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Dark Energy with a Little Help from its Friends

arXiv:2311.08888

Joaquim M. Gomes

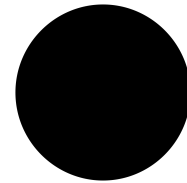
Edward Hardy

Susha Parameswaran

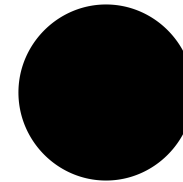
STRING PHENO '24

June 27th, 2024

A **transient** era of **Dark Energy** can be obtained through a scalar field coupled to either **Dark Matter**, **Dark Radiation** or **Quintessence**.



A **transient** era of **Dark Energy** can be obtained through a scalar field coupled to either **Dark Matter**, **Dark Radiation** or **Quintessence**.



The Beatles – With a Little Help From My Friends



← This talk

Toy model

$$V(\phi, \psi) = V(\phi) + \frac{1}{2} m_\psi^2 \psi^2 + \frac{1}{2} \frac{m_{\text{int}}^2}{\Lambda^2} \phi^2 \psi^2 + \lambda \psi^4$$

ϕ Dark Energy

ψ Friend

Hilltop

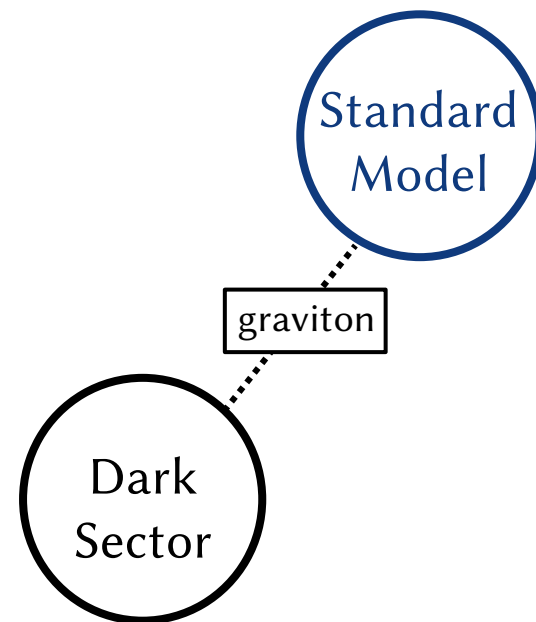
$$V_{\text{hill}}(\phi) = \rho_{\text{de}} \left(\left(\frac{\phi}{\Lambda} \right)^2 - 1 \right)^2$$

Maximum at the origin

Exponential

$$V_{\text{exp}}(\phi) = \rho_{\text{de}} e^{-\phi/\Lambda}$$

No extrema



Swampland

[Ooguri et al., 2019]

de Sitter Conjecture

$$M_{\text{Pl}} \frac{|\nabla V|}{V} \geq \mathcal{O}(1)$$

$$M_{\text{Pl}} \frac{|\nabla V|}{V} \leq \mathcal{O}(1)$$

Slow-roll accelerated expansion

$$V(\phi) = \rho \exp(-\phi/\Lambda)$$

No accelerated
expansion

$$\frac{M_{\text{Pl}}}{\Lambda} \geq \mathcal{O}(1)$$



Swampland

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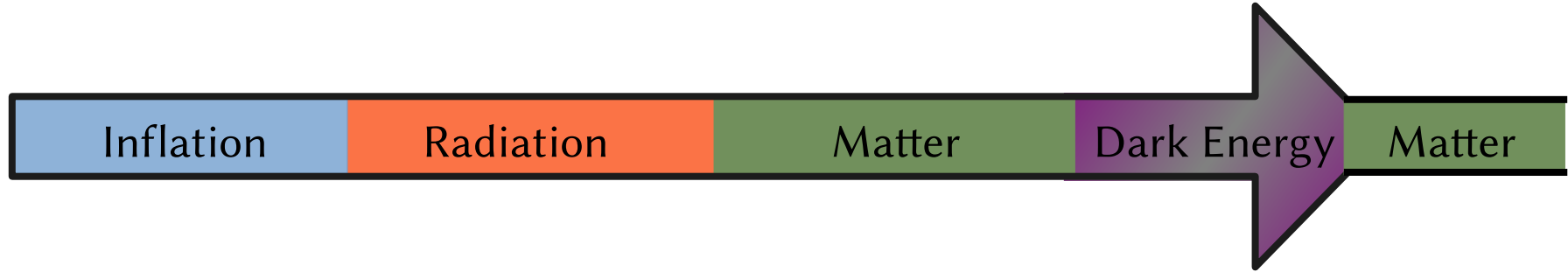
$$\frac{M_{\text{Pl}}}{\Lambda} \geq \mathcal{O}(1)$$

$$V(\phi, \psi) = \rho \exp(-\phi/\Lambda) + \frac{1}{2} m^2 \psi^2 + \frac{1}{2} \lambda \phi^2 \psi^2$$

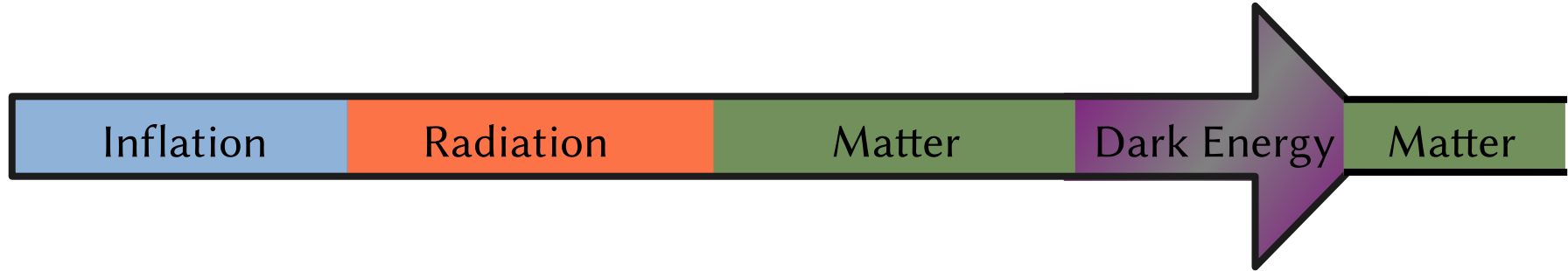
Accelerated expansion

$$\frac{M_{\text{Pl}}}{\Lambda} \sqrt{1 + \frac{m_\psi^4 \psi^2 \Lambda^2}{\rho_{\text{de}}^2}} \geq \mathcal{O}(1)$$

Metastable dS



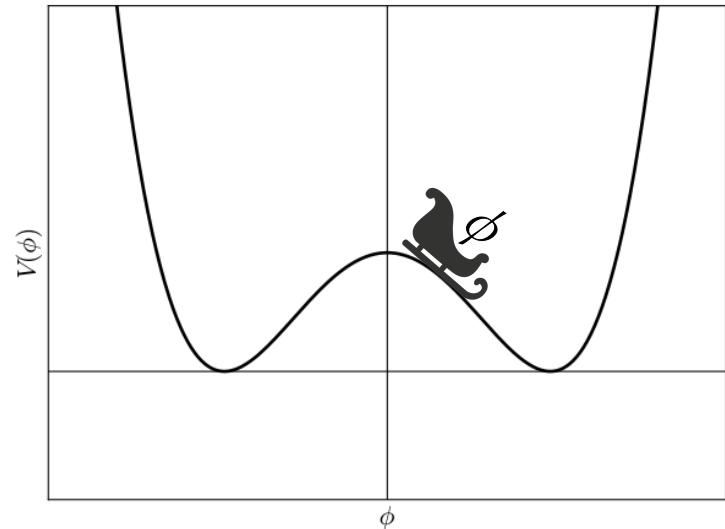
Metastable dS



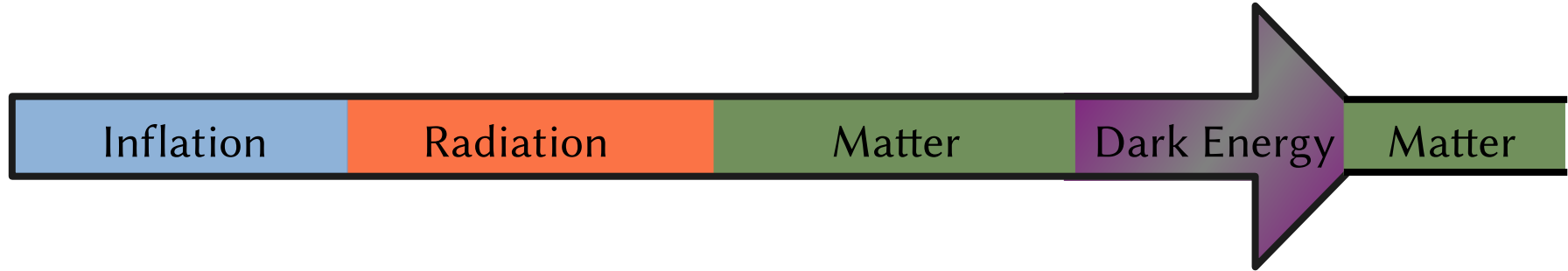
$$\ddot{\phi} + 3H\dot{\phi} + V'(\phi) = 0$$

$$\rho_{\phi} = \frac{1}{2}\dot{\phi}^2 + V(\phi)$$

Quintessence relies on Hubble friction



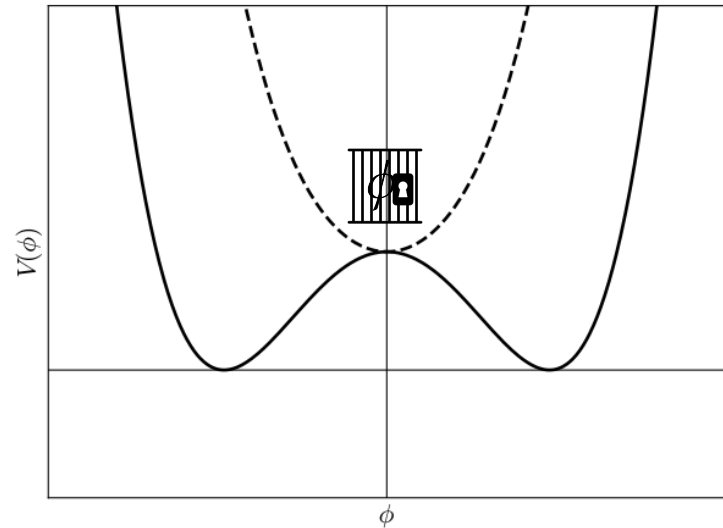
Metastable dS



$$\ddot{\phi} + 3H\dot{\phi} + V'(\phi, \underline{\psi}) = 0$$

$$\rho_{\phi} = \frac{1}{2}\dot{\phi}^2 + V(\phi, \underline{\psi})$$

Instead one could rely on an interaction



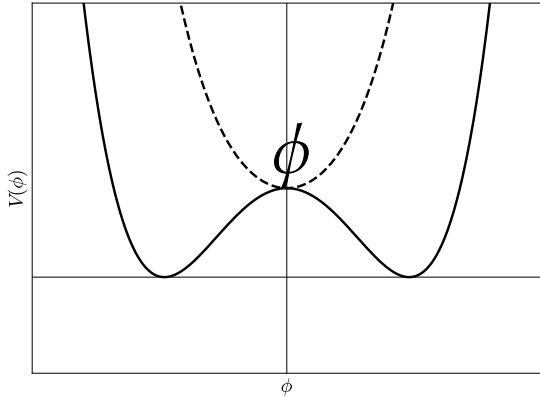
[Dvali and Kachru, 2003]

[Axenides and Dimopoulos, 2004]

Stabilization

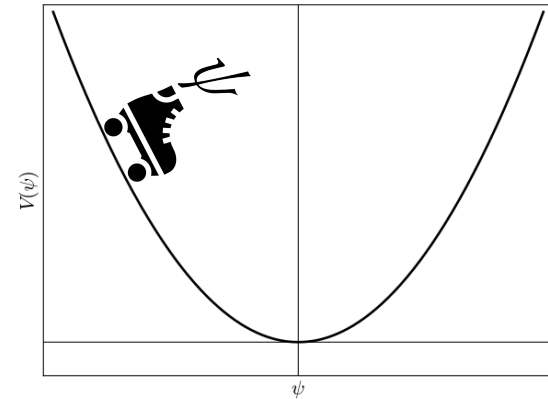
Dark Matter Assistance

$$m_{\phi}^2 = V''(\phi) + \frac{m_{\text{int}}^2}{\Lambda^2} \langle \psi \rangle^2$$



Temporary de Sitter

$$15H_0 \gtrsim m_{\psi} \gtrsim H_0$$



While fast oscillating

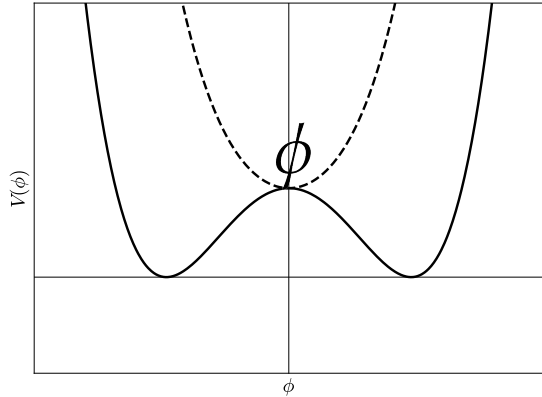
[Dvali and Kachru, 2003]

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Destabilization

Dark Matter Assistance

$$m_{\phi}^2 = V''(\phi) + \frac{m_{\text{int}}^2}{\Lambda^2} \langle \psi \rangle^2$$

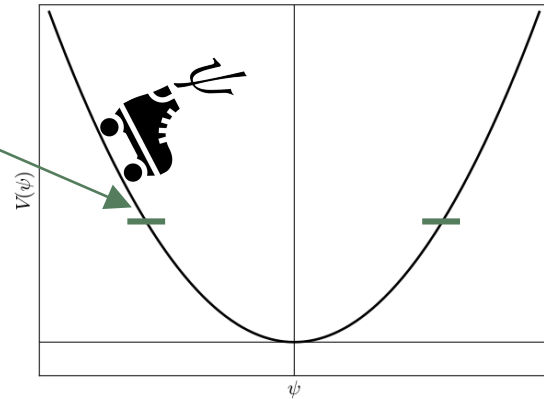


Temporary de Sitter

$$\psi_c = 2\sqrt{\rho_{\text{DE}}}/m_{\text{int}}$$

Critical field value

$$15H_0 \gtrsim m_{\psi} \gtrsim H_0$$



While fast oscillating

[Dvali and Kachru, 2003]

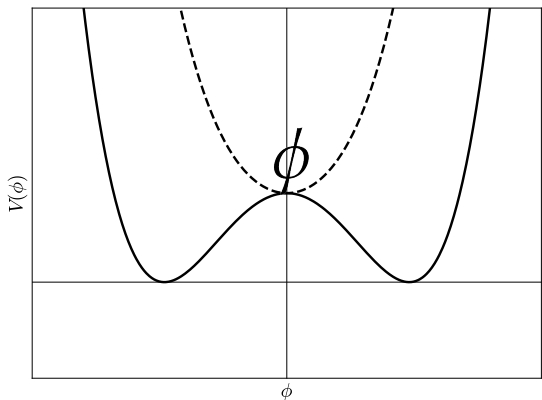
[Axenides and Dimopoulos, 2004]

Destabilization

Dark Matter Assistance

hilltop	$N_e \lesssim 7$
exponential	$N_e \lesssim 1$

$$m_\phi^2 = V''(\phi) + \frac{m_{\text{int}}^2}{\Lambda^2} \langle \psi \rangle^2$$



Temporary de Sitter

$$\ddot{\hat{\psi}} + \omega_\psi \hat{\psi} = 0$$

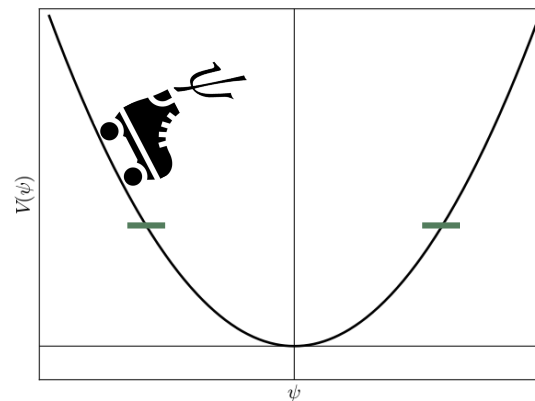
$$\ddot{\hat{\phi}} + \omega_\phi(\psi(t)) \hat{\phi} = 0$$

$$\hat{\phi} = \exp(s\tau) f(\tau)$$

$$\phi \propto \exp((\bar{s}m_\psi - 3H_0/2)t)$$

Parametric resonance

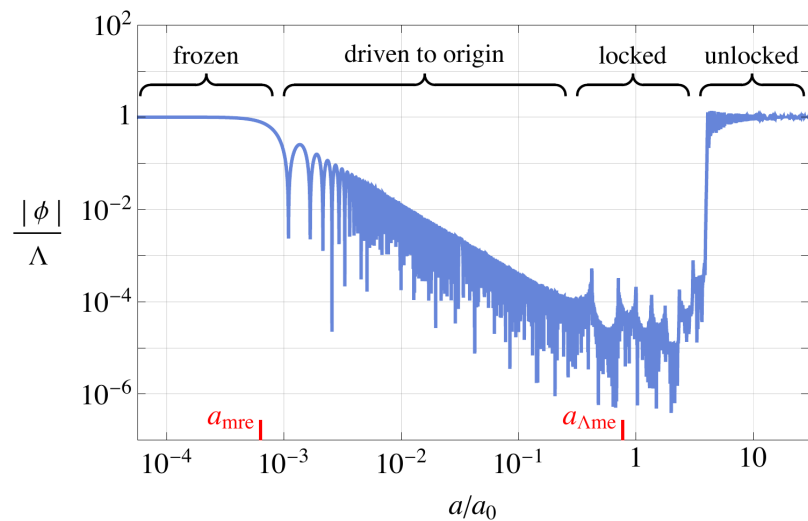
$$15H_0 \gtrsim m_\psi \gtrsim H_0$$



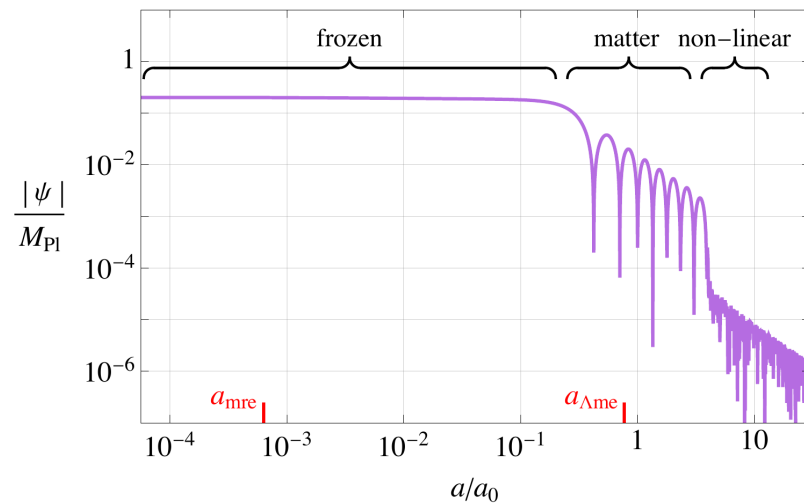
While fast oscillating

[Copeland and Rajantie, 2005]

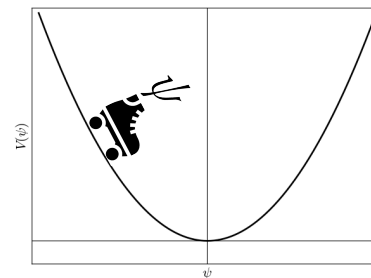
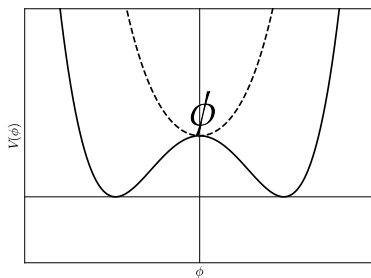
Cosmology



Dark Energy field evolution



Friend field evolution



Conclusion

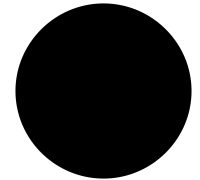
Friend

ψ

Dark Energy

ϕ

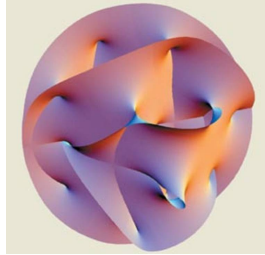
other Friend



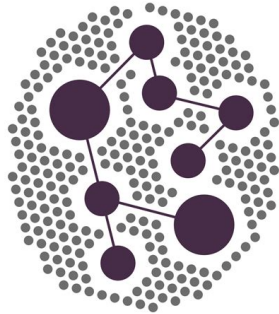
- short lived dark energy period
- potential satisfying the refined de Sitter conjecture
- exponential potential is less stable

[Casas and Montero and Ruiz, 2024]

Future Work



String compactifications



More elaborated
dark sectors

$$\partial_\mu \phi \partial^\mu \phi + m_\phi^2 \phi^2$$

Moduli stabilization

Questions?

Dark Energy with a Little Help from its Friends

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Ciência, Tecnologia
e Ensino Superior

