Quintessential inflation: origin and tests

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based on on D. Bettoni, G. Domènech and J.Rubio, JCAP 1902 (2019) 034 (arXiv:1810.11117)

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1st message: Origin

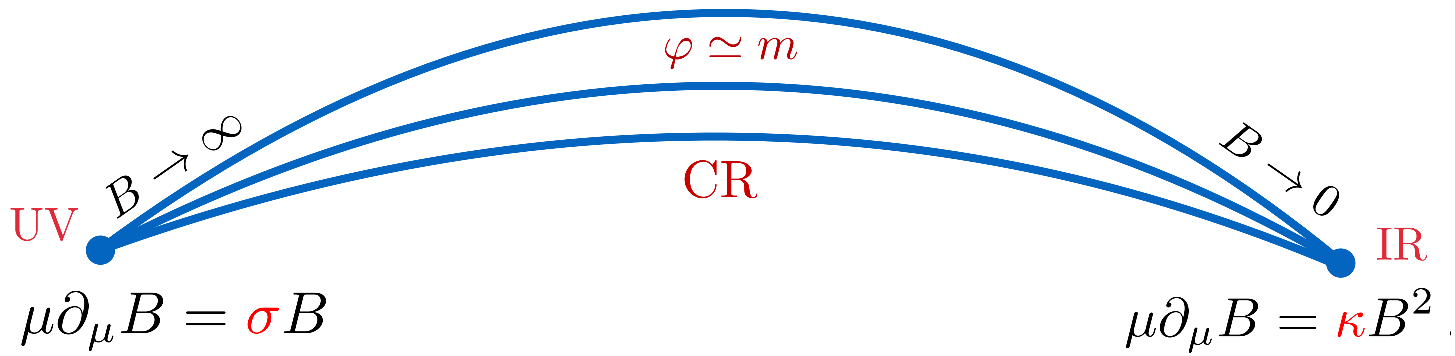
Inflation and dark energy may be the consequence of the emergence scale symmetry at non-trivial fixed points

see, for instance, J.Rubio, C. Wetterich, Phys.Rev. D96 (2017) no.6, 063509 (arXiv:1705.00552)

Inflation/DE from scale symmetry

All dimensionless couplings and masses in the theory are allowed to depend on the expectation value of a scalar field χ

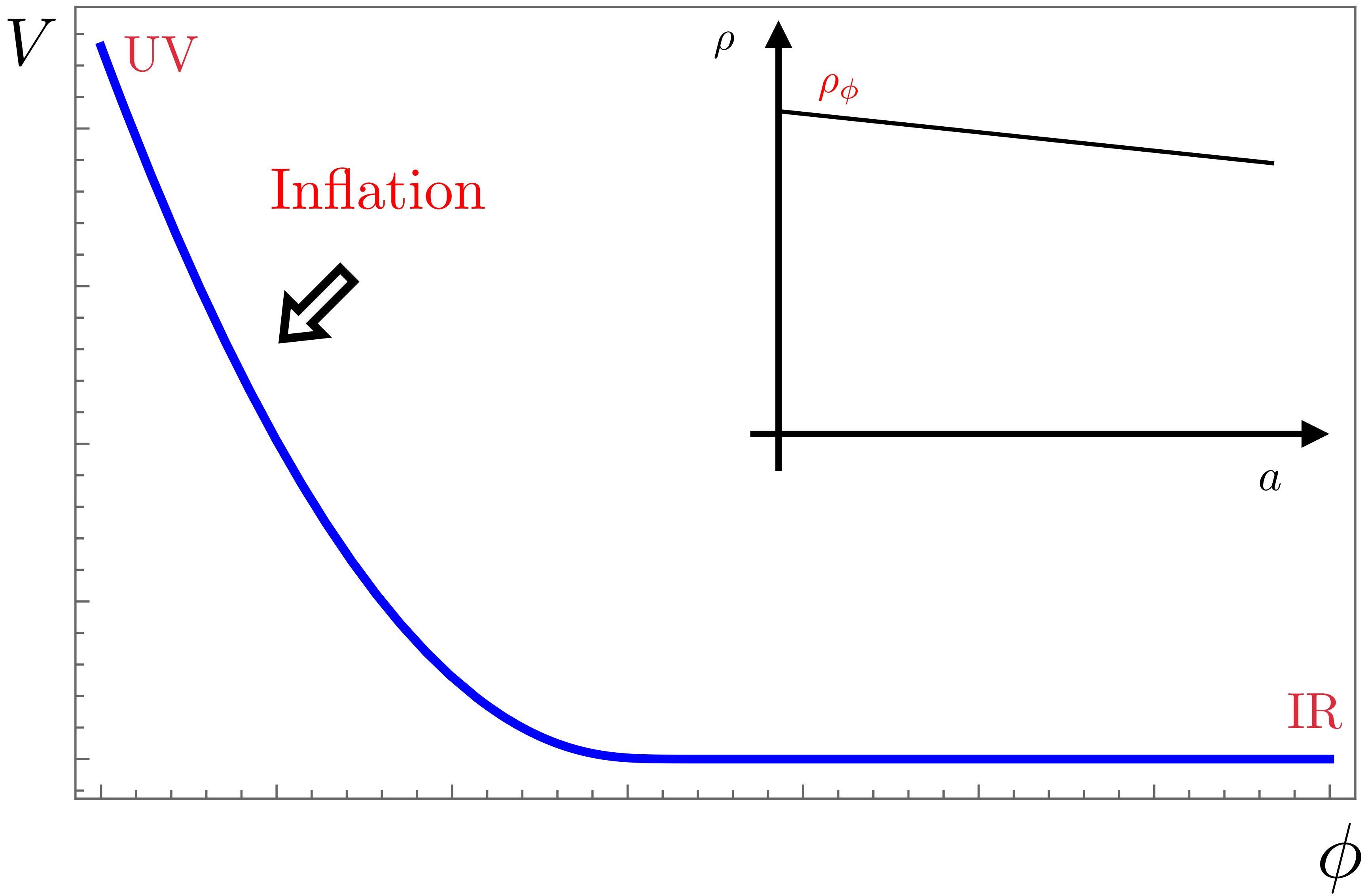
$$\frac{\mathcal{L}}{\sqrt{-g}} = \frac{\varphi^2}{2} R - \frac{B(\varphi/\mu) - 6}{2} (\partial\varphi)^2 - \mu^2\varphi^2$$



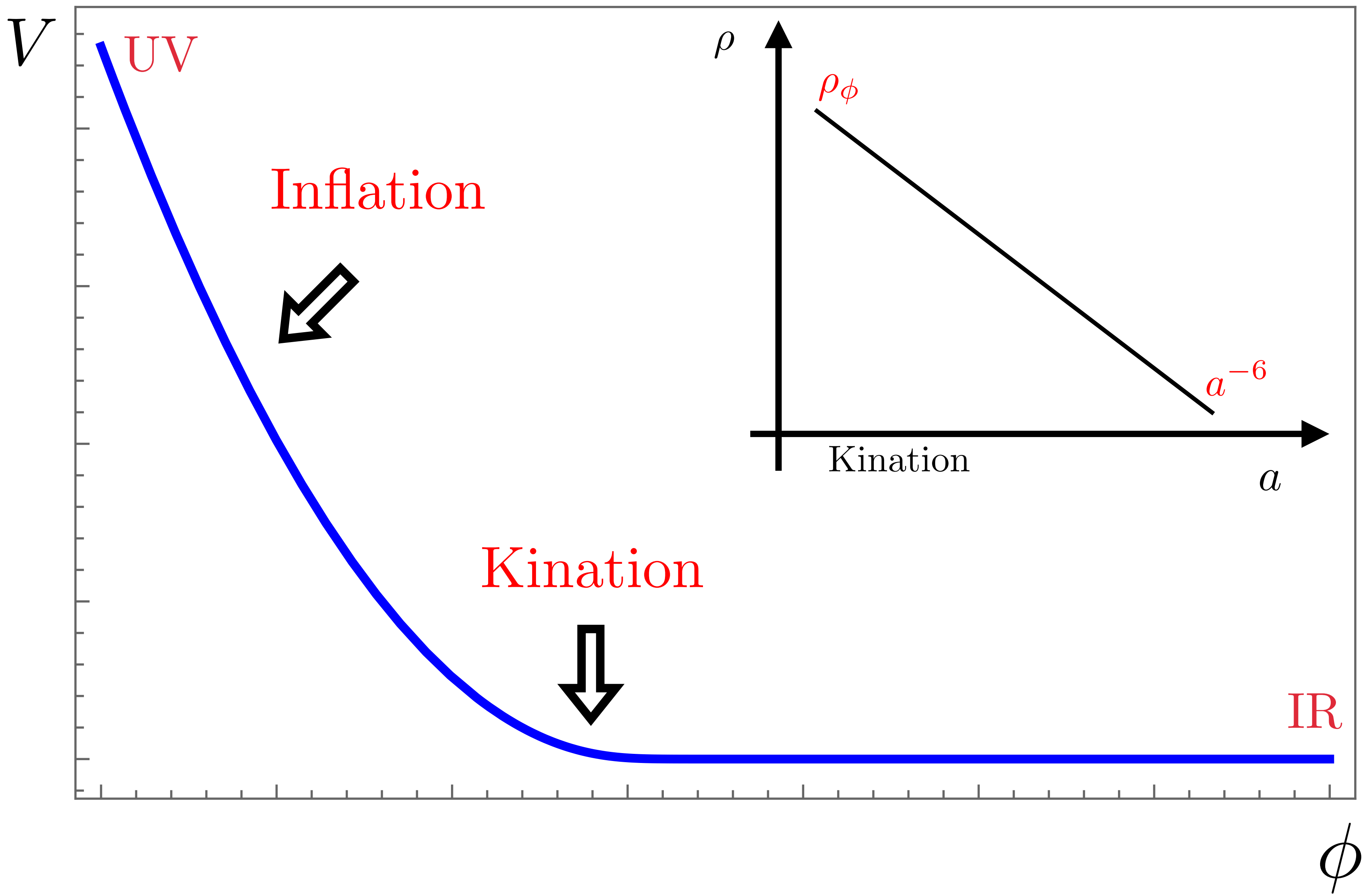
μ has no intrinsic meaning and can be used to set the mass/time scales

$$\mu^{-1} = 10^{10}\,\mathrm{yr} = 1.2 \times 10^{60}\, M_P^{-1}$$

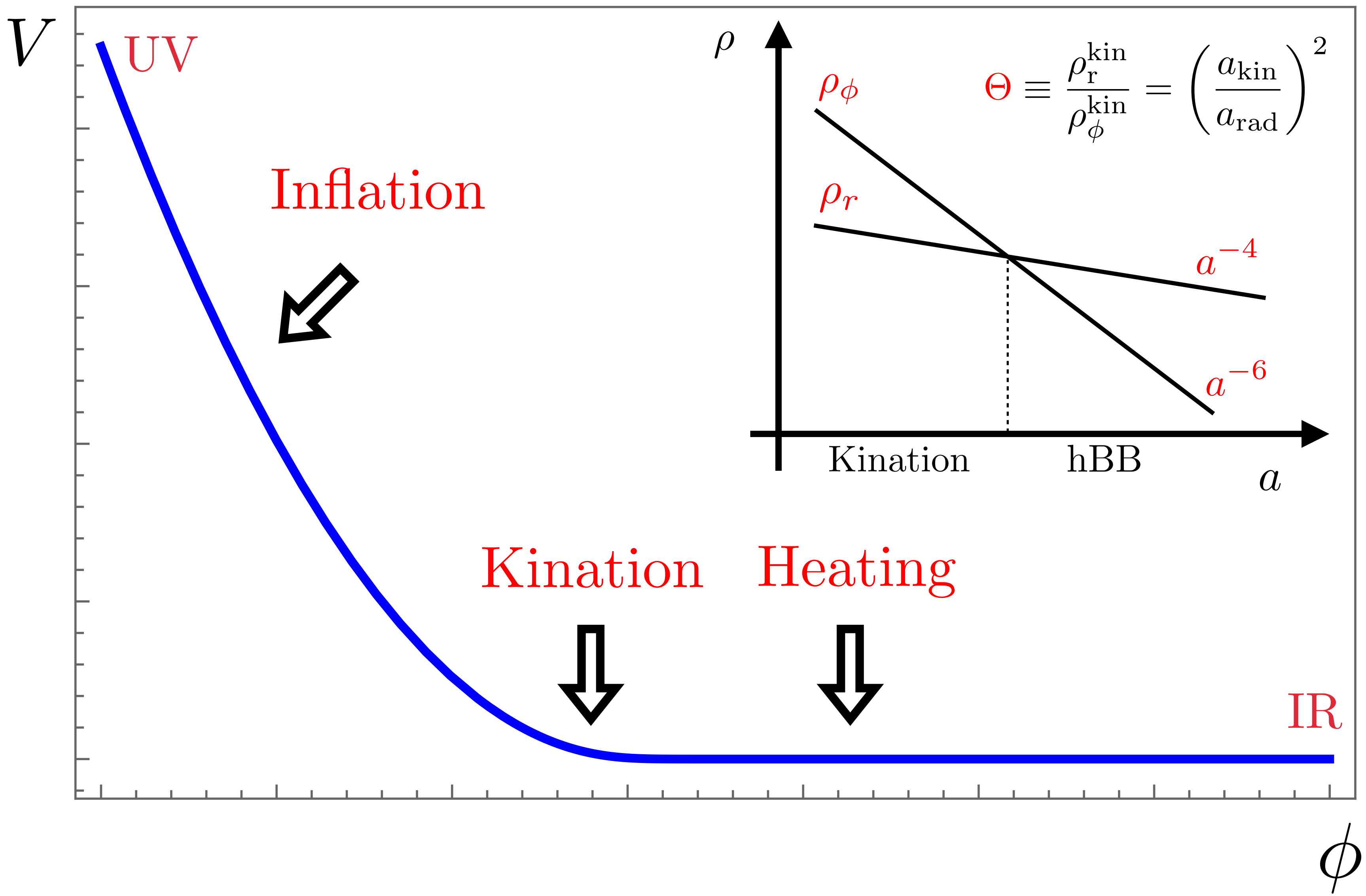
Quintessential inflation



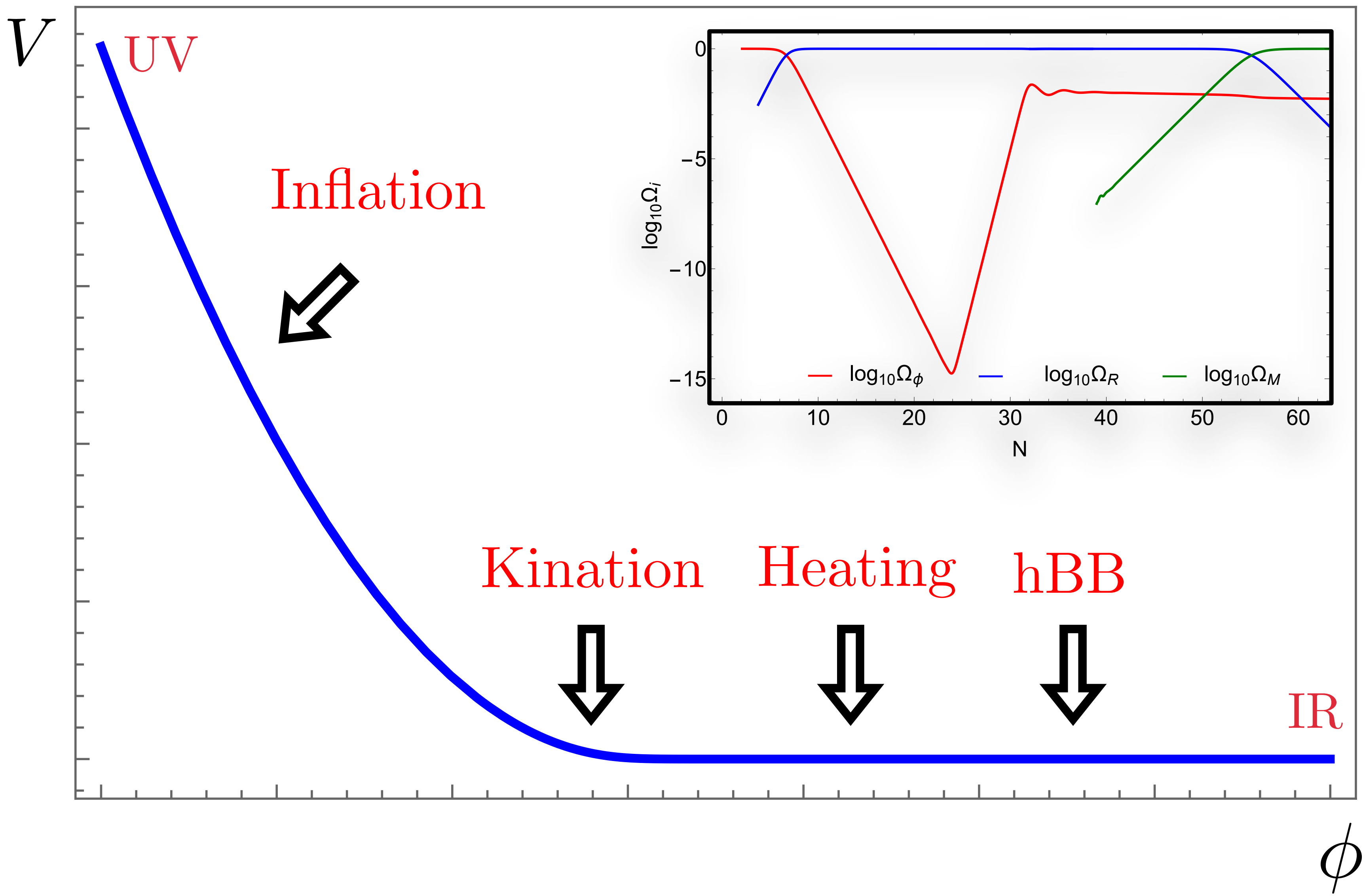
Entering the crossover



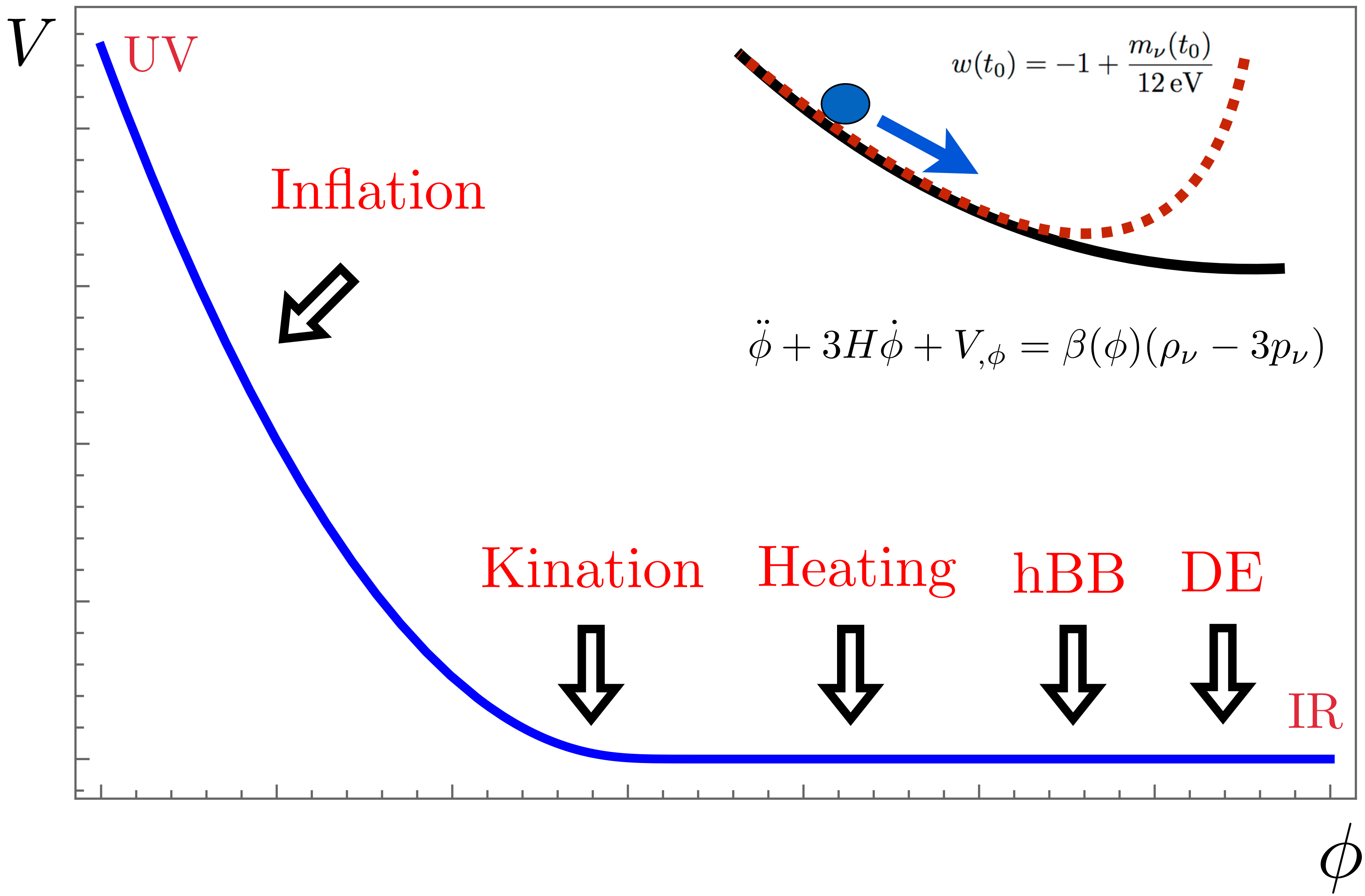
Heating the Universe



The hot Big Bang era



Approaching the IR



2nd message: Tests

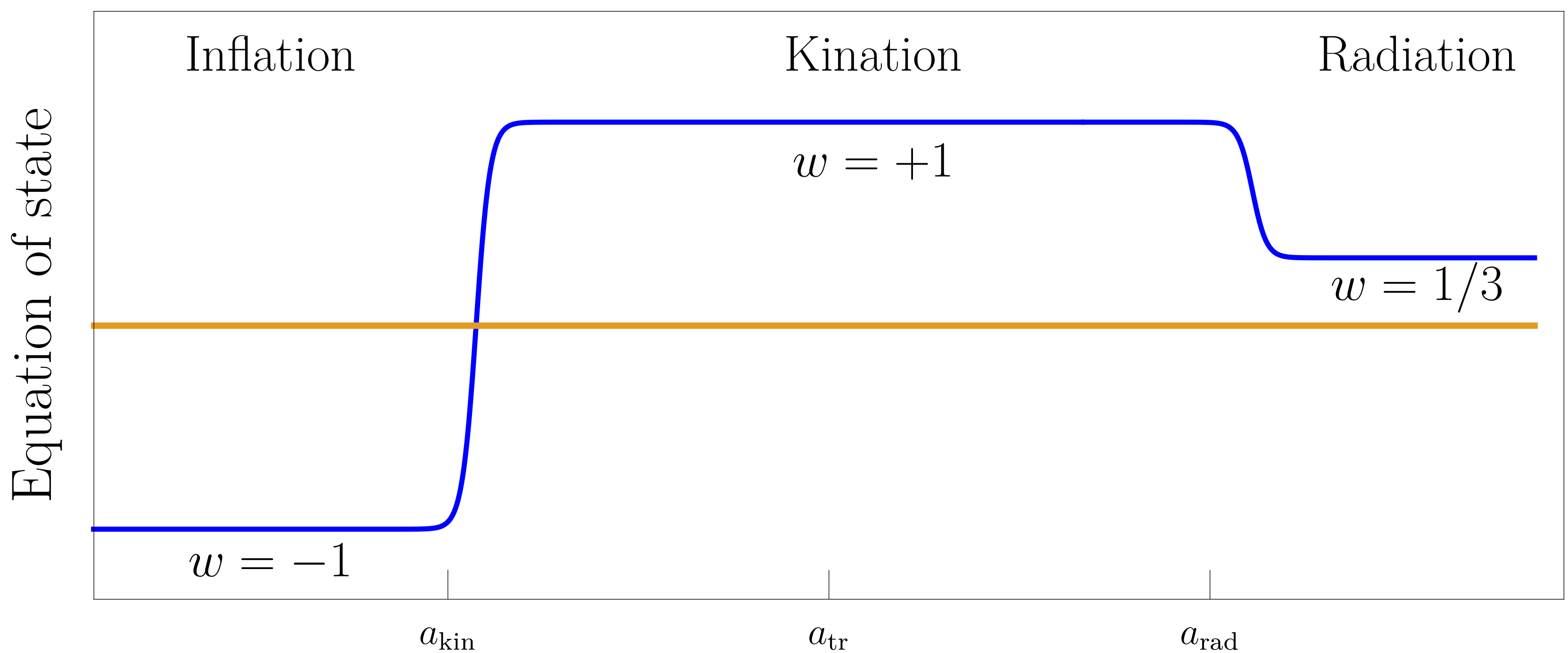
The end of inflation can trigger the spontaneous symmetry breaking of internal symmetries

D. Bettoni, G. Domènech and J.Rubio, JCAP 1902 (2019) 034 (arXiv:1810.11117)

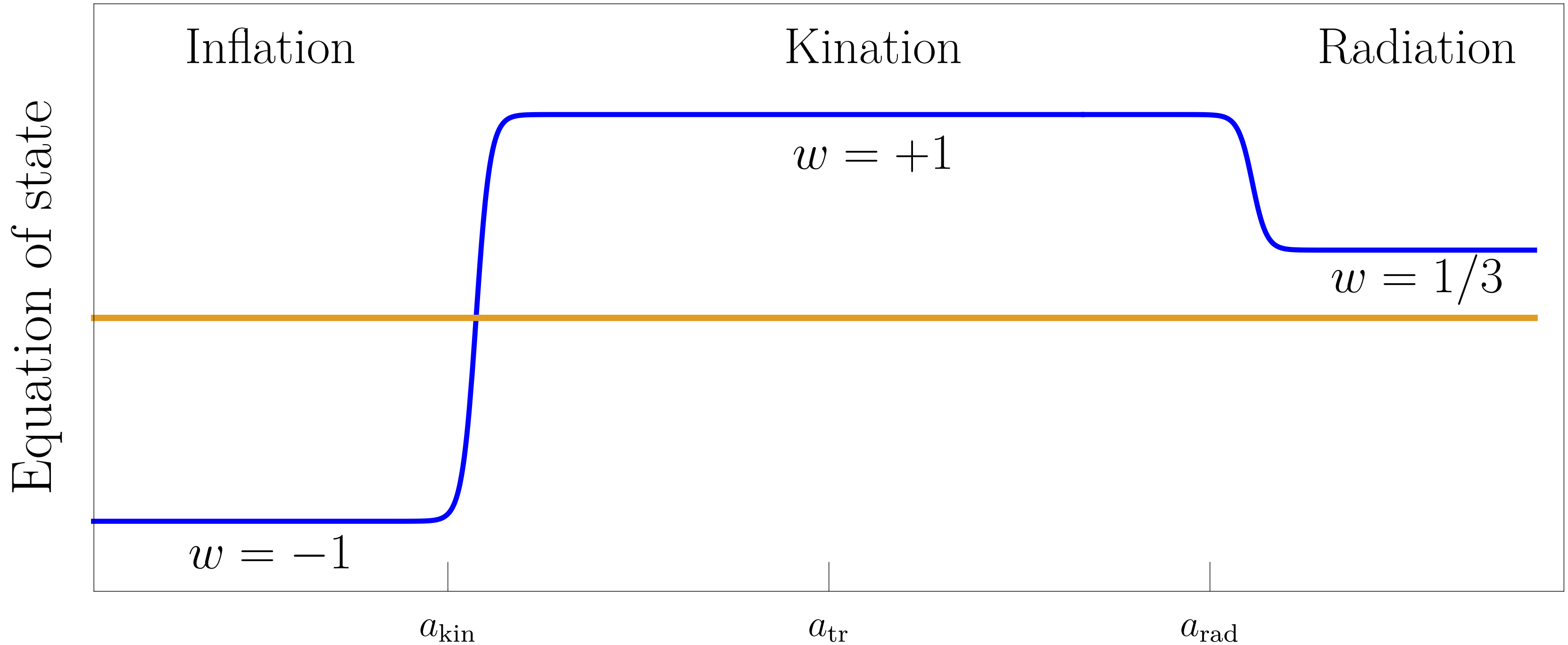
Non-minimally U(1) spectator

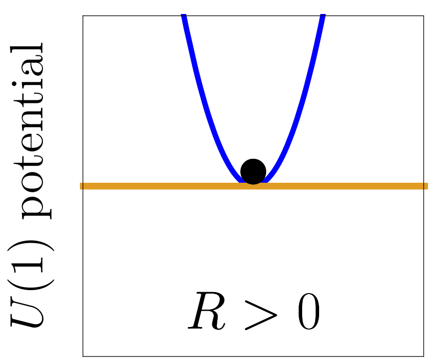
$$\frac{\mathcal{L}}{\sqrt{-g}} = -\partial_\mu \chi^\dagger \partial^\mu \chi - \xi R \, \chi^\dagger \chi - \lambda \left(\chi^\dagger \chi\right)^2$$

$$R = 3H^2(1-3w)$$



Spectator field dynamics

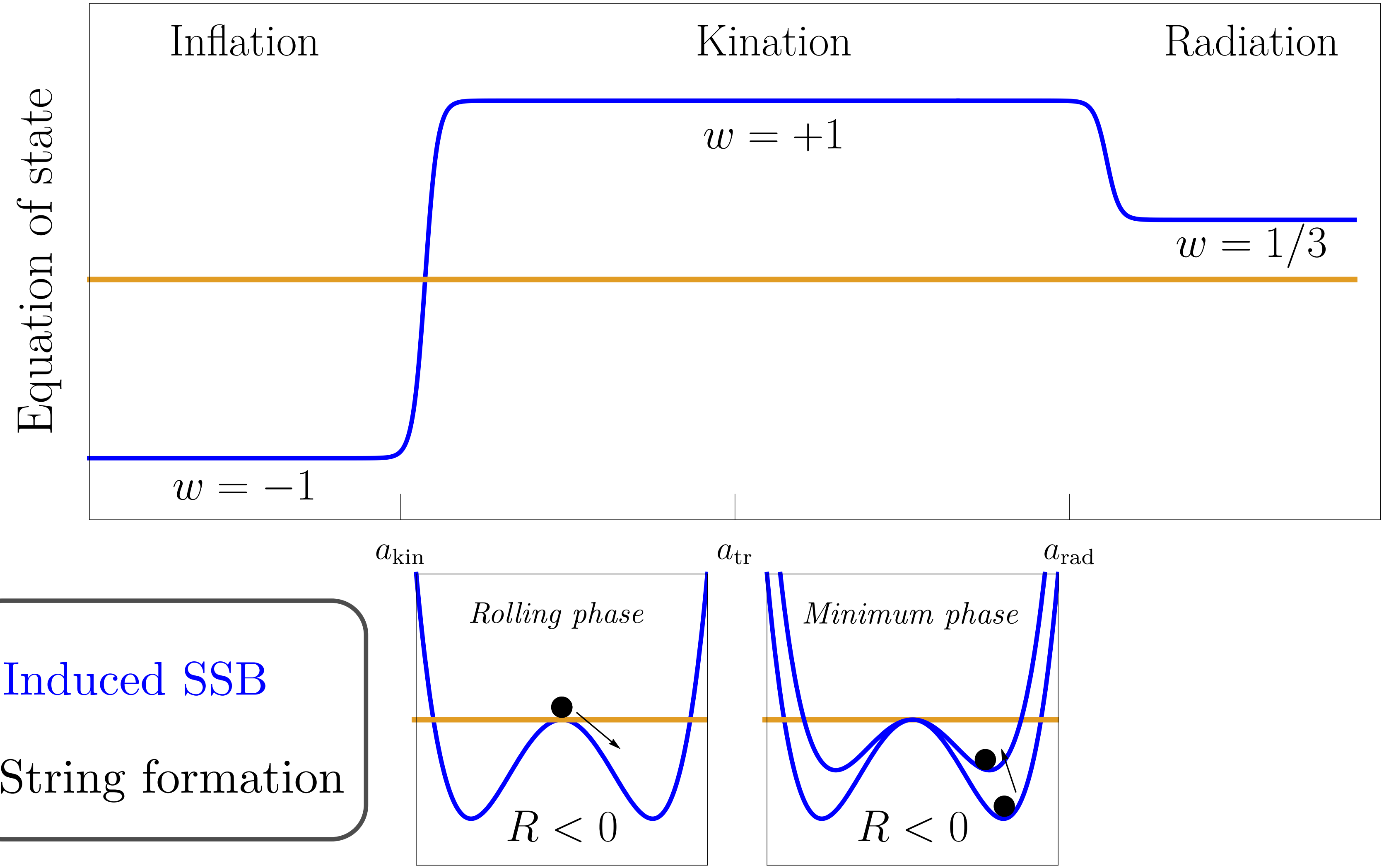




ξ renders field field heavy

No isocurvature perturbations

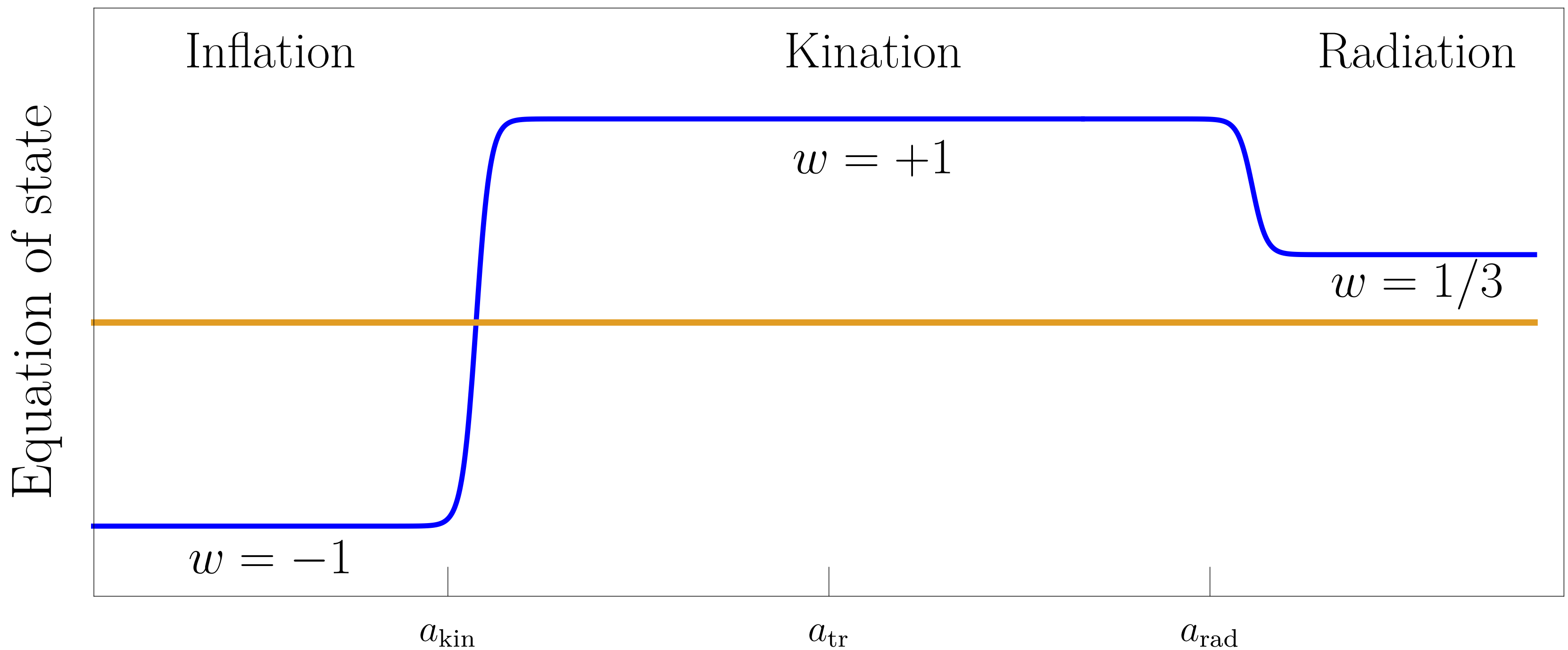
Spectator field dynamics



Induced SSB

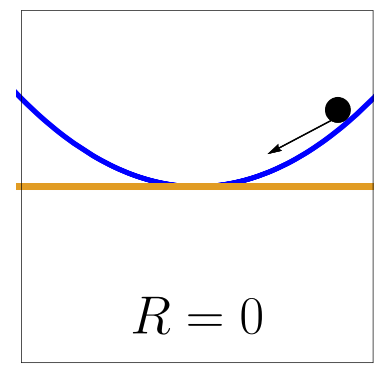
String formation

Spectator field dynamics

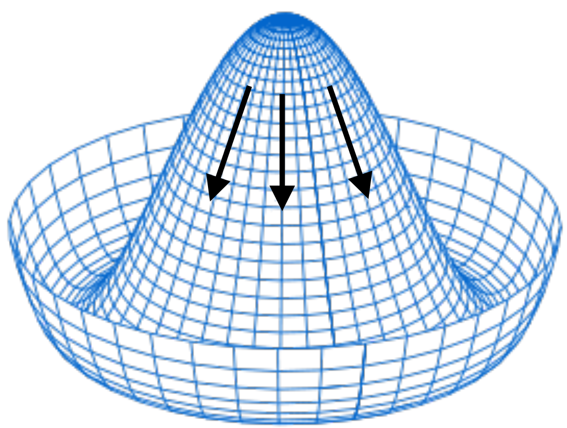


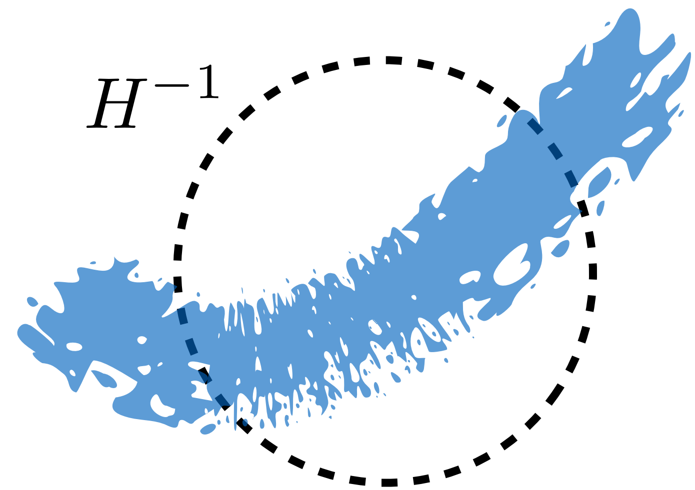
U(1) symmetry is restored

Strings decay



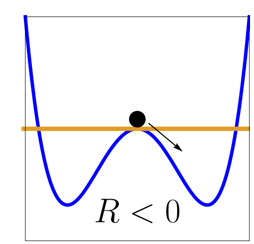
Cosmic strings' properties

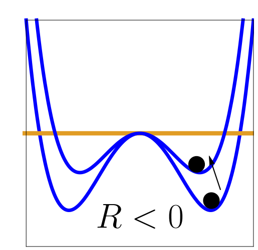




- Fat
- Isolated
- Non-scaling
- Short-lived

$$\Omega_{\rm cs} \sim \frac{|\chi(t)|^2}{M_{\rm P}^2} \begin{cases} |\chi| \propto a^{\sqrt{6\xi}} \\ \\ |\chi| \propto a^{-\frac{6}{n-2}} \end{cases}$$





Integrated spectrum

$$\Omega_{\rm GW}(\tau, k) = \int_{\tau_{\rm i}}^{\tau} d\log\tau' \, \frac{\Delta P_{\rm GW}(\tau', k)}{\Delta\log\tau'} \left(\frac{a(\tau')}{a(\tau)}\right)^{b}$$

Instantaneous spectrum

$$\frac{\Delta P_{\rm GW}(t,k)}{\Delta N} \simeq \begin{cases} P_{\rm peak}(t)\left(\frac{k}{k_{\rm peak}(t)}\right)^{\alpha} & \text{for} \quad k \lesssim k_{\rm peak} \\ P_{\rm peak}(t)\left(\frac{k}{k_{\rm peak}(t)}\right)^{-\bar{\alpha}} & \text{for} \quad k > k_{\rm peak} \end{cases}$$

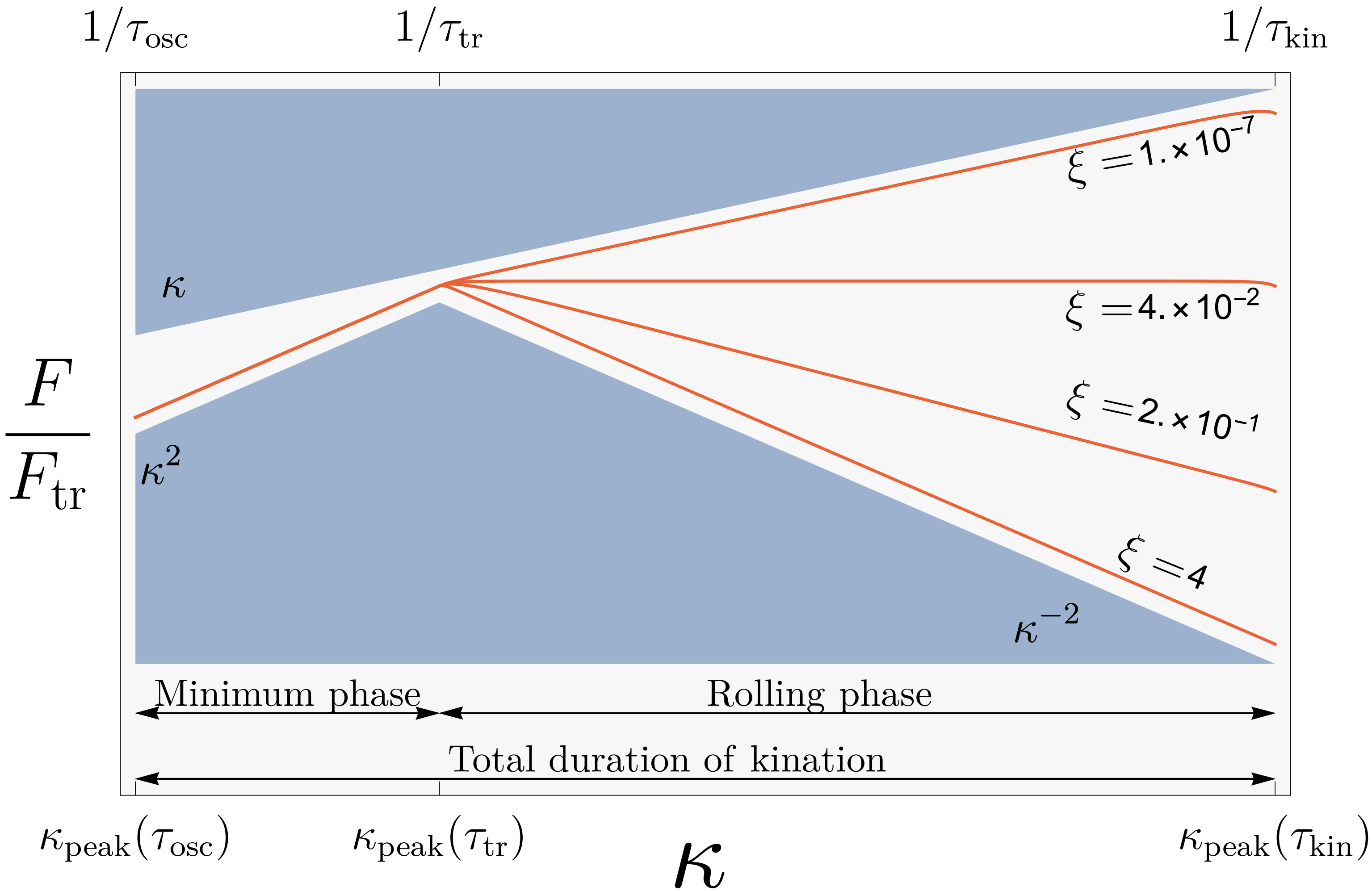
$$\text{with} \qquad k_{\rm peak}(t) \sim aH \qquad P_{\rm peak}(t) \sim \left(\frac{|\chi(t)|}{M_{\rm P}}\right)^{4}$$

Enhancement due to background evolution

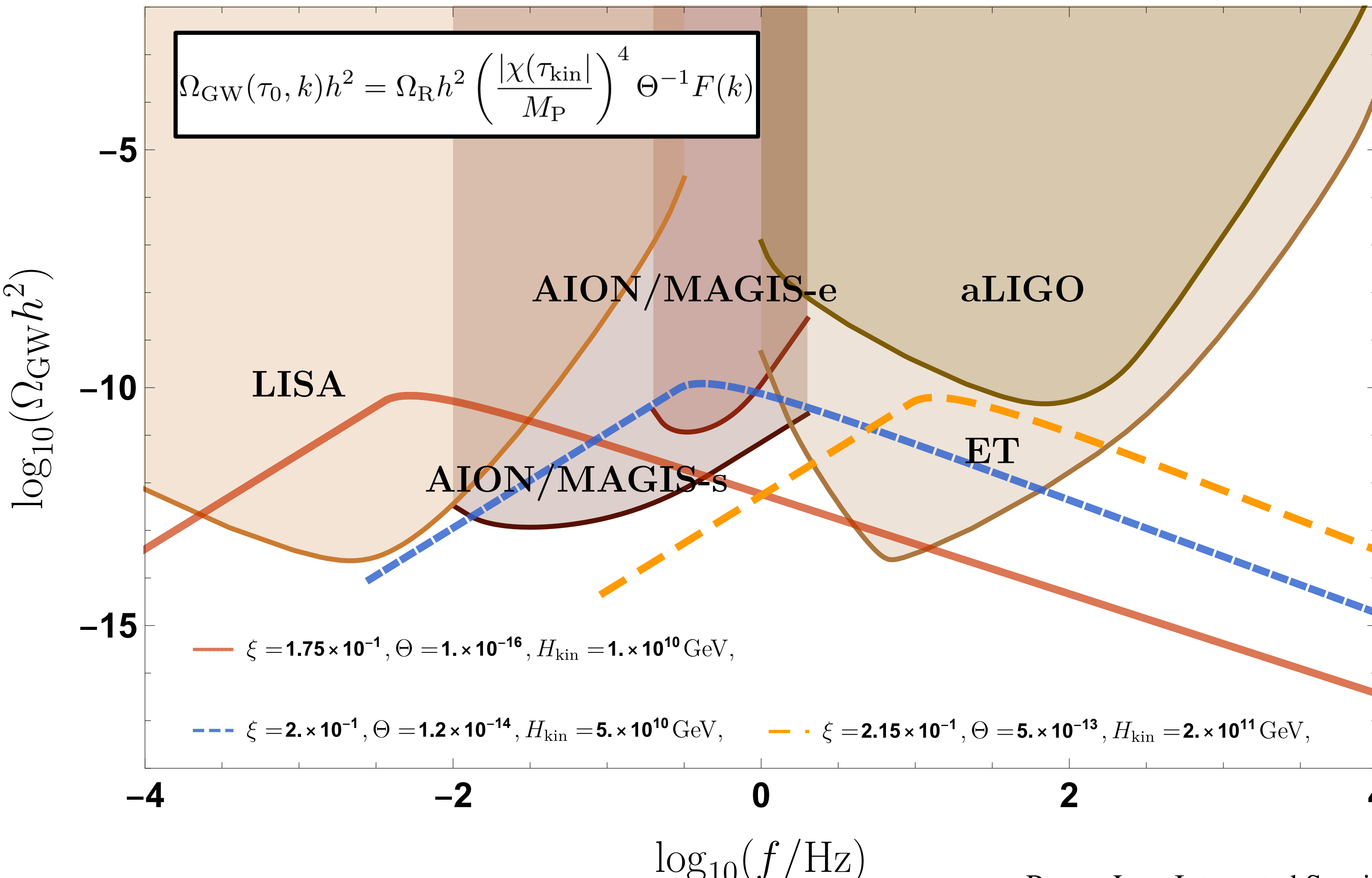
$$\rho_{\rm GW} \sim a^{-4} \qquad \rho_{\phi} \sim a^{-6}$$

Parameter dependence

$$\Omega_{\rm GW}(\tau_0,k)h^2 = \Omega_{\rm R}h^2\left(\frac{|\chi(\tau_{\rm kin}|}{M_{\rm P}}\right)^4\Theta^{-1}F(k)$$



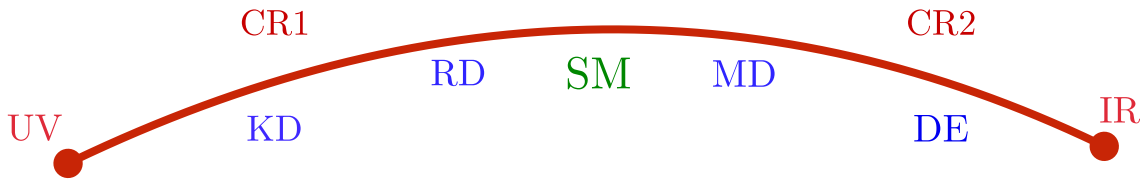
Detection prospects



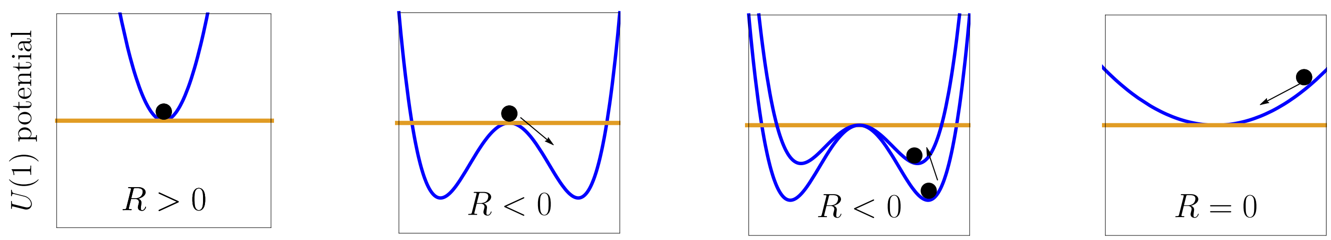
Power-Law Integrated Sensitivities

Conclusions

- **Quintessential inflation from scale symmetry**
  1. **Simple description of all cosmological epochs**
  2. **Depletion of inflaton condensate does not need to be complete**



- **Quintessential inflation + non-minimally coupled spectator fields**
  1. **Formation of short-lived cosmic strings**
  2. **Potentially detectable GW background!**
  3. **Spectral amplitude related to inflationary scale and duration of heating**
  4. **Spectral tilts determined by non-minimal coupling**



- **Nature of U(1)? AD Baryogenesis!**

  See D. Bettoni, J. Rubio, Phys.Lett. B784 (2018) 122-129 (arXiv:1805.02669)

- **Easily generalizable to other groups and topological defects**

Backup slides

Higher order operators

$$\frac{\mathcal{L}}{\sqrt{-g}} = -\partial_\mu \chi^\dagger \partial^\mu \chi - (m_\chi^2 + \xi R)\chi^\dagger \chi - \lambda \frac{(\chi^\dagger \chi)^{n/2}}{\Lambda^{n-4}}$$

$$\Omega_{\rm GW}(\tau, k > k_{\rm tr}) \propto \begin{cases} k^{1+\gamma} & \text{if} \quad \xi < 3/8\,, \\ k^{-\bar{\alpha}} & \text{if} \quad \xi > 3/8\,. \end{cases}$$

$$\Omega_{\rm GW}(\tau, k < k_{\rm tr}) \propto \begin{cases} k^{1+\gamma} & \text{if} \quad n > 14\,, \\ k^{\alpha} & \text{if} \quad n < 14\,. \end{cases}$$

Phase	α	$\bar{\alpha}$	β	γ	$\beta - \alpha$	$\bar{\alpha} + \beta$	tilt range
Rolling	2	~ 2	$1 - 2\sqrt{6\xi}$	$-2\sqrt{6\xi}$	$-1 - 2\sqrt{6\xi}$	$3 - 2\sqrt{6\xi}$	1 to −2
Minimum	2	~ 2	$\frac{10+n}{n-2}$	$\frac{12}{n-2}$	$\frac{14-n}{n-2}$	$3\frac{n+2}{n-2}$	1 to 2