Tachyonic Encore:
A universal shift of inflationary observables

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Single-field inflation is enough

Single-field inflation is NOT enough

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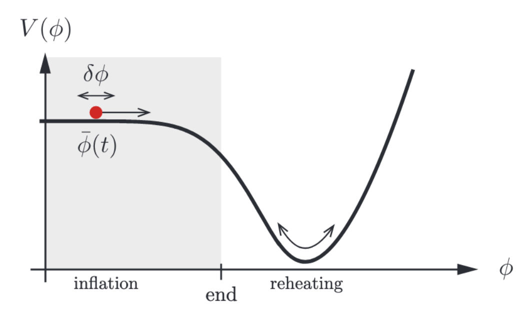
$$P_\zeta = \frac{1}{8\pi^2}\frac{H^2}{M_{\rm Pl}^2}\frac{1}{\epsilon_\phi}$$

$$P_T = \frac{2}{\pi^2}\frac{H^2}{M_{\rm Pl}^2}$$

$$n_s - 1 = \frac{d\log P_\zeta}{d\log k} = 2\eta_\phi - 2\epsilon_\phi$$

$$r = \frac{\mathcal{A}_T}{\mathcal{A}_\zeta} = 16\epsilon_\phi$$

$$f_{\rm NL} \sim \mathcal{O}(10^{-2})$$



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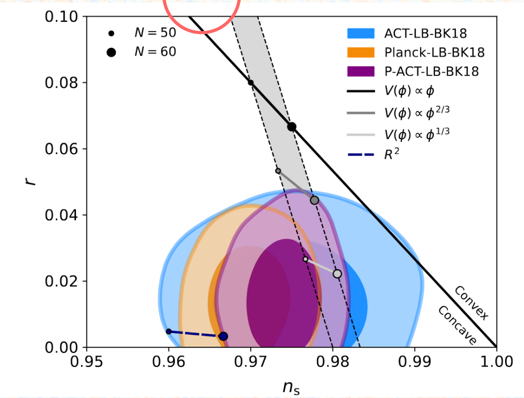
$V(\phi) = m^2\phi^2/2$



[ACT, 2025]

$n_s(\text{CMB}) \simeq 0.974 \qquad r < 0.036$

Multi-field inflation can be enough

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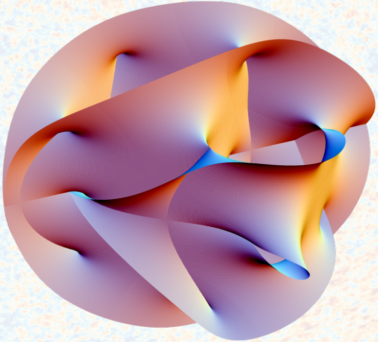
- Generic prediction of UV-completions of inflation



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- Generic prediction of UV-completions of inflation

additional fields (e.g. 

)

$\Downarrow$

isocurvature perturbations

$\Downarrow$

sourcing of curvature

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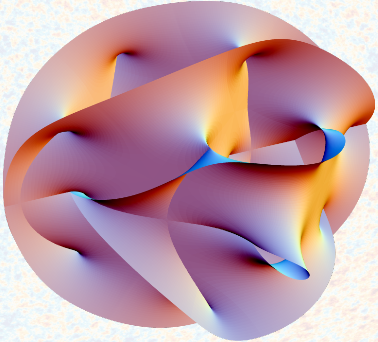
modifications to observables
(+ non-gaussianities)



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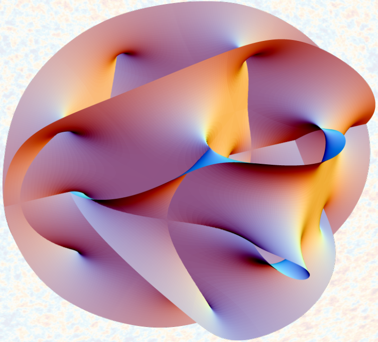

Typically highly model-dependent

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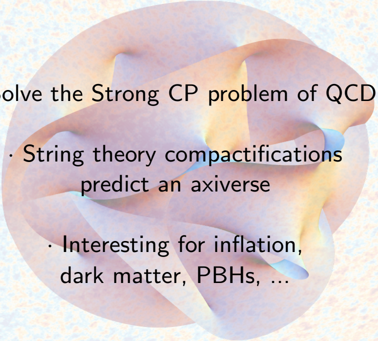

· Solve the Strong CP problem of QCD

· String theory compactifications predict an axiverse

· Interesting for inflation, dark matter, PBHs, ...

Typically highly model-dependent

Inflaton +


IMPROVED...
BETTER DETERGENT BOOSTER THAN EVER!
AXION
DETERGENT BOOSTER
Safe whitening brightening power for all your wash...pre-soaks too!
CAUTION: EYE IRRITANT
READ IMPORTANT INFORMATION ON SIDE PANEL
NET WT. 25 OZS. (1 LB. 9 OZS.)

Inflaton + axion: during inflation

$$\mathcal{L} = \boxed{-\frac{1}{2}(\partial\varphi)^2 - V(\varphi)}$$

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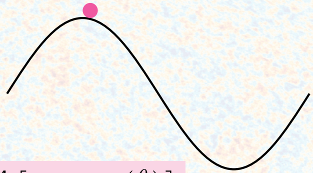

$$\mathcal{L} = -\frac{1}{2}(\partial\varphi)^2 - V(\varphi) - \frac{1}{2}(\partial\theta)^2 - \Lambda^4\left[1 - \cos\left(\frac{\theta}{f}\right)\right]$$

spectator axion

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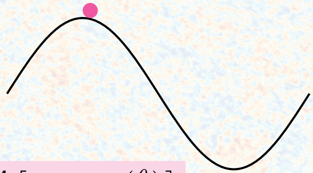
Axion is frozen near the hilltop during inflation
(unstable equilibrium)



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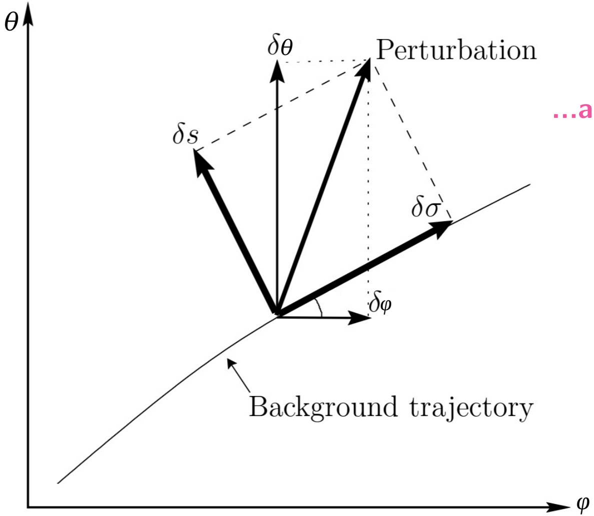
Adiabatic...

$$\mathcal{R} = \frac{\delta\sigma}{\sqrt{2\epsilon}}$$

$$\delta\sigma \simeq \delta\varphi$$



...and entropic

$$\mathcal{S} = \frac{\delta s}{\sqrt{2\epsilon}}$$

$$\delta s \simeq \delta\theta$$

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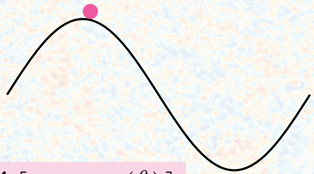

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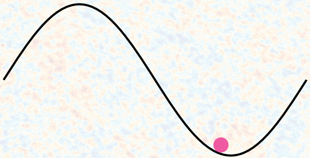
$$\mathcal{R} = \frac{\delta\sigma}{\sqrt{2\epsilon}} \qquad \mathcal{S} = \frac{\delta s}{\sqrt{2\epsilon}}$$

$$\delta\sigma \simeq \delta\varphi \qquad \delta s \simeq \delta\theta$$

Effectively single field dynamics: standard predictions at N_{end}

Inflaton + axion: post-inflationary tachyonic bursts



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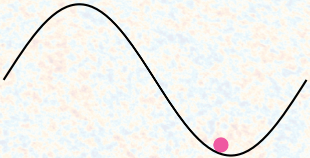
The axion rolls down **after** the end of inflation
$\hookrightarrow$ all scales are super-horizon



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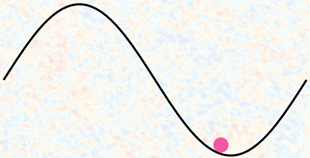

$$\dot{\mathcal{R}} \simeq 2\frac{\Omega}{H}\,\mathcal{S}$$

$$\ddot{\mathcal{S}} + (3+\eta)\,H\dot{\mathcal{S}} + m^2_{\mathcal{S},\mathrm{eff}}\,\mathcal{S} = 0$$

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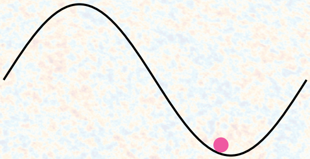

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field-space turn-rate

(larger when θ starts close to the hilltop)

$$m^2_{\mathcal{S},\mathrm{eff}} \simeq V_{,ss} - V_{,\sigma\sigma} + 4\Omega^2 < 0$$

Tachyonic enhancement of isocurvature

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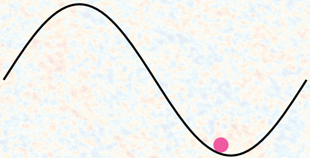

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$$\Downarrow$$

Transfer of isocurvature to curvature

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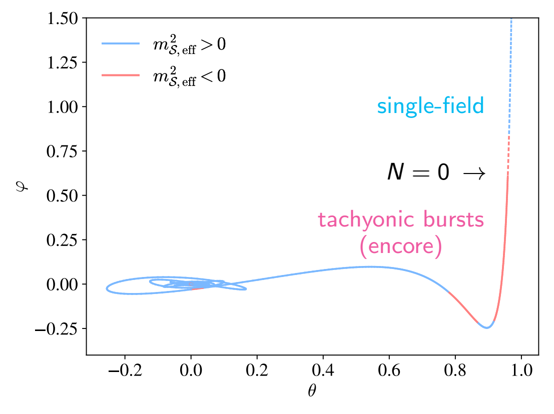

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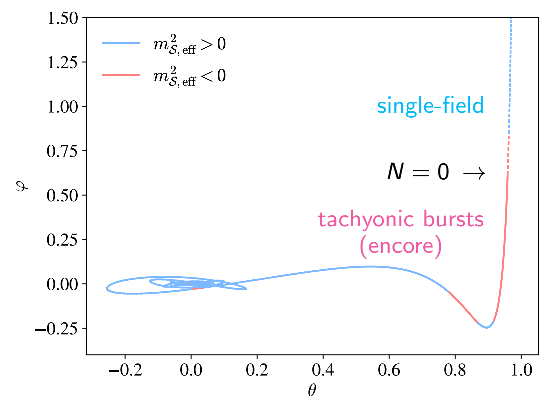

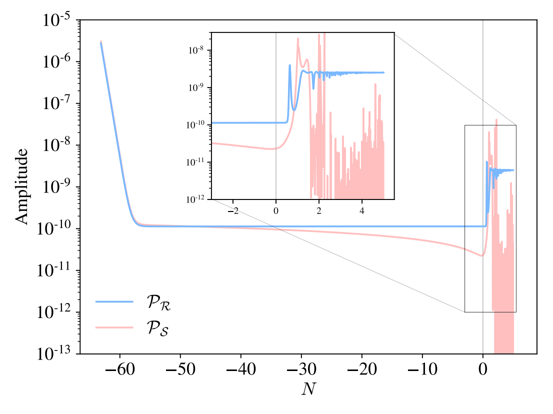

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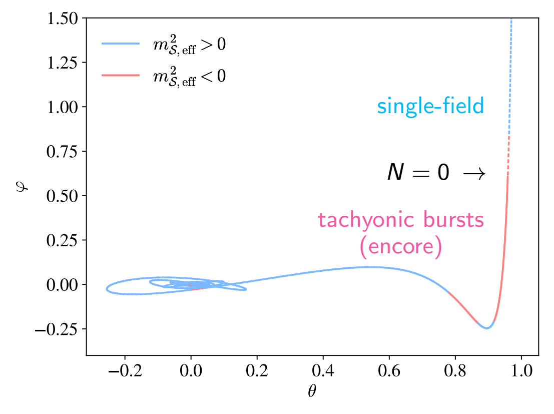
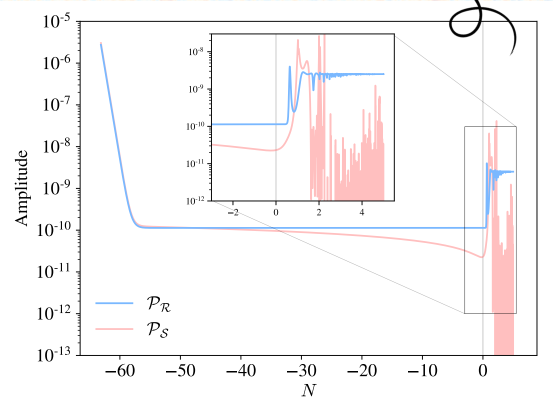
Enhancement: $\mathcal{E}(\theta_{\rm in}) \equiv \frac{\mathcal{P}_\mathcal{R}^{\rm post}}{\mathcal{P}_\mathcal{R}^{\rm pre}}$





Observables

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$$r^{\text{post}} = \frac{r^{\text{pre}}}{\mathcal{E}} \qquad n_s^{\text{post}} = \frac{1}{\mathcal{E}} n_{\mathcal{R}_0} + \frac{\mathcal{E}-1}{\mathcal{E}} n_{Q_s} \qquad f_{\text{NL}}^{\text{local}} \simeq \frac{5}{6}\frac{N_{\theta\theta}}{N_\theta^2} = \frac{5}{12}\frac{1}{f^2}$$

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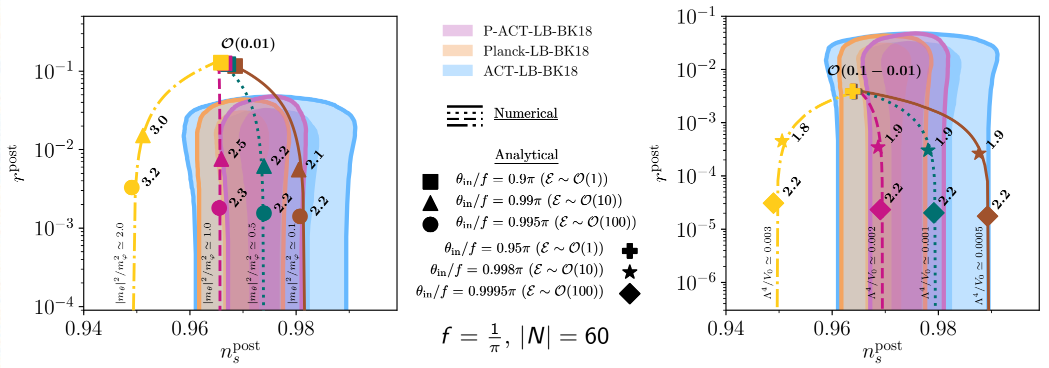

Chaotic

Starobinsky

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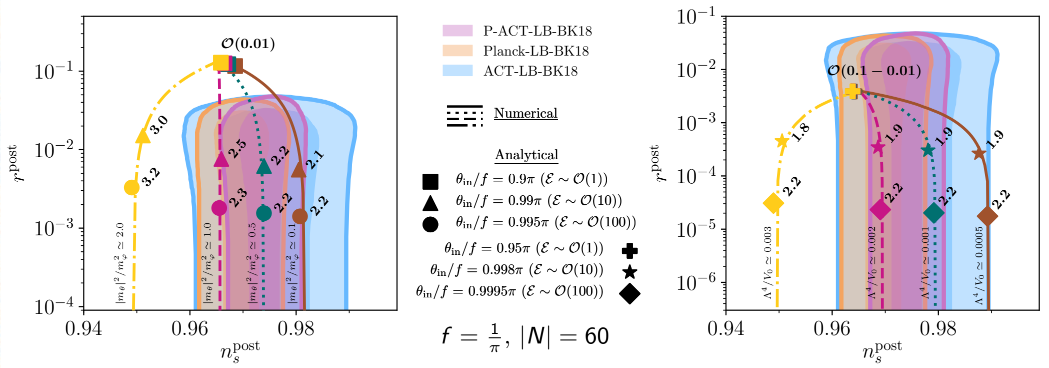

Chaotic **Starobinsky**

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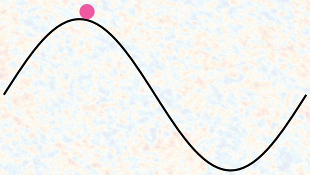

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Conditions for the encore

- Intervals of **negative** $m^2_{\mathcal{S},\mathrm{eff}}$ after N_{end} (transient tachyonic instabilities) $\Rightarrow$ θ_{in} **at hilltop**
- Spectator starts turning **after** N_{end} (all scales outside of the horizon) $\Rightarrow$ **light-enough axion**

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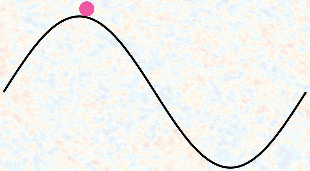

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$\downarrow$

- Scale-independent enhancement of the curvature spectrum
- Modified observables: **observations constrain the axion**

General results

$$\boxed{r^{\text{post}} = \frac{r^{\text{pre}}}{\mathcal{E}(\theta_{\text{in}})} \qquad n_s^{\text{post}} \simeq 1 + 2\eta_{ss} - 2\epsilon_\varphi \qquad f_{\text{NL}}^{\text{local}} \simeq \frac{5}{12}\frac{1}{f^2}}$$

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  $\hookrightarrow$ predictions in better agreement with ACT
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Thank you :)

Avoiding fine-tuning (backup)

Chaotic
Starobinsky

(I) Hilltop initial condition: $\boxed{\Delta\theta \lesssim 10^{-3}}$ or $\boxed{\Delta\theta \lesssim 10^{-2}}$

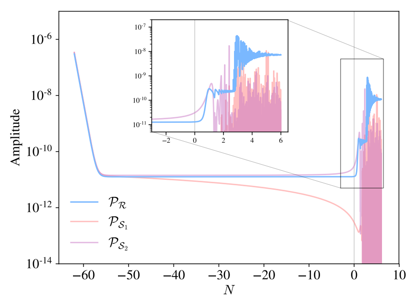
In fact: uniform distribution $0 < \theta_{\rm in} < 2\pi f \quad \Rightarrow \quad \underline{P(\Delta\theta) \sim \mathcal{O}(\Delta\theta)}$

stochastic fluctuations
do not alter this result

(II) Axion mass range: $\boxed{0.13 \lesssim \dfrac{|m_\theta^2|}{m_\varphi^2} \lesssim 0.95}$ or $\boxed{5 \times 10^{-4} \lesssim \dfrac{\Lambda^4}{V_0} \lesssim 2 \times 10^{-3}}$

But axions are not lonely...

An axiverse yields less restrictive conditions!



Negative curvature (backup)

Required to generate the desired frozen phase followed by the rolling phase.

Plus, **during** inflation:

$$m^2_{\mathcal{S},\text{eff}} \simeq V_{,ss} - V_{,\sigma\sigma} + 6\epsilon H^2$$

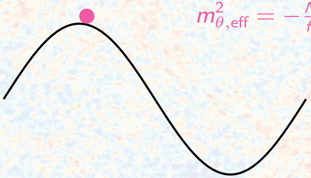
$$\downarrow$$

$$m^2_{\mathcal{S},\text{eff}} \simeq m^2_{\theta,\text{eff}} - m^2_{\varphi} + 6\epsilon H^2$$

$$\downarrow$$

$$m^2_{\mathcal{S},\text{eff}} \simeq -\frac{\Lambda^4}{f^2} - m^2_{\varphi} + 6\epsilon H^2$$

$\hookrightarrow$ **helps reduce decay of isocurvature**



$m^2_{\theta,\text{eff}} = -\frac{\Lambda^4}{f^2} < 0$