July 27th, 2021

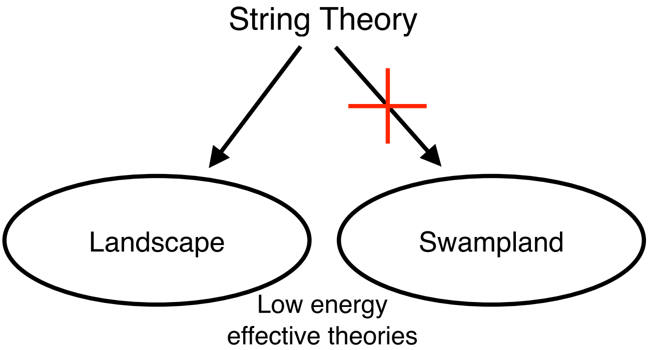
The String Theory Swampland in the Euclid & SKA era

LPSC, Grenoble

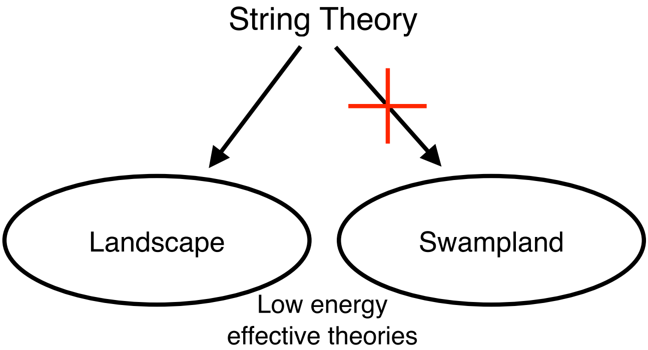
Cyril Renevey

Barrau, Renevey, Martineau, Astrophys.J. 912 (2021), 2101.02942

the Landscape & the Swampland



the Landscape & the Swampland



de Sitter conjecture:

$$\text{Scalar field theories in Landscape} \implies \left|\frac{V'(\phi)}{V(\phi)}\right| > \lambda_c \sim \mathcal{O}(1)$$

Obied, Ooguri, Spodyneiko, Vafa (2018), 1806.08362

Reliability of the de Sitter conjecture

Several limits for classical vacua (neglected quantum corrections):

- Maldacena-Nunez no-go theorem for supergravity:
  $|V'/V| \geq 6/\sqrt{(d-2)(11-d)}$

  Maldacena, Nunez (2000), hep-th/0007018

- Compactification of Type IIA on Calabi-Yau manifolds:
  $|V'/V| \gtrsim 2$

  Herzberg, Kachru, Taylor, Tegmark (2007), 0711.2512

Reliability of the de Sitter conjecture

Several limits for classical vacua (neglected quantum corrections):

- Maldacena-Nunez no-go theorem for supergravity:
  $|V'/V| \geq 6/\sqrt{(d-2)(11-d)}$

  Maldacena, Nunez (2000), hep-th/0007018

- Compactification of Type IIA on Calabi-Yau manifolds:
  $|V'/V| \gtrsim 2$

  Herzberg, Kachru, Taylor, Tegmark (2007), 0711.2512

De Sitter conjecture based on the TCC: $\left|V'/V\right| > \sqrt{2/3}$

Bedroya, Vafa (2019), 1909.11063

Andriot, Cribiori, Erkinger (2020), 2004.00030

Reliability of the de Sitter conjecture

Several limits for classical vacua (neglected quantum corrections):

- Maldacena-Nunez no-go theorem for supergravity:
  $|V'/V| \geq 6/\sqrt{(d-2)(11-d)}$

  Maldacena, Nunez (2000), hep-th/0007018

- Compactification of Type IIA on Calabi-Yau manifolds:
  $|V'/V| \gtrsim 2$

  Herzberg, Kachru, Taylor, Tegmark (2007), 0711.2512

De Sitter conjecture based on the TCC: $\left|V'/V\right| > \sqrt{2/3}$

Bedroya, Vafa (2019), 1909.11063

Andriot, Cribiori, Erkinger (2020), 2004.00030

Refined de Sitter conjecture to include scalar fields close to local maximum: $\left|V'/V\right| > \lambda_c \quad \text{or} \quad V''/V < -\alpha_c,$

Ooguri, Palti, Shiu, Vafa (2018), 1810.05506

Quintessence and the Friedmann's equations

Quintessence action:

$$S = \int d^4x\sqrt{-g}\left(R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi)\right)$$

Homogeneity and isotropy lead to

$$H^2 := \left(\frac{\dot{a}}{a}\right)^2 = \frac{\kappa}{3}(\rho_m + \rho_\phi)$$

$$\dot{\rho}_i = -3H(\rho_i + p_i), \qquad i = m, \phi$$

where

$$\rho_\phi = \frac{\dot{\phi}^2}{2} + V(\phi) \quad \text{and} \quad p_\phi = \frac{\dot{\phi}^2}{2} - V(\phi)$$

Modified Friedmann's equations

New variables:

$$w_\phi := \frac{p_\phi}{\rho_\phi}, \quad \Omega_\phi := \frac{\kappa \rho_\phi}{3H} \quad \text{and} \quad \lambda := -\frac{V'(\phi)}{V(\phi)}$$

Modified Friedmann's equations

New variables:

$$w_\phi := \frac{p_\phi}{\rho_\phi}, \quad \Omega_\phi := \frac{\kappa\rho_\phi}{3H} \quad \text{and} \quad \lambda := -\frac{V'(\phi)}{V(\phi)}$$

Equations become:

$$\frac{\mathrm{d}w_\phi}{\mathrm{d}N} = (w_\phi - 1)\left[3(1+w_\phi) - \lambda\sqrt{3(1+w_\phi)\Omega_\phi}\right]$$

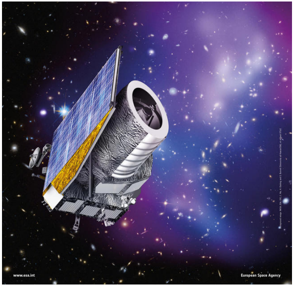
$$\frac{\mathrm{d}\Omega_\phi}{\mathrm{d}N} = -3(w_\phi - w_m)\Omega_\phi(1-\Omega_\phi)$$

$$\frac{\mathrm{d}\lambda}{\mathrm{d}N} = -\sqrt{3(1+w_\phi)\Omega_\phi}(\Gamma(\phi)-1)\lambda^2$$

with:

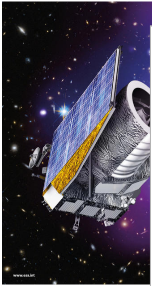
$$\Gamma(\phi) := \frac{VV''}{(V')^2} \quad \text{and} \quad N := \ln a$$

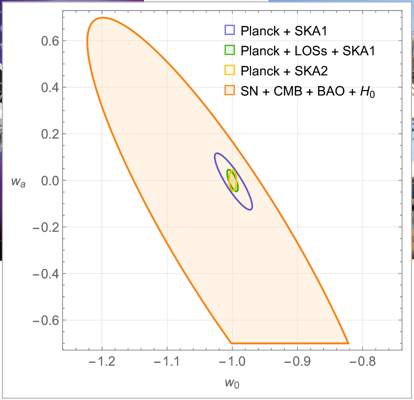
Testing the EOS with Euclid & SKA

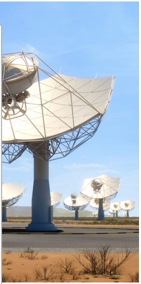


Testing the EOS with Euclid & SKA

$$w_\phi(a) = w_0 + w_a(1-a)$$



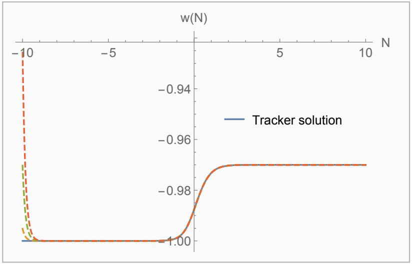




$$\text{SN+CMB+BAO+H}_0 \implies \lambda_c \sim \mathcal{O}(1) < |\lambda| < 0.6 \text{ at } 95\%\text{C.L.}$$

Scolnic et al. (2018), 1710.00845
Agrawal, Obied, Steinhardt, Vafa (2018), 1806.09718
Sprenger, Archidiacono, Brinckmann, Clesse, Lesgourgues (2019), 1801.08331

Quintessence inspired from string theory

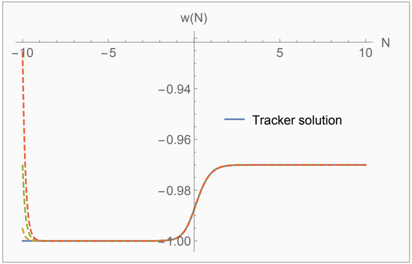


Exponential:

$$V(\phi) = V_0 e^{-\lambda_1 \phi}$$

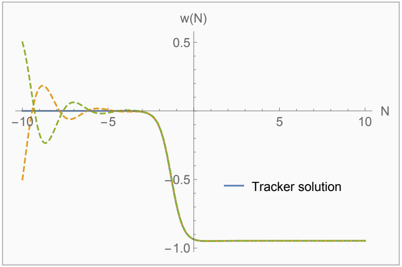
$$\lambda_1 > 0$$

Quintessence inspired from string theory



Exponential:

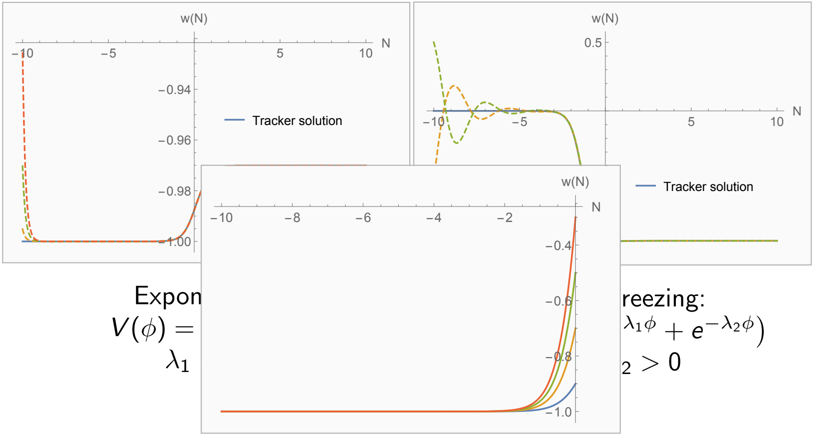
$$V(\phi) = V_0 e^{-\lambda_1 \phi}$$
$$\lambda_1 > 0$$



Scaling Freezing:

$$V(\phi) = V_0 \left(e^{-\lambda_1 \phi} + e^{-\lambda_2 \phi}\right)$$
$$\lambda_1 > \lambda_2 > 0$$

Quintessence inspired from string theory



Expon

$V(\phi) =$

λ_1

reezing:

$\lambda_1\phi + e^{-\lambda_2\phi})$

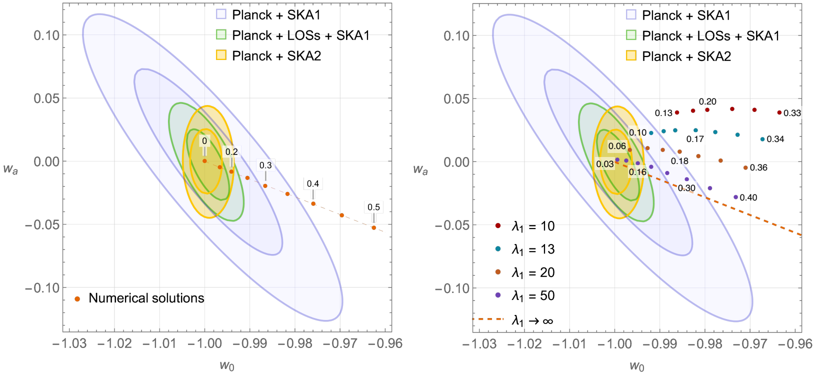
$_2 > 0$

Thawing:

$V(\phi) = V_0(\cos(f\phi) + 1)$

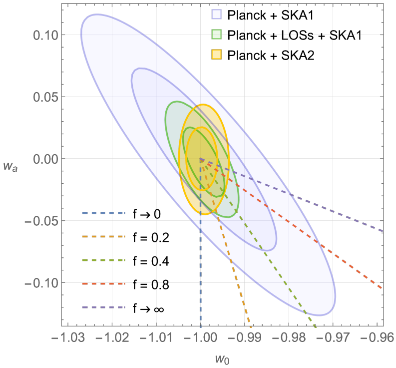
$f > 0$

Scaling Freezing: $V(\phi) = V_0\left(e^{-\lambda_1\phi} + e^{-\lambda_2\phi}\right)$

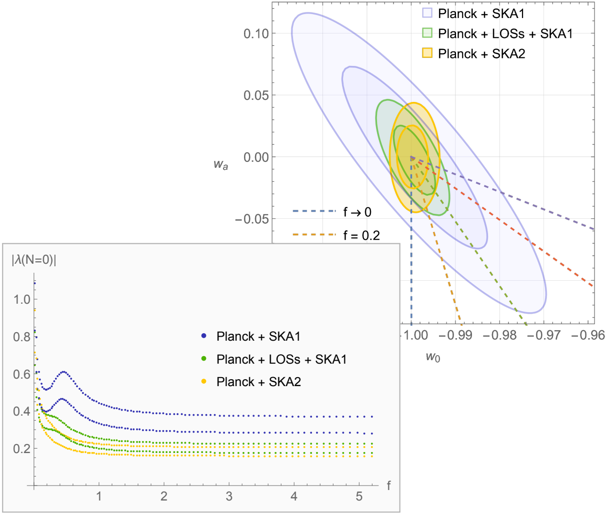


	Pl. + SKA1	Pl. + LOSs + SKA1	Pl. + SKA2
67% CL	$\lvert\lambda\rvert < 0.28$	$\lvert\lambda\rvert < 0.17$	$\lvert\lambda\rvert < 0.16$
95% CL	$\lvert\lambda\rvert < 0.36$	$\lvert\lambda\rvert < 0.22$	$\lvert\lambda\rvert < 0.20$

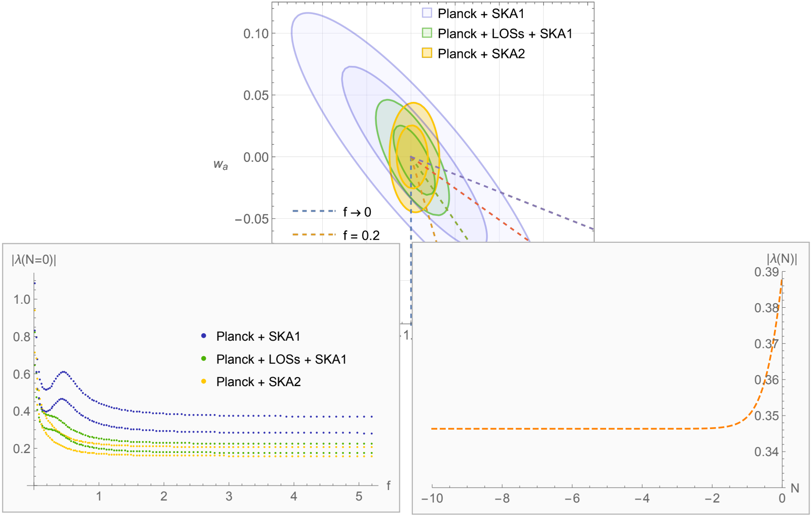
Thawing Models: $V(\phi) = V_0(\cos(f\phi) + 1)$



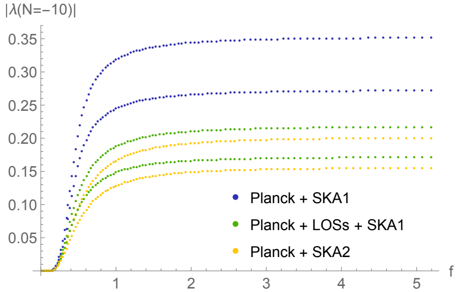
Thawing Models: $V(\phi) = V_0(\cos(f\phi) + 1)$



Thawing Models: $V(\phi) = V_0(\cos(f\phi) + 1)$



Thawing Models: $V(\phi) = V_0(\cos(f\phi) + 1)$



	Pl. + SKA1	Pl. + LOSs + SKA1	Pl. + SKA2
67% CL	$\lvert\lambda\rvert < 0.27$	$\lvert\lambda\rvert < 0.17$	$\lvert\lambda\rvert < 0.16$
95% CL	$\lvert\lambda\rvert < 0.35$	$\lvert\lambda\rvert < 0.22$	$\lvert\lambda\rvert < 0.20$

In concordance with
Heisenberg, Bartelmann, Brandenberger, Refregier (2019), 1902.03939

Drawbacks & future works

- De Sitter conjecture is yet only a conjecture
- We do not yet know the limit value λ_c
- Cosine potential always satisfies the refined de Sitter conjecture:

$$\frac{|V'|}{V} > \lambda_c \quad \text{or} \quad \frac{V''}{V} < -\alpha_c,$$

- The constraints are model dependent
- We do not take multi-fields into account

Thank You!