Tachyonic preheating and its observational signatures

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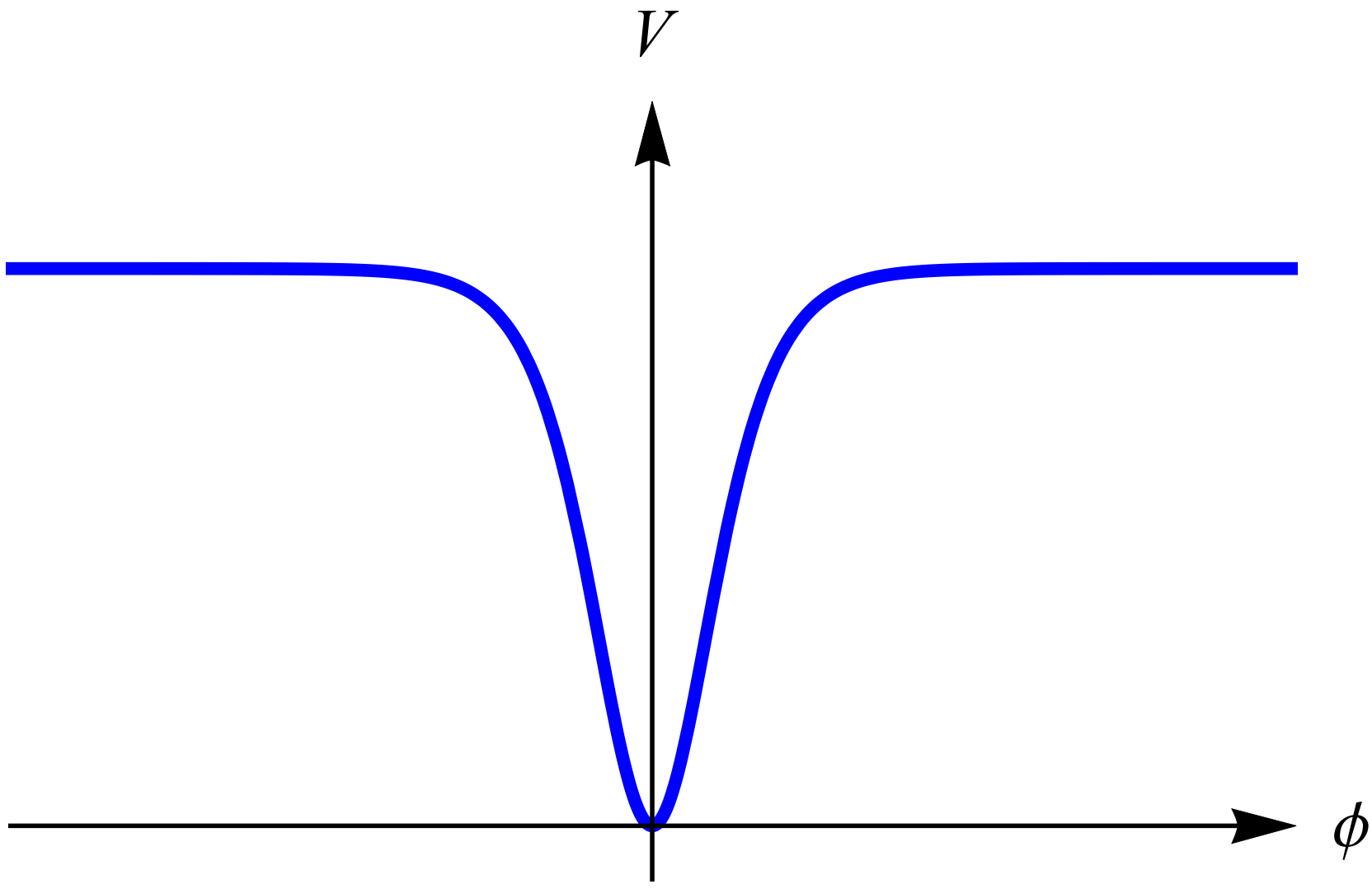
Based on 1902.10148, 2007.03484, 2102.02712, 2108.10767, 2201.04145 in collaboration with J. Rubio, A. Karam, M. Raidal, H. Veermäe, N. Koivunen

Cosmic inflation



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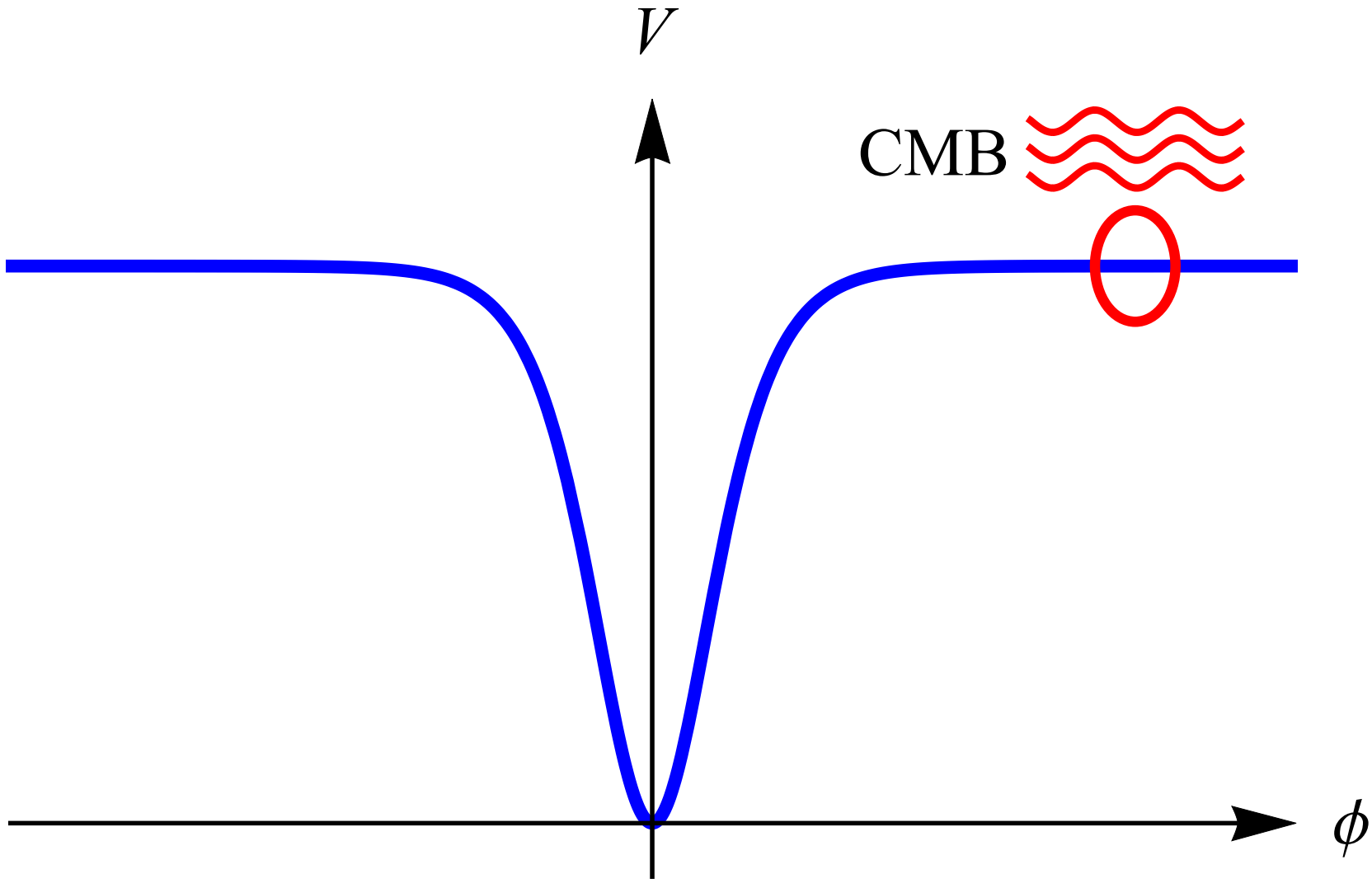

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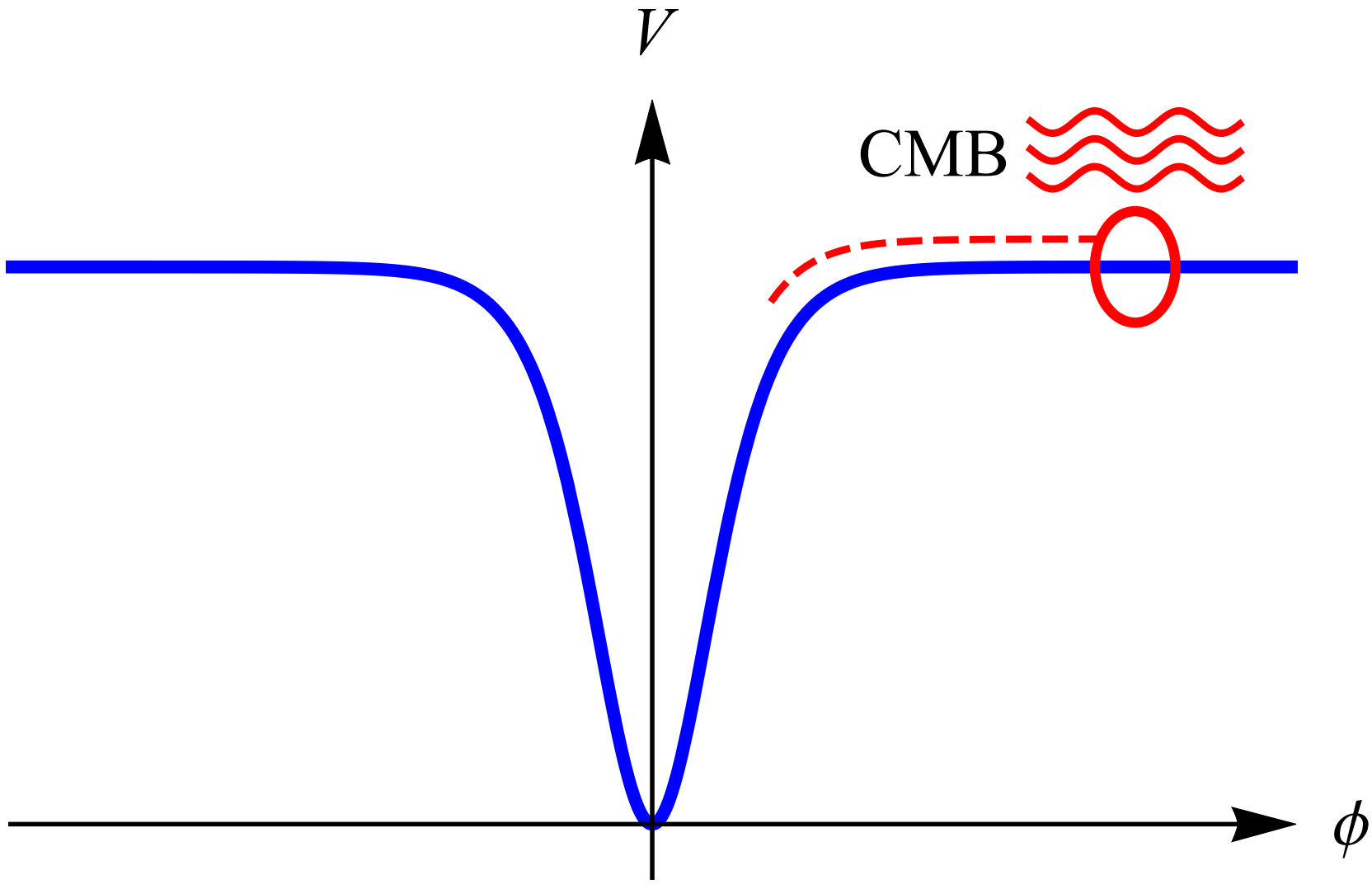

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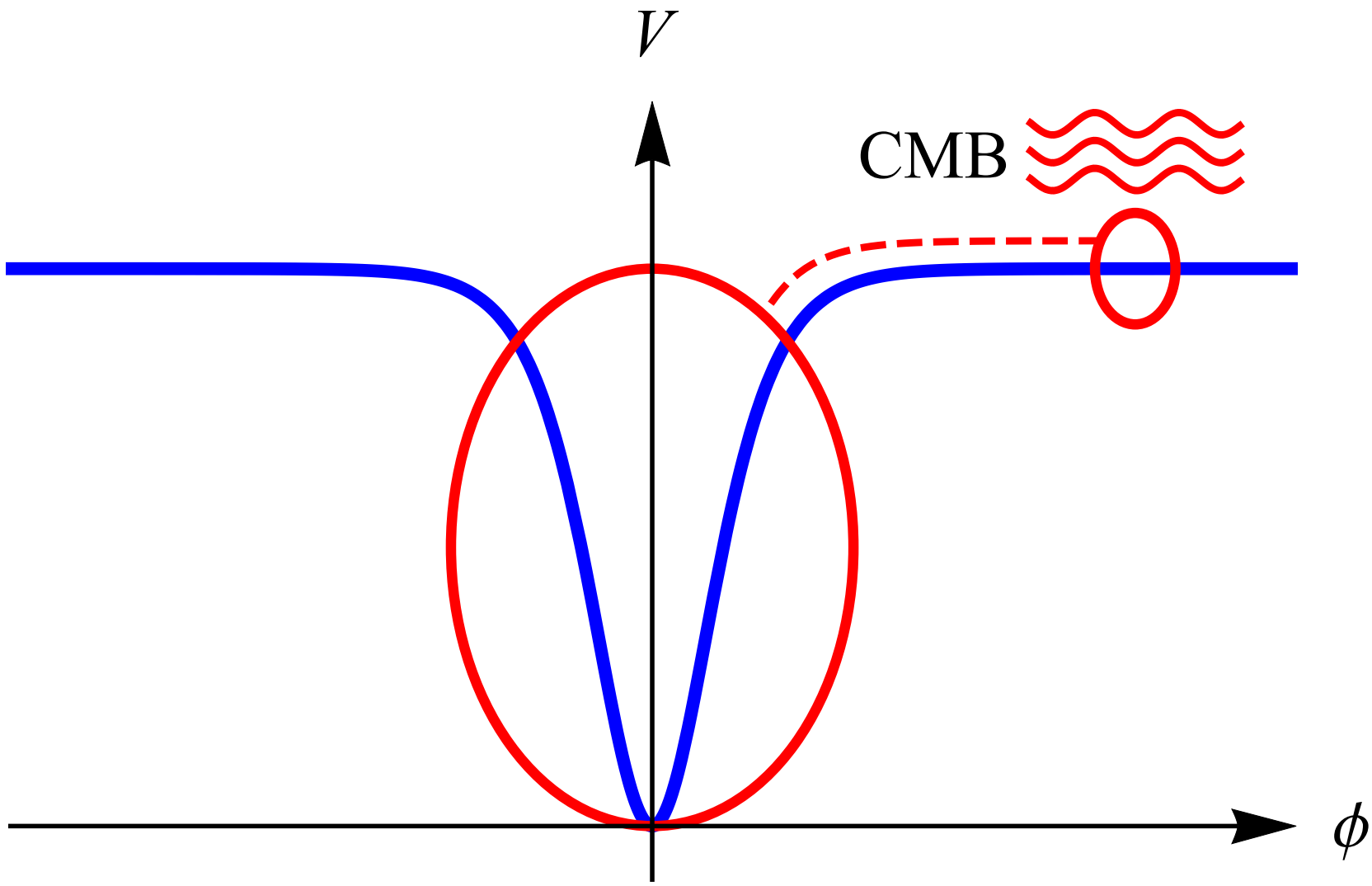
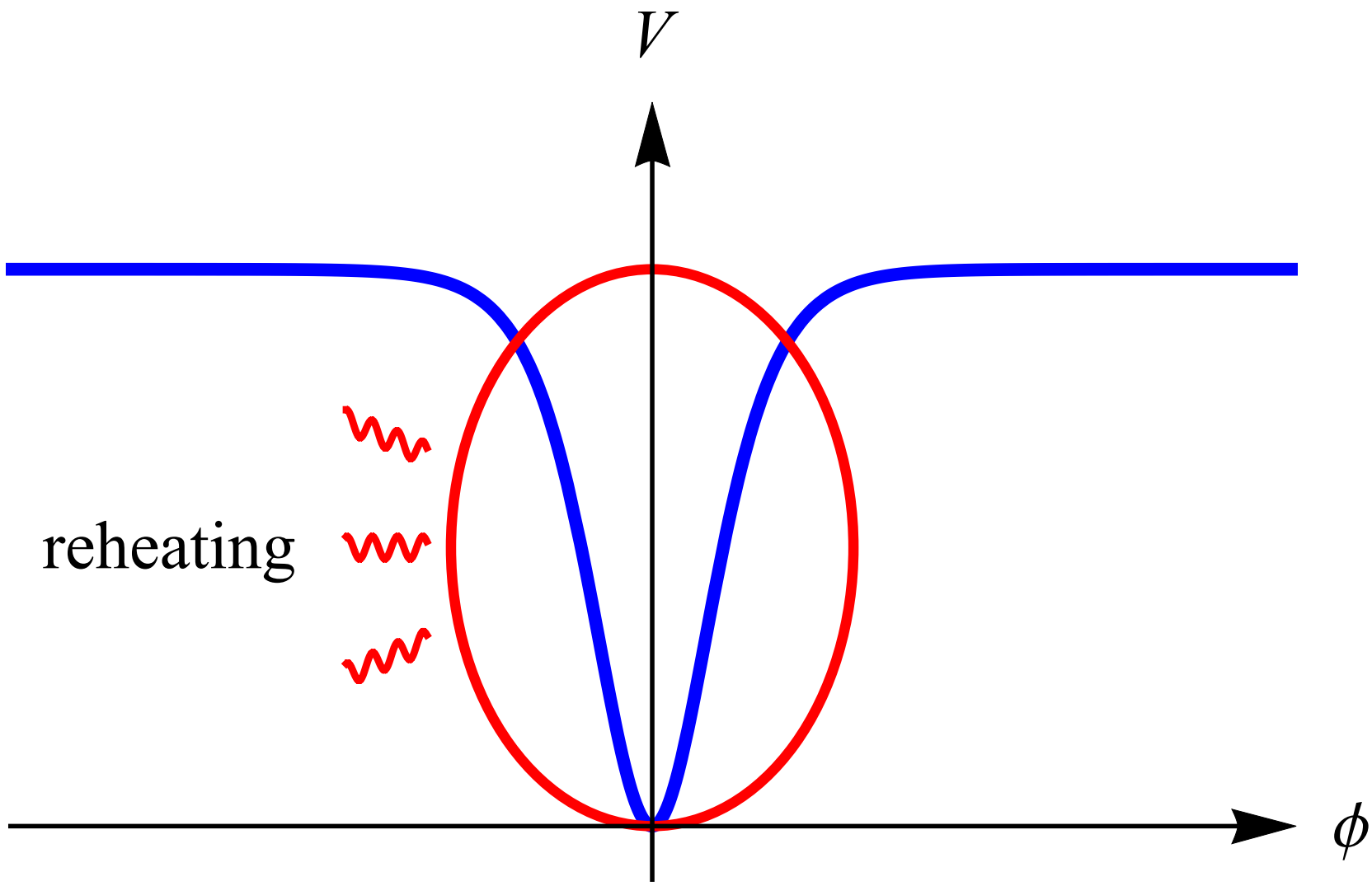


(P)reheating



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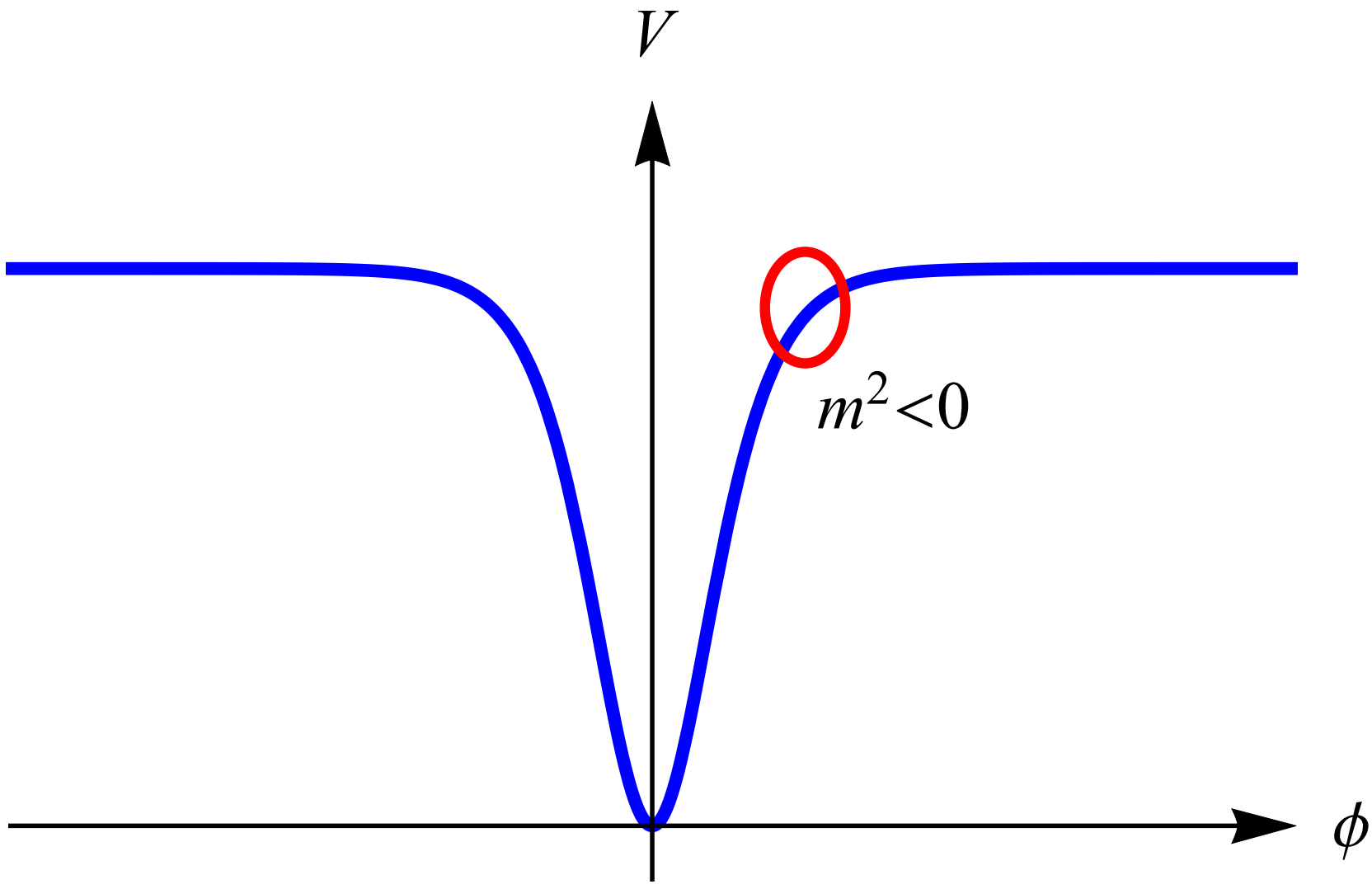

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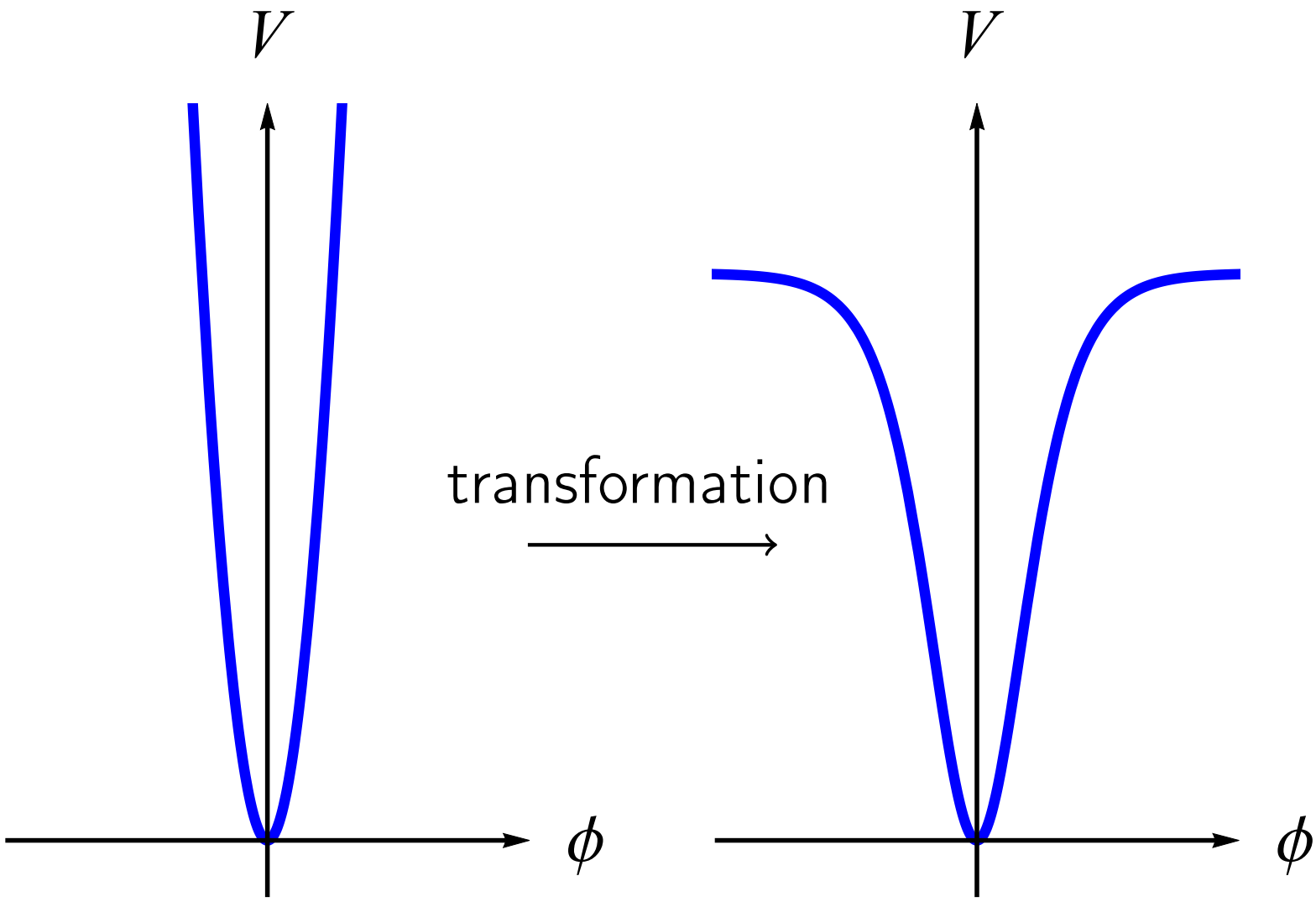

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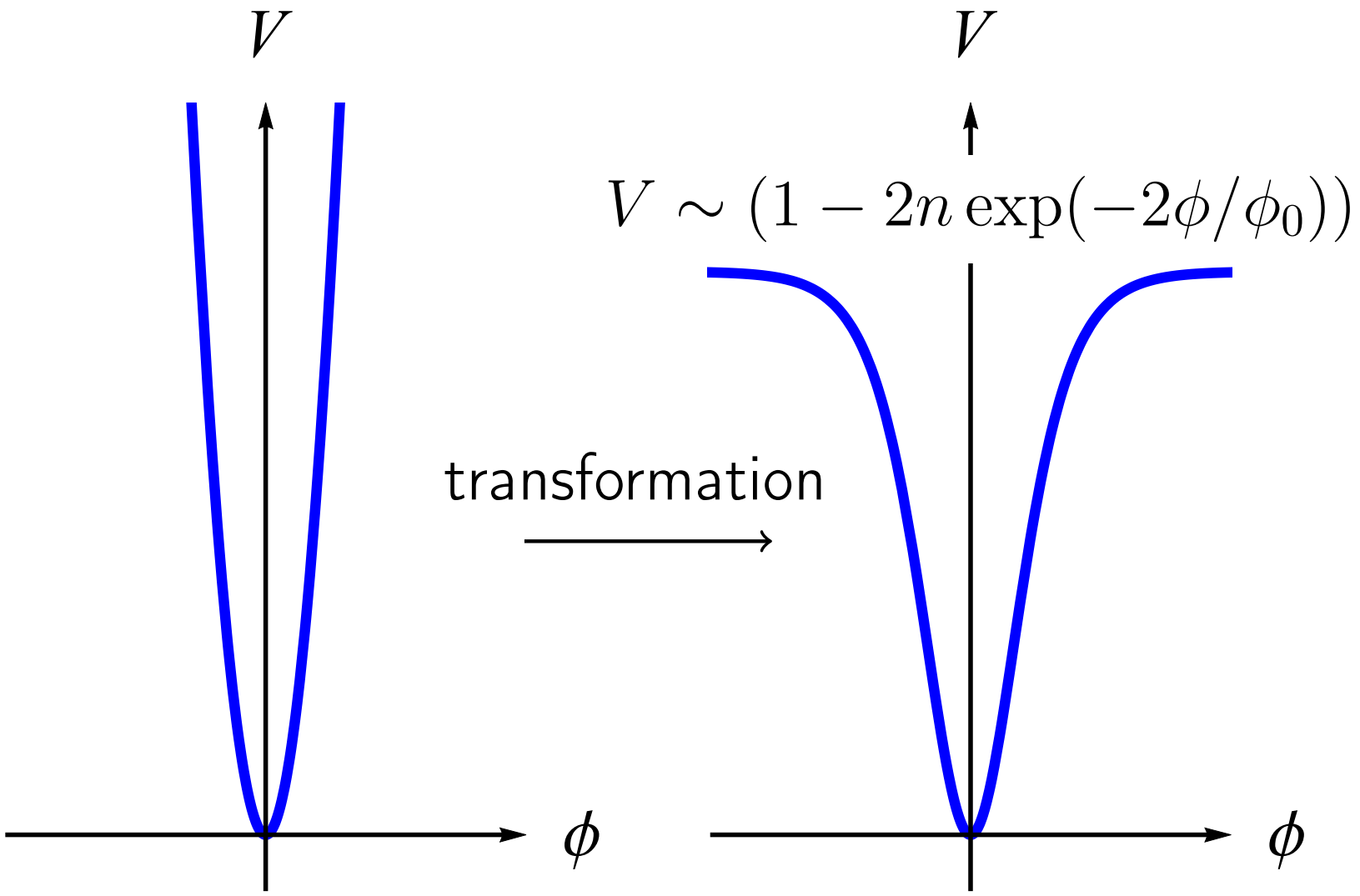

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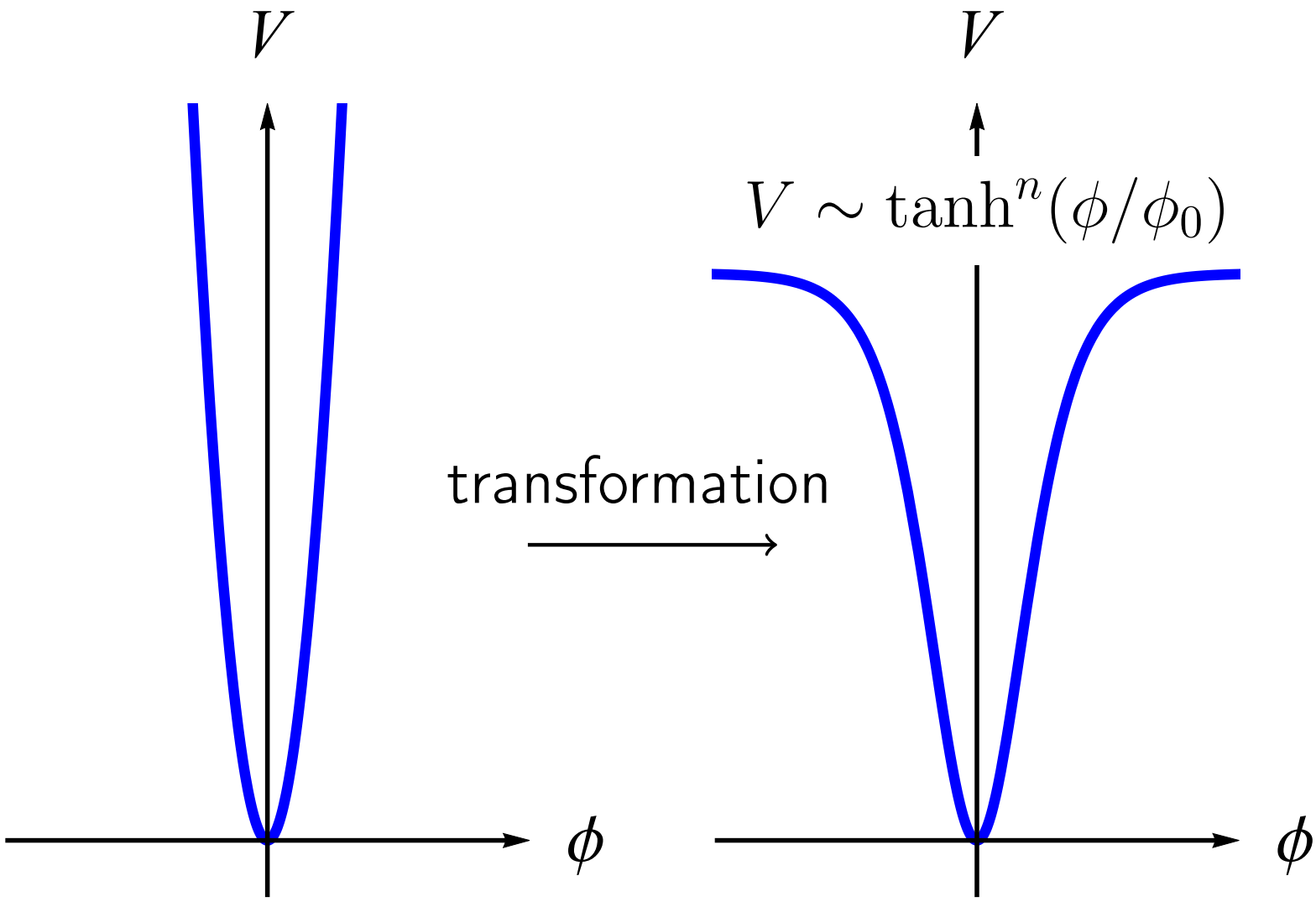
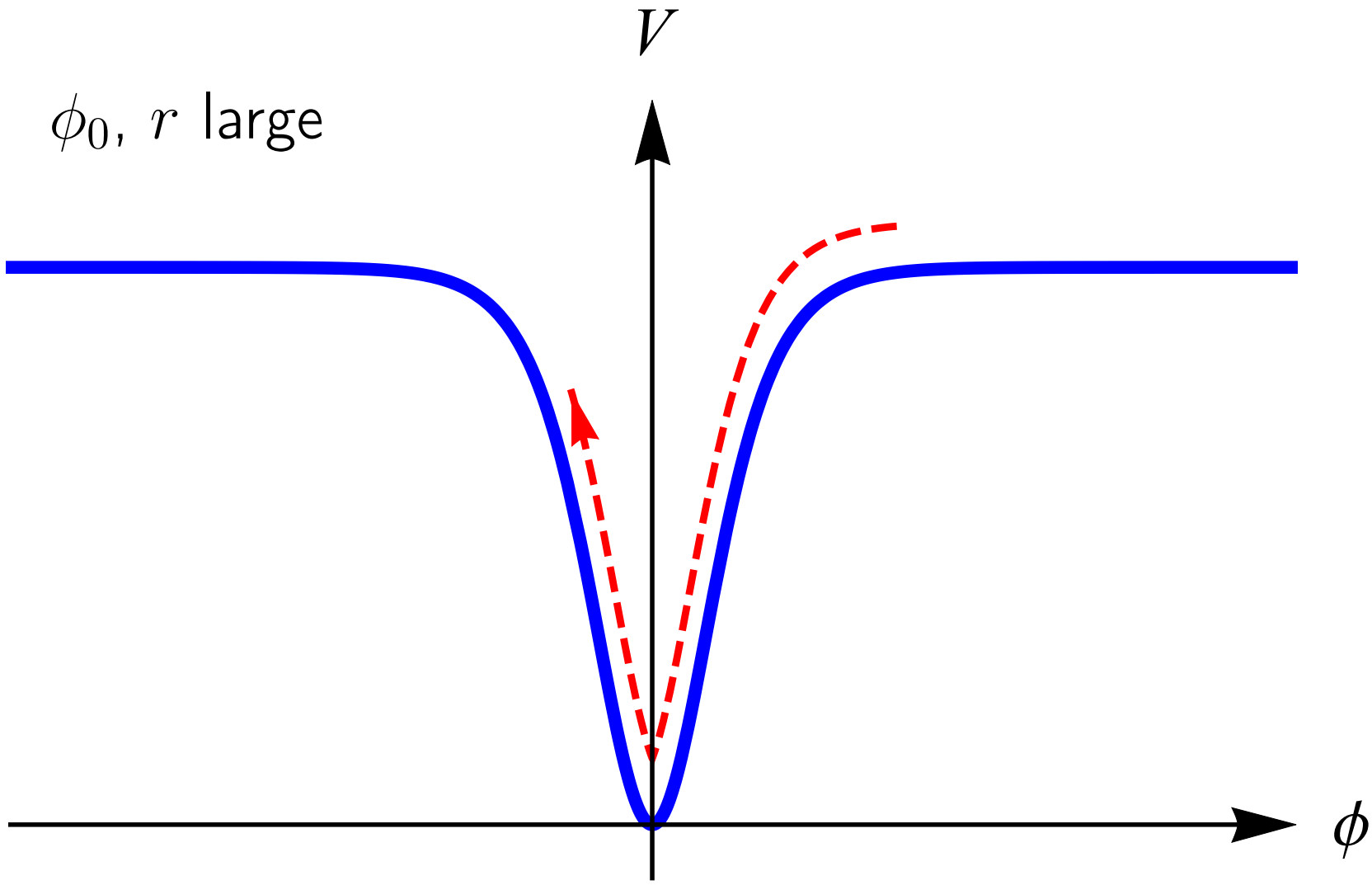


Plateau inflation: CMB

$$n_s = 1 - \frac{2}{N} \approx 0.96 \quad \text{[Planck: } 0.965\text{]}$$

$$r = \frac{2\phi_0^2}{N^2} \qquad \text{[Planck+BICEP: } < 0.036\text{]}$$

Oscillations



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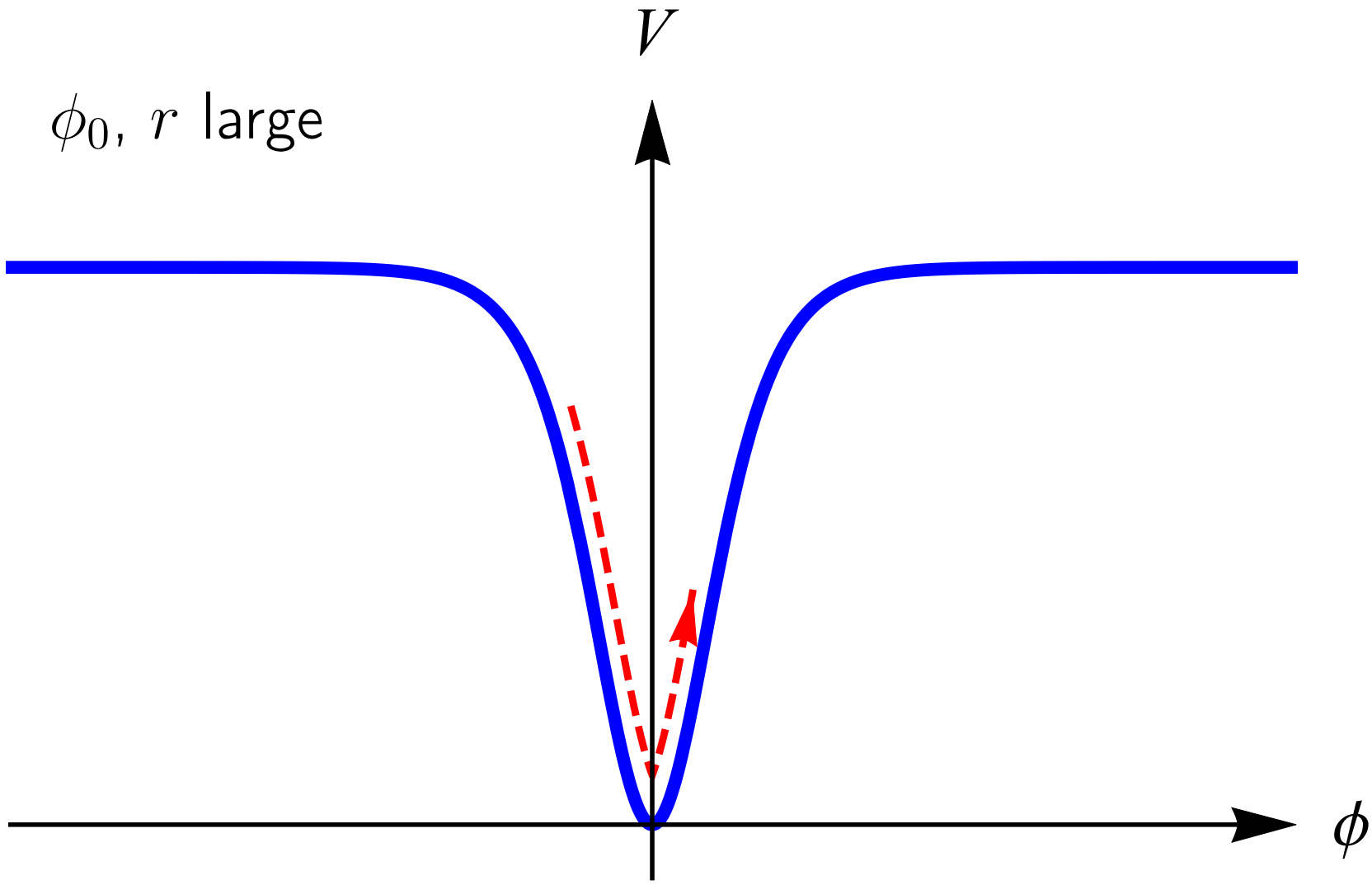

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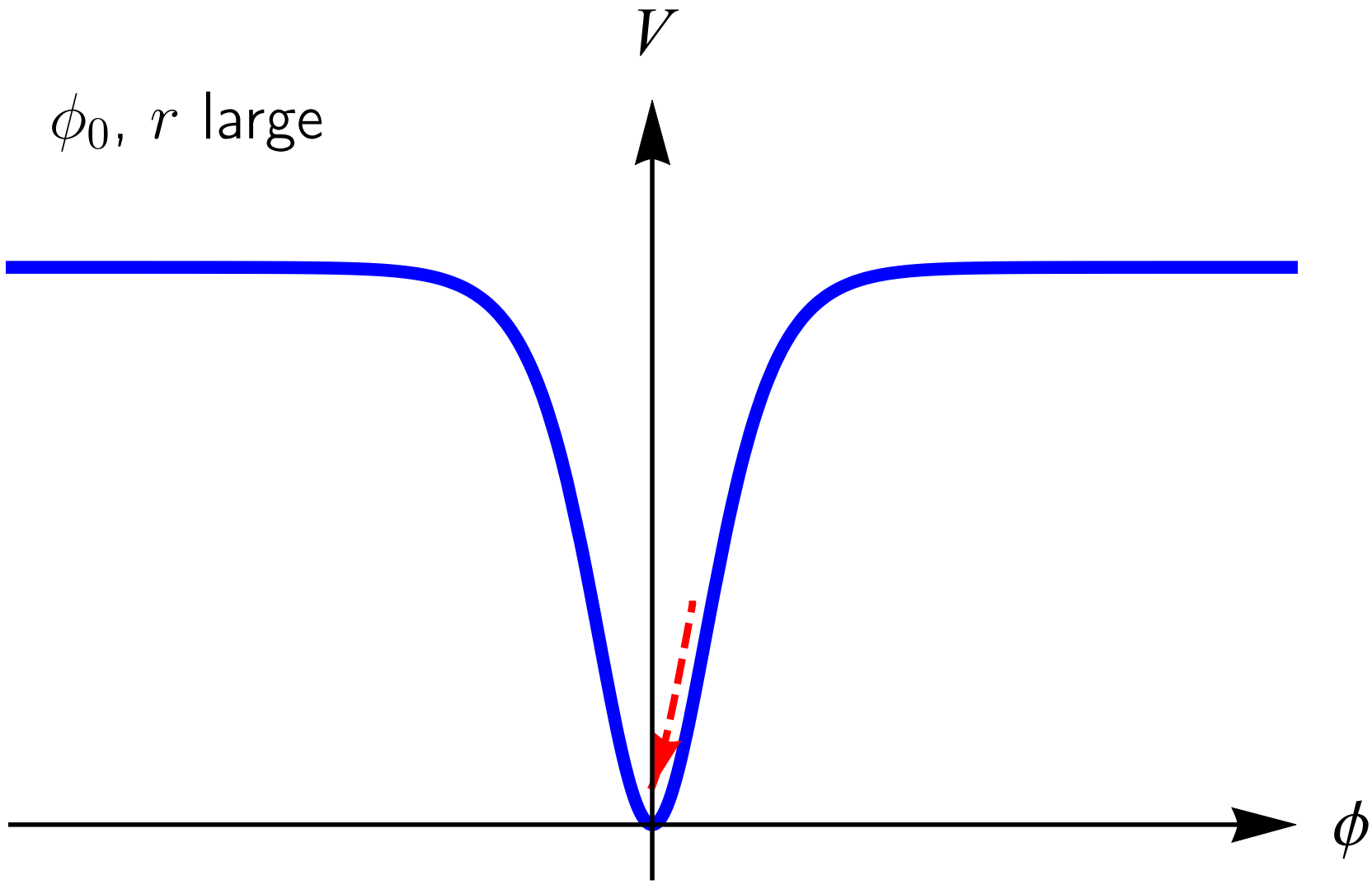

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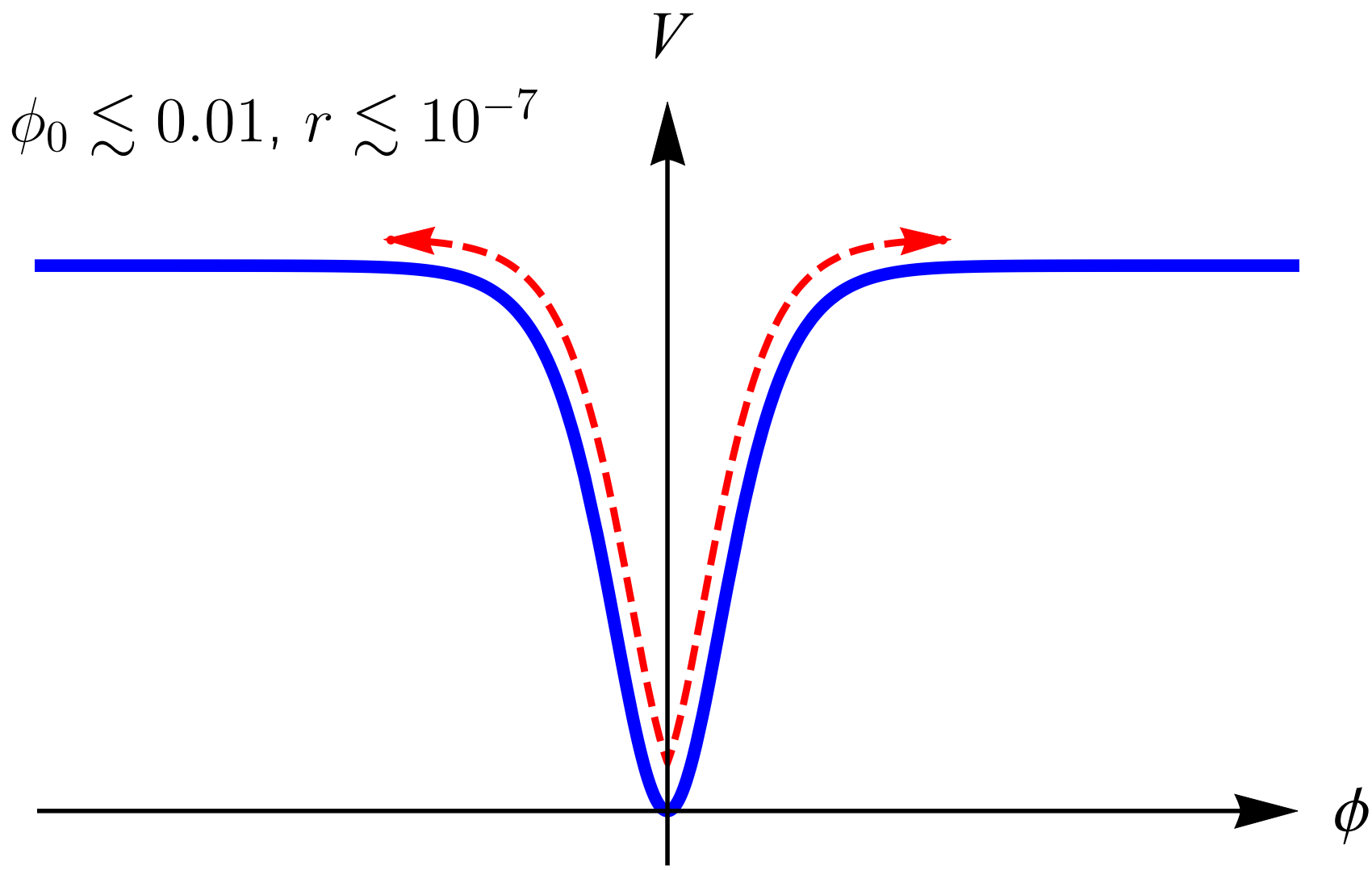

Solving the perturbations

Linear perturbation theory

- Fourier modes decouple
- Early evolution
- Parameter dependency
- Growth exponents: $\phi_k \propto e^{\mu_k t}$

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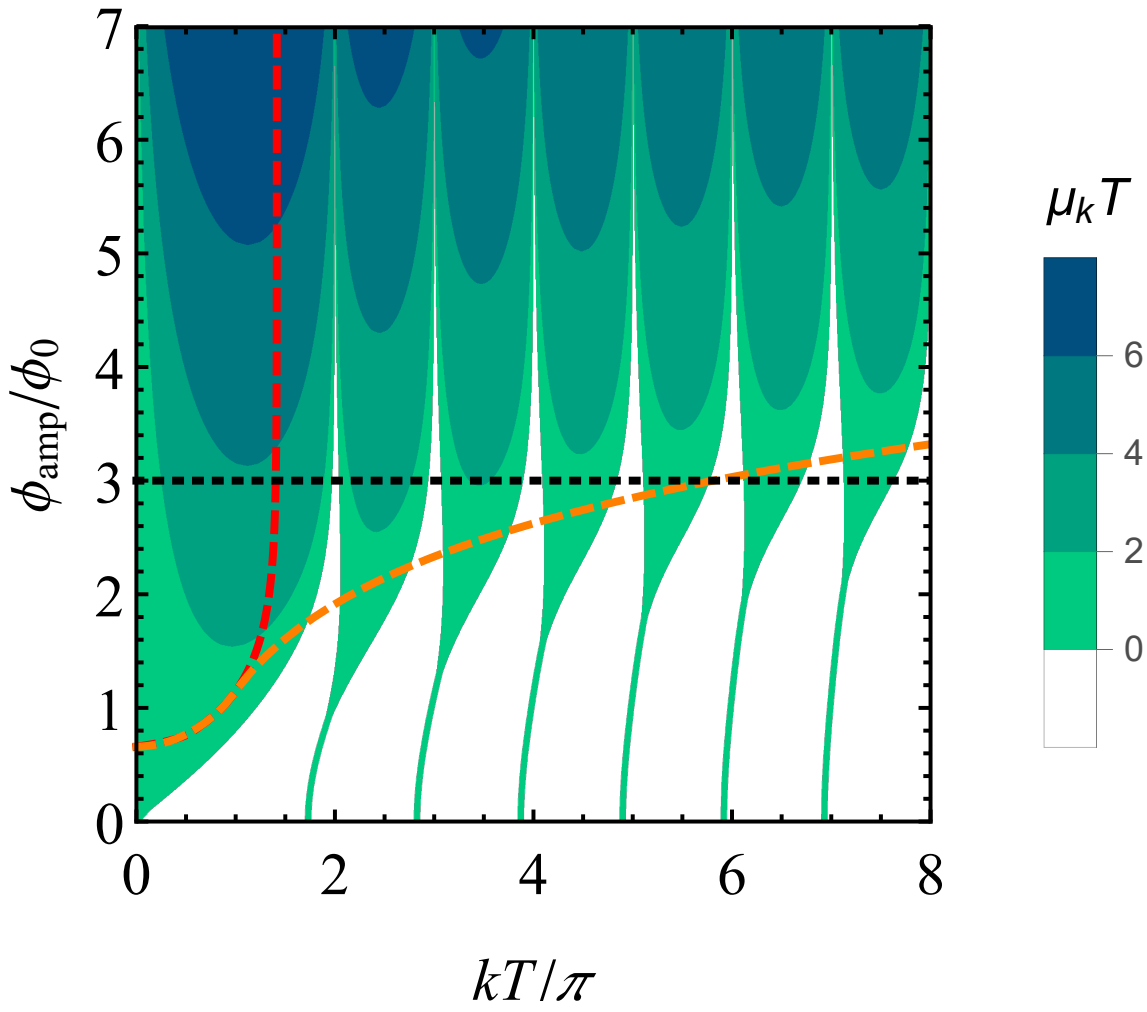


Phenomenology: n_s

To make accurate CMB predictions from a model, need number of e-folds N

In particular, $n_s \approx 1 - \frac{2}{N} \Rightarrow \Delta n_s \sim 10^{-3} \Delta N$

Tachyonic preheating: $\Delta N_{\mathsf{reh}} \ll 1$, 'instant preheating'

Phenomenology: GWs

Gravitational waves form at the characteristic scale $k \sim 1/T \sim m_{\rm th}\phi_0^{1/2}$, $m_{\rm th} \equiv \sqrt{U_0}/\phi_0 \approx 5 \times 10^{-6}$

Redshifted to today: for $\phi_0 \sim 10^{-4} \ldots 10^{-2}$, frequency 1–10 GHz

Phenomenology: supermassive DM?

A free massive scalar field can be produced on the side, also tachyonically [2007.03484]

Efficient production around $m \sim 10^{13}$ GeV

Beyond conventional models

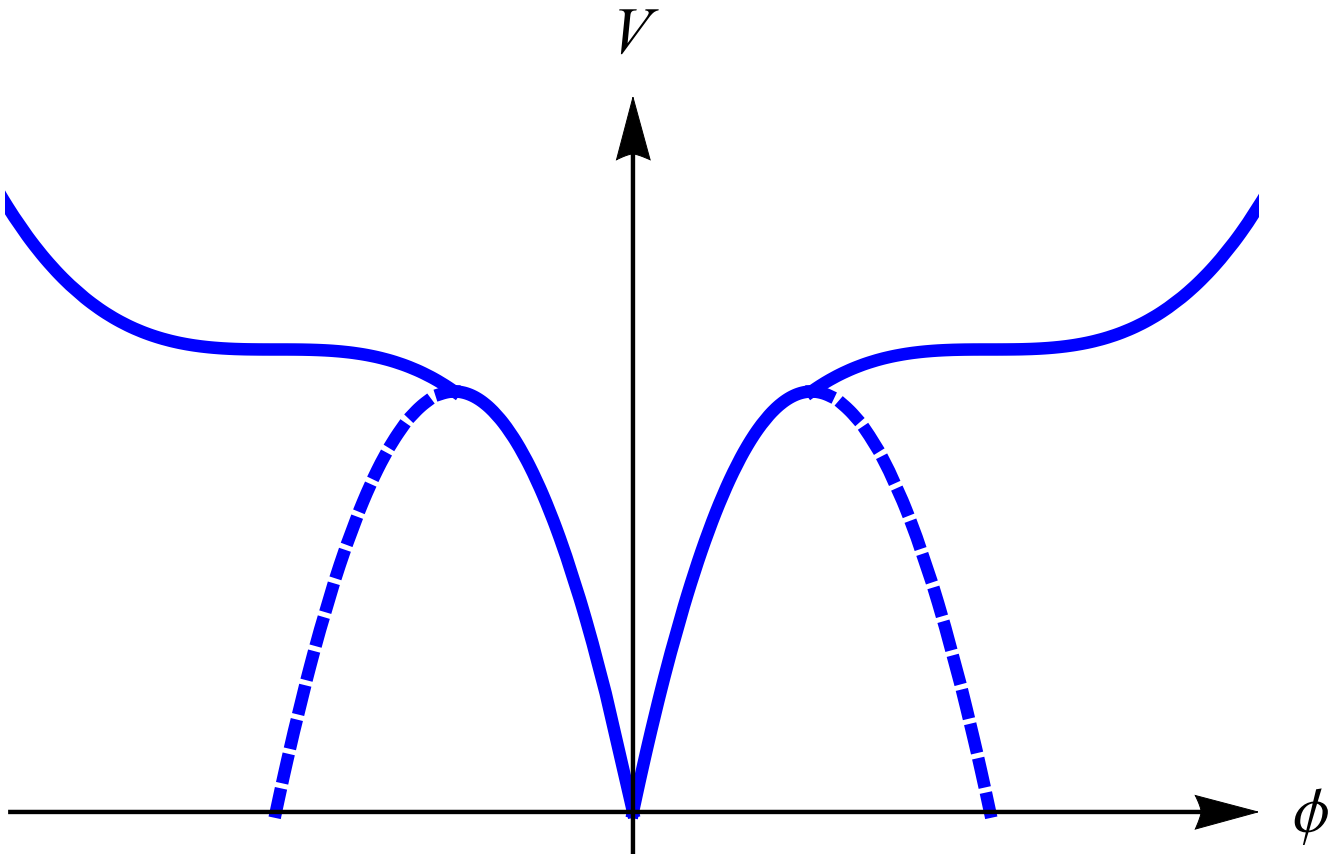
Until now: potential form of roughly $U_0 \tanh^n(\phi/\phi_0)$ was assumed

- Valid for all conventional models
- Strength of CMB perturbations sets $m_{\rm th} \equiv \sqrt{U_0}/\phi_0 \approx 5 \times 10^{-6}$

If relaxed, can decouple plateau inflation and preheating: a wider range of signals possible

In general: effective preheating $\Leftrightarrow$ sub-Planckian field excursions

Beyond conventional models



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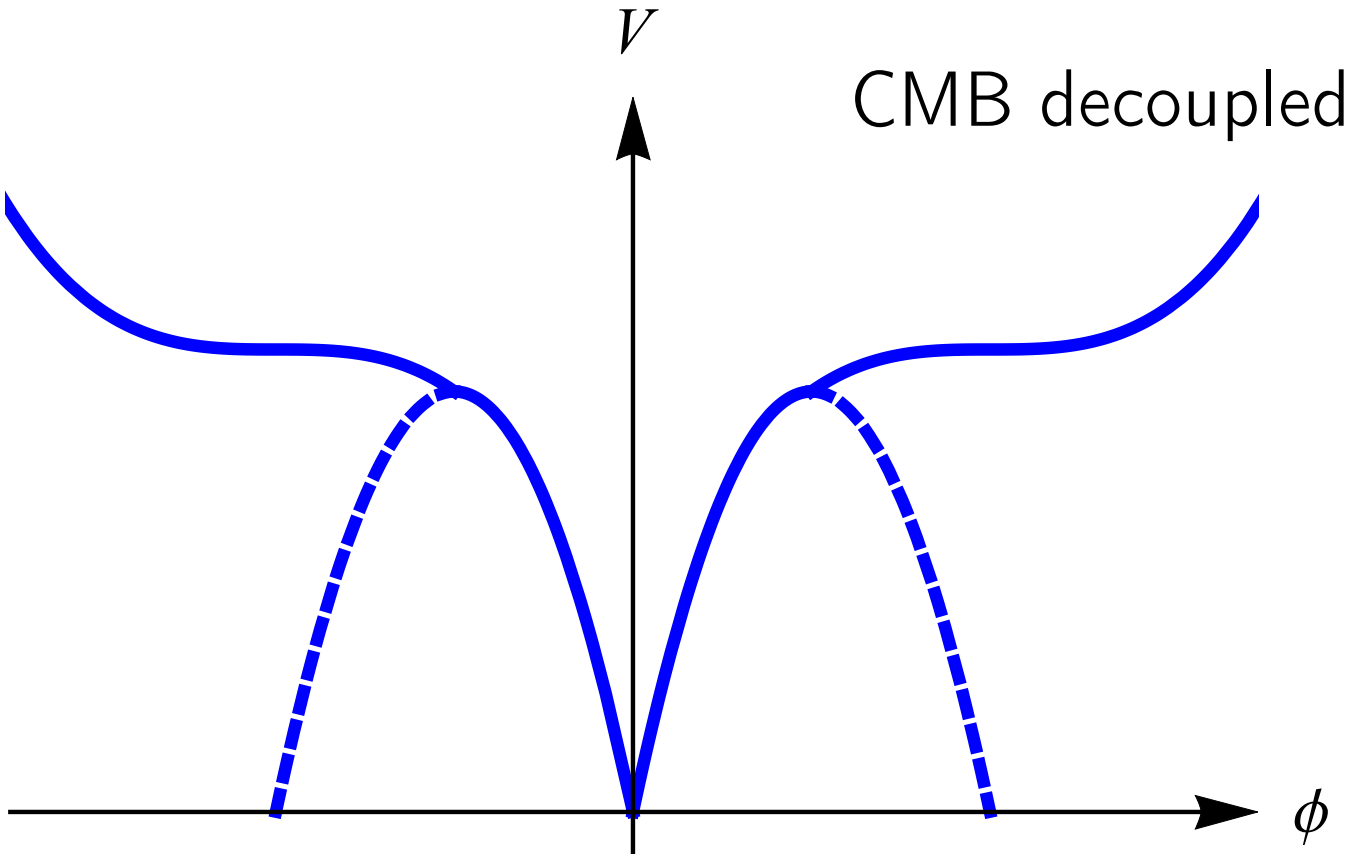

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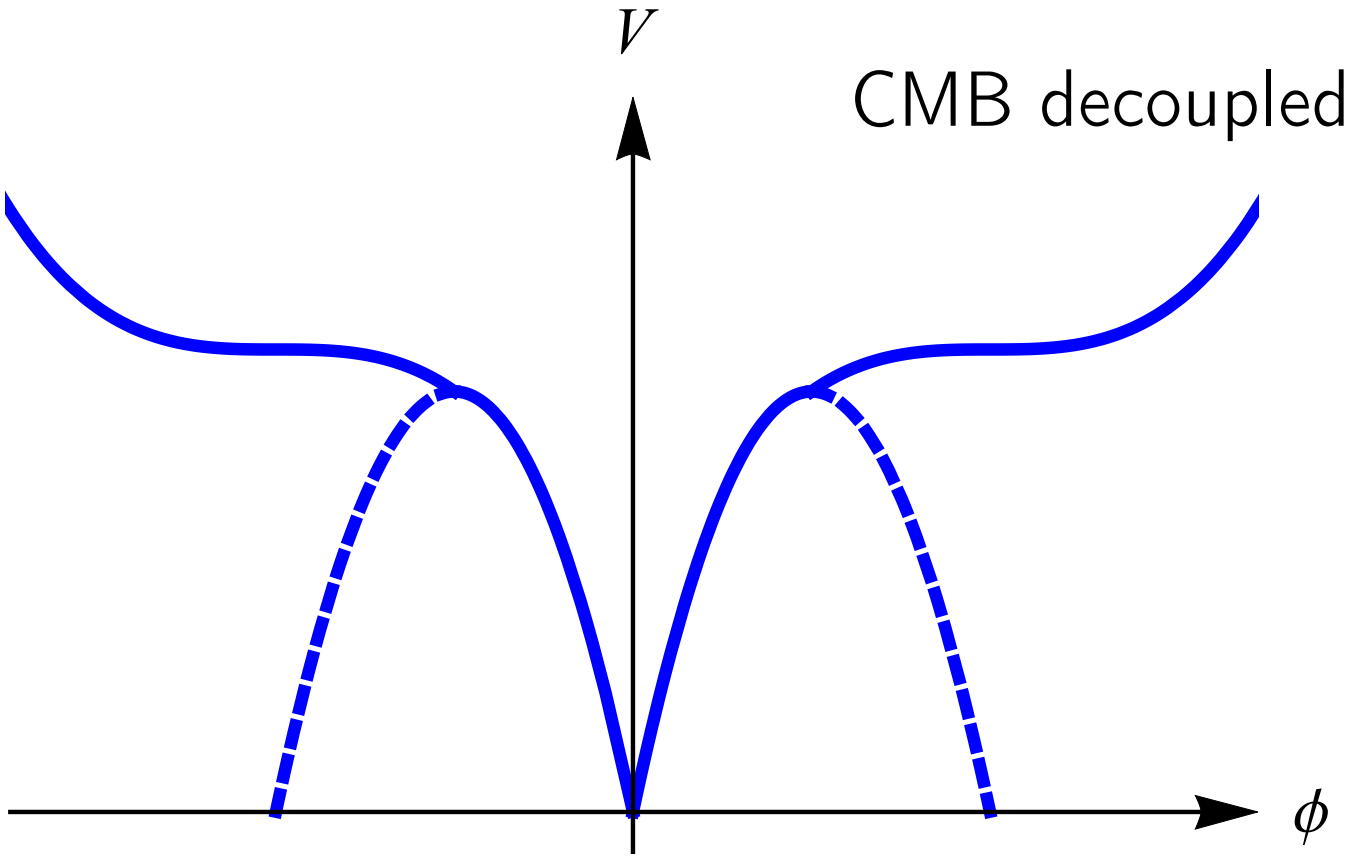

Tachyonic preheating: $\Delta\phi \ll 1$

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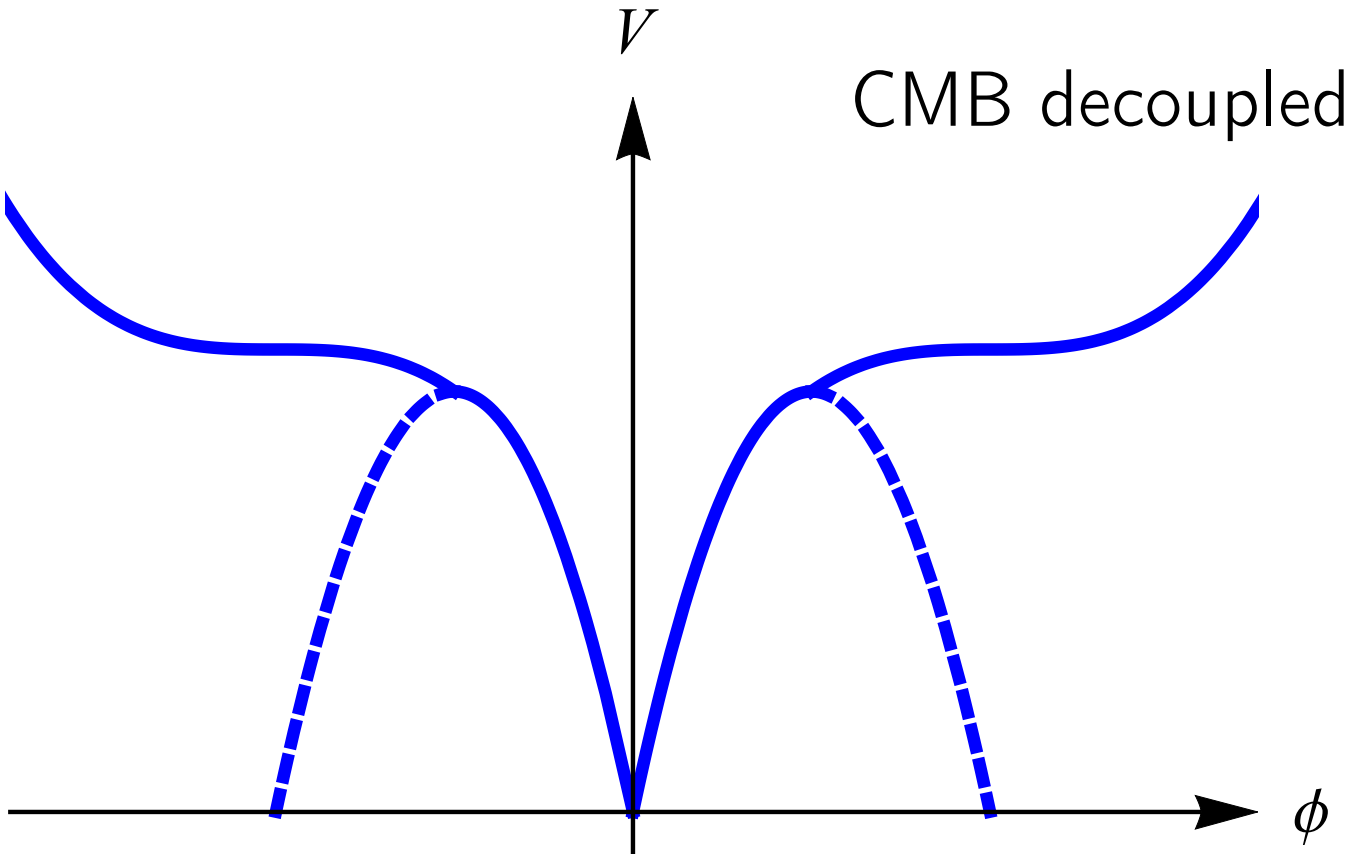

Tachyonic preheating: $\Delta\phi \ll 1$

$f_{\mathsf{GW}} \gg 5 \times 10^{-7}\mathsf{Hz} \times [T_{\mathsf{reh}}/\mathsf{GeV}]$

Unit conversions

See arXiv:[2110.12251]

```
In:  << "NaturalUnits.m";
In:  NaturalUnitsSetup[NewUnitSystem -> CosmologyUnits,
     NewNatUnits -> {eV}];

In:  NaturalConvert[5*10^-6 MP*2.7 K/(10^15 GeV), Hz]
Out: 4.30435*10^9 Hz
```

Summary

In Plateau inflation, tachyonic preheating occurs for (highly) sub-Planckian field excursions, $r \lesssim 10^{-7}$

Affects CMB predictions

Possibility for the production of strong GWs and super-heavy DM