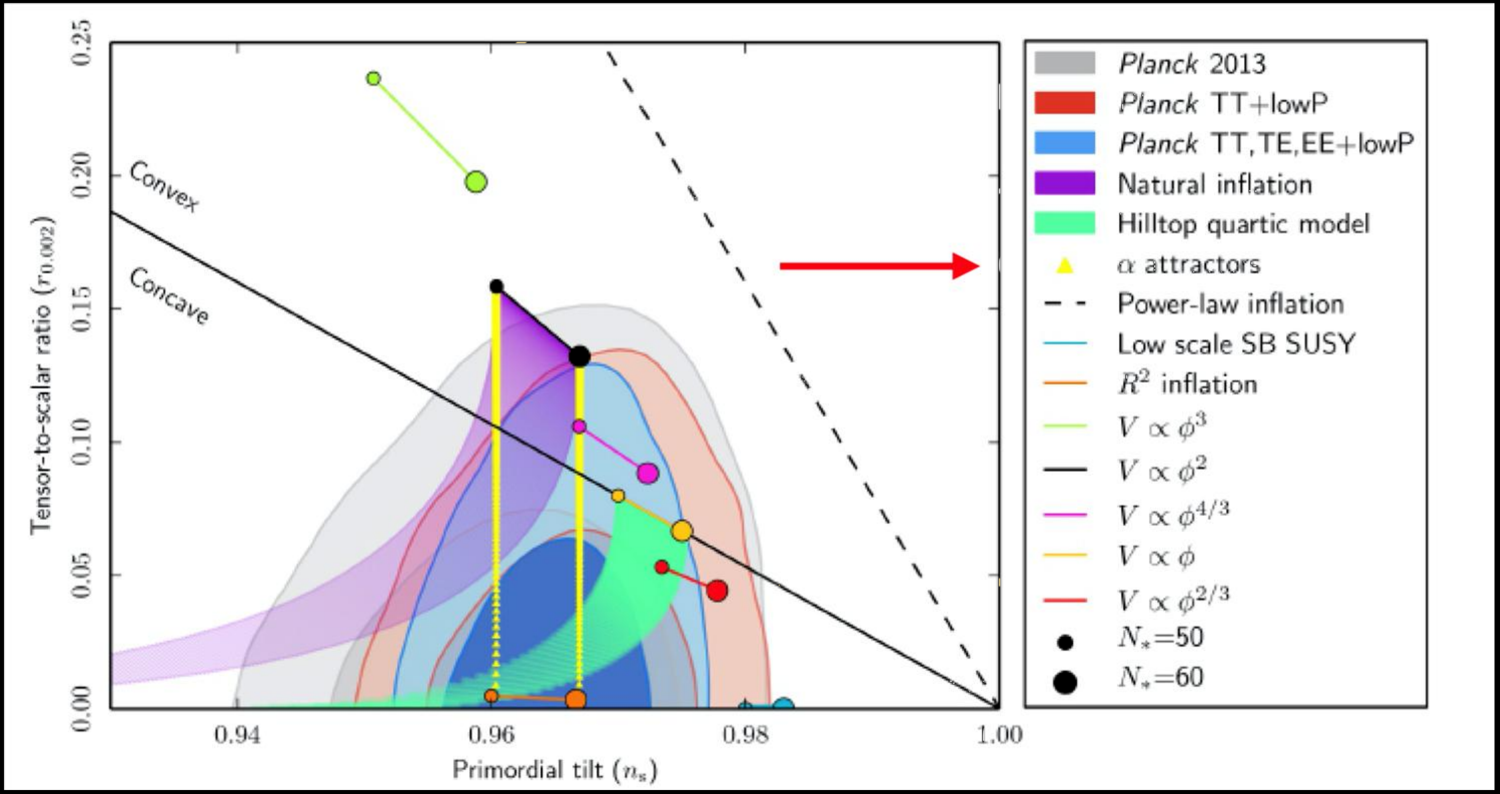
Goncharov & Linde 84; Kallosh & Linde 13 & 15

hep-th/0111025; 0808.0691; 1603.06789

need $f \simeq M_p$
loved by data
predicts $r \simeq (n_s - 1)^2$

Practical consequences for inflationary models

Axions *Dilatons*



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All This and More!

For microscopic inflationary models allows progress on the eta problem in ***two*** ways:

because of use of K for modulus stabilization

because flatness of potential is due to large field and not small parameter