

INVISIBLES @ CERN 2025

Kick it like DESI:

PNGB quintessence with a dynamically generated
initial velocity

based on [2412.07418] JCAP 03 (2025) 015

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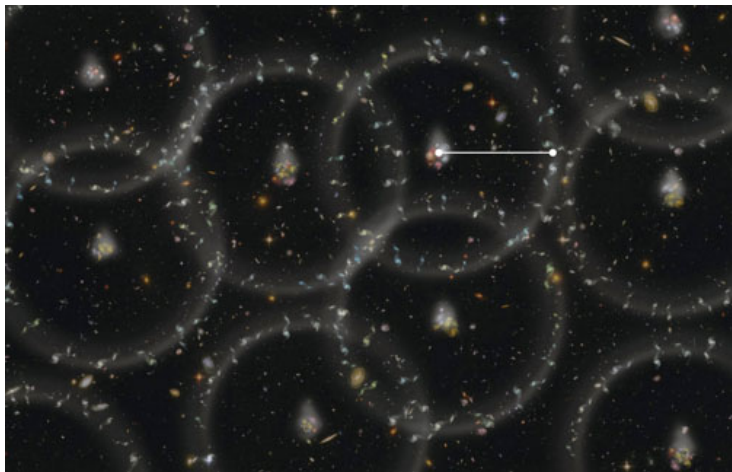


Acknowledgements

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NextGenerationEU/PRTR

DESI data: LSS

- distrib. of galaxies \rightarrow sound horizon $r_d \simeq 150$ Mpc $\rightarrow H(z)$



source: www.astro.ucla.edu/wright/BAO-cartoon.jpg

DESI data: LSS

- distrib. of galaxies \rightarrow sound horizon $r_d \simeq 150$ Mpc $\rightarrow H(z)$
- DESI DR1 (2024) + CMB + SN: $\omega_{\text{DE}} > -1$ at $(2.5 - 3.9)\sigma$
- DESI DR2 (2025) + CMB + SN: $\omega_{\text{DE}} > -1$ at $(2.8 - 4.2)\sigma$

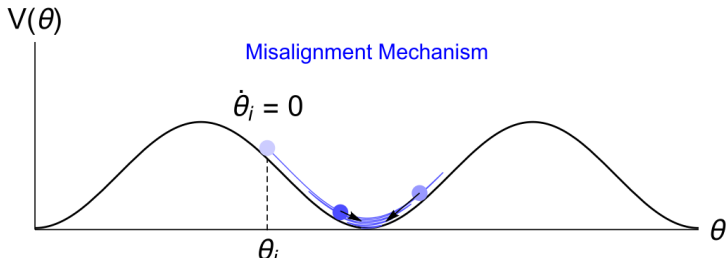
$$\text{e.o.s. } \omega_{\text{DE}} = \frac{\rho_{\text{DE}}}{\rho_{\text{DE}}} = \frac{\rho_{\text{kin}} - V}{\rho_{\text{kin}} + V} = -1 \text{ for C.C. } \Lambda$$

Tension with Λ CDM

Hint for **dynamical** dark energy!

PNGB quintessence [Friemann, Hill, Stebbins, Waga 1995]

Compact field $\theta \equiv \theta + 2\pi$, e.g. PNGB of some global approx. U(1)



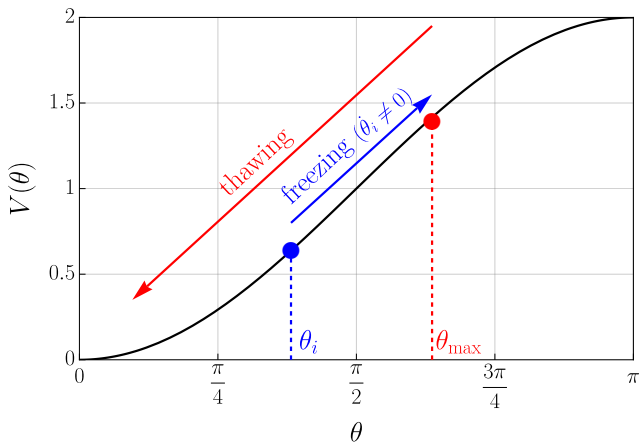
source: [Co, Hall, Harigaya 2019]

$$\text{energy density: } \rho_\theta = \frac{\dot{\theta}^2}{2} f_a^2 + m_a^2 f_a^2 (1 - \cos(\theta))$$

shift sym. protects **flatness**: $m_a \simeq H_0 \simeq \mathcal{O}(10^{-33} \text{ eV})$

$$\rho_\theta \simeq \rho_{\text{crit}} : f_a \simeq M_{\text{Pl.}}$$

Thawing/Freezing

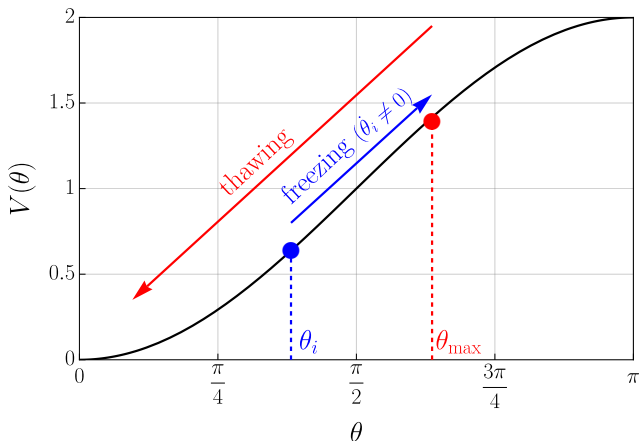


Thawing quintessence: $\dot{\theta}_i = 0$

early: $H \gg m_a$, $\theta = \theta_i = \text{const.}$, $\omega_\theta = -1$

later: $H \simeq m_a$, $\theta < \theta_i$, $\omega_\theta \uparrow$

Thawing/Freezing



Freezing quintessence: $\dot{\theta}_i \neq 0$

early: $H \gg m_a$, $\theta = \theta_i = \text{const.}$, $-1 < \omega_\theta \leq 1$

later: $H \simeq m_a$, $\theta > \theta_i$, $\omega_\theta \downarrow$

Interacting quintessence: models for $\dot{\theta}_i \neq 0$

- $\dot{\theta} \sim 1/a^3$ usually assumed that $\dot{\theta}_i \rightarrow 0$
- shift symmetry allows for couplings:
 - inverse spont. baryog. [Alonso, Scholtz 2020] $\bar{\psi}\gamma^\mu\psi\partial_\mu\theta$ ✗
 - helical dark gauge boson backgr. [Kobayashi, Jain 2020] $\theta F_{\mu\nu}\tilde{F}^{\mu\nu}$ ✓
 - charge transfer from DM [Domcke, Harigaya, Mukaida 2022]
 $(\theta + \varphi_{\text{DM}})G_{\mu\nu}\tilde{G}^{\mu\nu}$ (✓)
- asymmetric potential [Csaki, Kaloper, Terning 2005], $f_a(z)$ (✓)

Results and shameless self promotion

- freezing \rightarrow inflection point \rightarrow thawing
- source of $\dot{\theta}_i$: $\Omega_m^{\text{CMB}} = \Omega_m + \frac{\dot{\theta}_i^2 f_a^2}{2\rho_{\text{crit}}(1+z_i)^3}$
- Simple χ^2 fit at **background** level: [Ferreira, Wolf et al. 2024]
 - Planck + ACT CMB
 - DESI BAO DR1
 - Pantheon+ SN
- Fit improves b.c. of additional parameter $\dot{\theta}_i$:

m_a/H_0	$f_a/M_{\text{Pl.}}$	θ_i	$\dot{\theta}_i/m_a$	χ^2
1.618	0.133	2.606	0	34.966
1.021	0.466	0.849	4.010	25.889

Results and shameless self promotion

- Check out my poster \Rightarrow
- perturbations?
- more datasets?
- DM \leftrightarrow DE?

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Dark energy (DE)

- cosmological constant Λ : non-dynamical dark energy
- quintessence (QE): dynamical dark energy
- string theory (ST), quantum gravity seems to favor QE over Λ

Evolution (1)

Evolution (2)

- Thawing QE:
 - rolls down ($\dot{\phi} > 0$)
 - \rightarrow grows from -1
- Freezing QE:
 - climbs up ($\dot{\phi} < 0$)
 - \rightarrow decreases to -1
- "Kicked" QE [1]:
 - freezing followed by thawing

Data sets & methodology

Single χ^2 fit at background level:

- Planck + ACT CMB
- DESI BAO DR1 [2]
- Pantheon+ SN

source of $\dot{\phi}$: $\Omega_{DE}^{(DE)} = \Omega_m + \frac{\dot{\phi}^2}{2M_{pl}^2}$

Fit to data

Fit improves b.c. of additional parameter $\dot{\phi}_i$:

Ω_m	Ω_b	Ω_c	Ω_{DE}	w_0	w_a	χ^2
0.315	0.0423	2.635	0.602	-1	0	34,906
0.321	0.042	2.637	0.601	-1	0	35,209

- $\dot{\phi}_i \downarrow$ due to clashing with $\dot{\phi}_i \neq 0$
- $m_{pl} \downarrow$ b.c. $r \approx \frac{m_{pl}^2}{\dot{\phi}_i^2} \frac{1}{\dot{\phi}_i}$
- fit prefers $\dot{\phi}_i = \mathcal{O}(m_{pl})$
- $\dot{\phi}_i \downarrow$, $m_{pl} \downarrow$ \rightarrow $f_{DE} \uparrow$ b.c. $\frac{\dot{\phi}_i}{m_{pl}} \approx \text{const.}$

"Kicked" scenario violates three ST conjectures

Future improvements

- incl. DESI BAO DR2, SDES V
- "dynamical" $\dot{\phi}_i$ instead of IC
- perturbations?

References

- [1] Maximilian Berbig, Kick it like DESI: PNGB quintessence with a dynamically generated initial velocity. *JCAP*, 03/015, 2023.
- [2] A. G. Adame et al. DESI 2024 VE cosmological constraints from the measurements of baryon acoustic oscillations. *JCAP*, 02/021, 2025.
- [3] Rodrigo Alonso and Jakob Scholtz, Matter asymmetry sourced dark matter. *Phys. Rev. D* 104(2):023513, 2021.
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- [5] Valerie Domcke, Kristina Harigaya, and Kyohei Mukai, Charge transfer between rotating complex scalar fields. *JHEP*, 06/234, 2022.
- [6] Celia Coust, Nourouj Kaloger, and John Young, The Accelerated acceleration of the Universe. *JCAP*, 06/022, 2006.

More details

CPL parameter space