Light Higgs from Pole Attractor

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work in progress, in collaboration with M.Montul

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Outlook

- Toy 2-field model
- 3-field model
- Cosmological evolution

Approaches to Gauge Hierarchy Problem

- The traditional approaches (SUSY, CH, GHU) to the problem either provide a symmetry reason for the Higgs mass to be small or lower the Higgs sector cutoff.

- One can also assume that the Higgs mass is allowed to take a large range of values during its cosmological evolution. The evolution stops when the current vev is reached.

  Cosmic Attractor, Dvali,Vilenkin[0304043]
  Cosmological Relaxation, Graham,Kaplan,Rajendran [1504.07551]

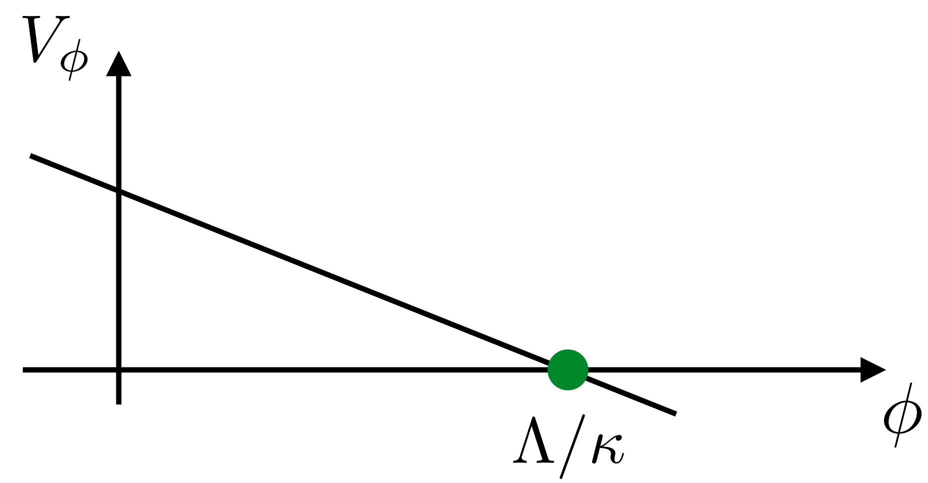
- Lesson from GKR: new solutions to the HP require highly non-“standard” physics

Light Scalar from Kinetic Pole (a toy model)

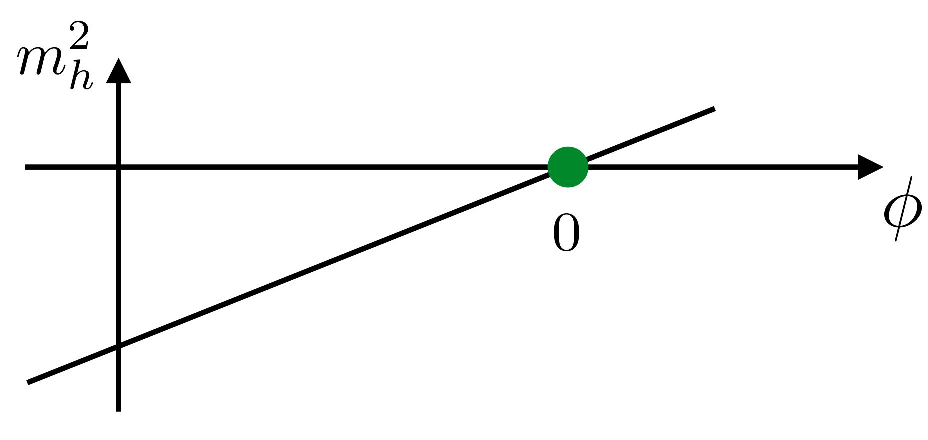
- The Higgs mass is scanned by a field ϕ

$$V_h \supset \left(-\Lambda^2 + \kappa\Lambda\phi\right) h^2$$

Λ - large cutoff, κ - typical ϕ coupling, breaking the shifts



$(V_\phi = -\kappa\Lambda^3\phi)$



Light Scalar from Kinetic Pole (a toy model)

- The scanning field evolution freezes close to $h \sim 0$ point due to exploding non-canonical kinetic term

$$\frac{1}{h^{2n}}(\partial_\mu \phi)^2$$

- Equivalent to stretching of the scanning field potential close to the attractor point $h \sim 0$

Light Scalar from Kinetic Pole (a toy model)

- Integrating out the Higgs field

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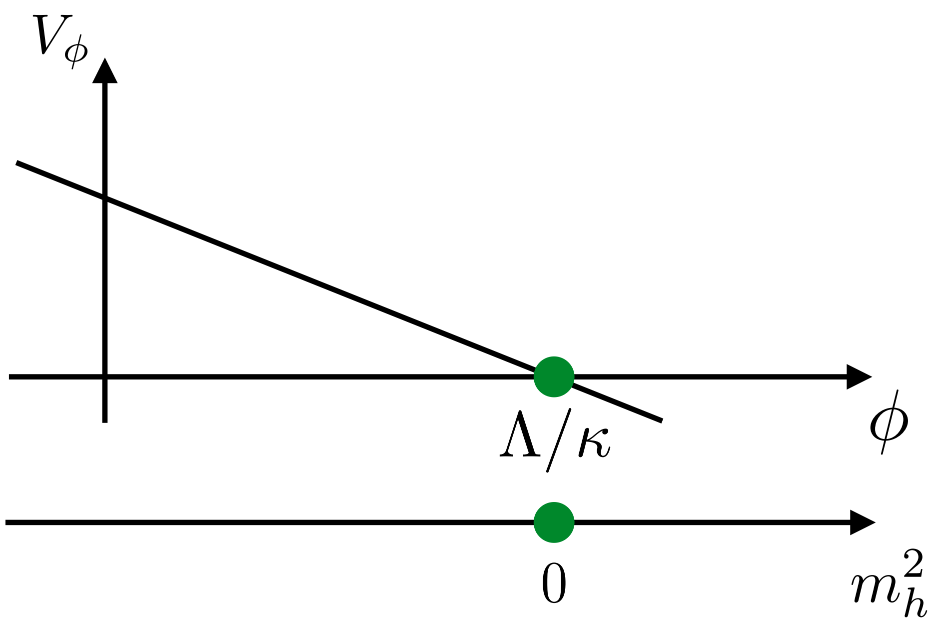

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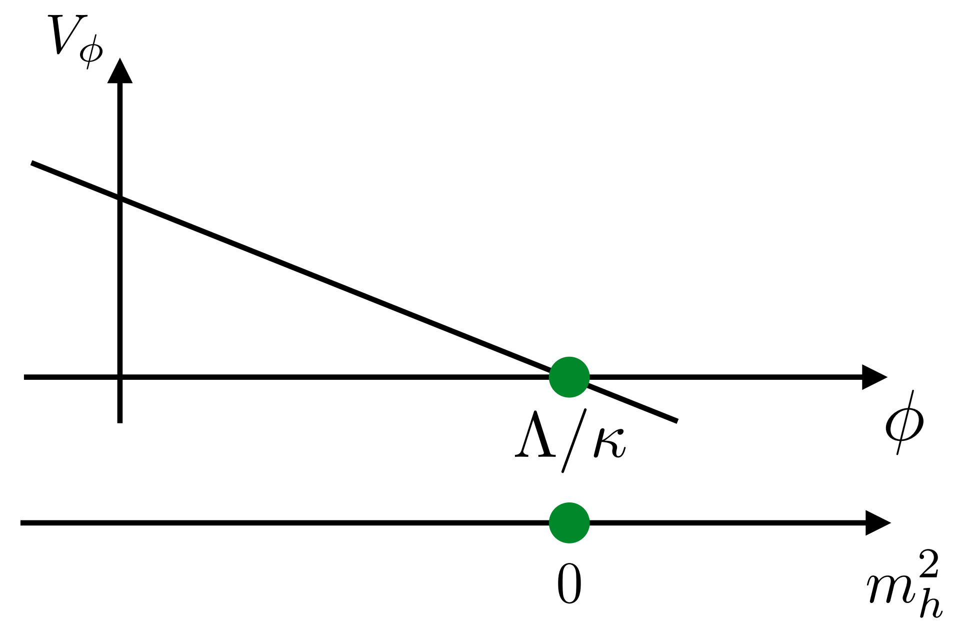
$$h^2 \to \Lambda^2 - \kappa\Lambda\phi$$

$$\frac{1}{(\Lambda/\kappa - \phi)^n}(\partial_\mu \phi)^2$$



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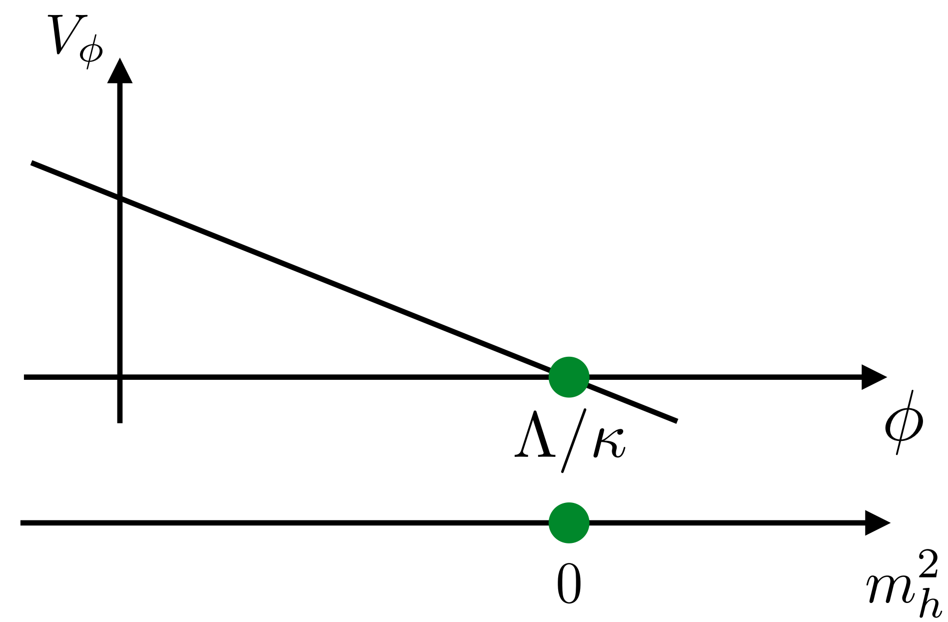
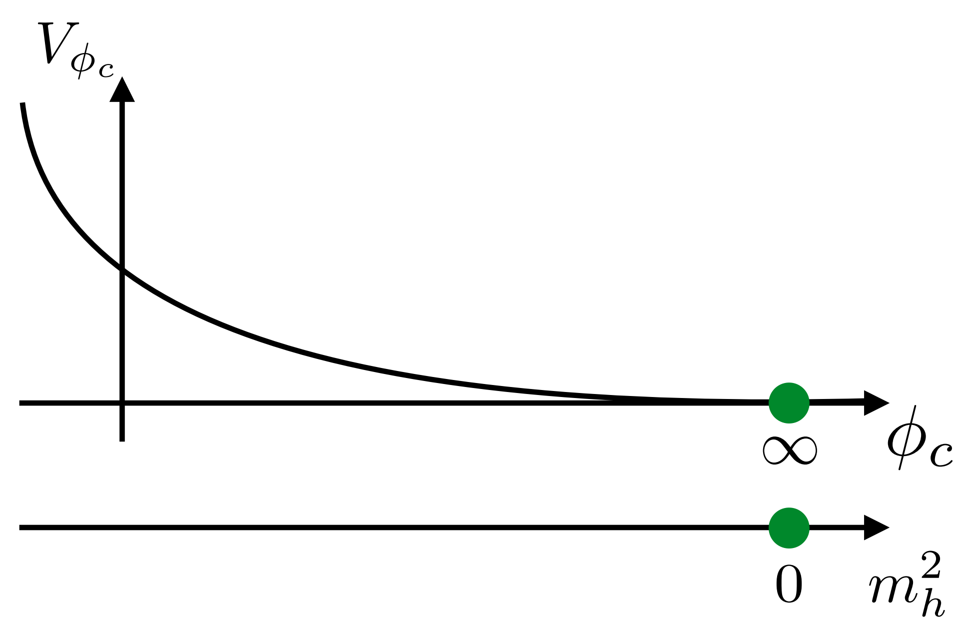
$$\phi - \Lambda/\kappa \to -e^{-\phi_c}$$
$$(n = 2)$$

$$(\partial_\mu \phi_c)^2$$





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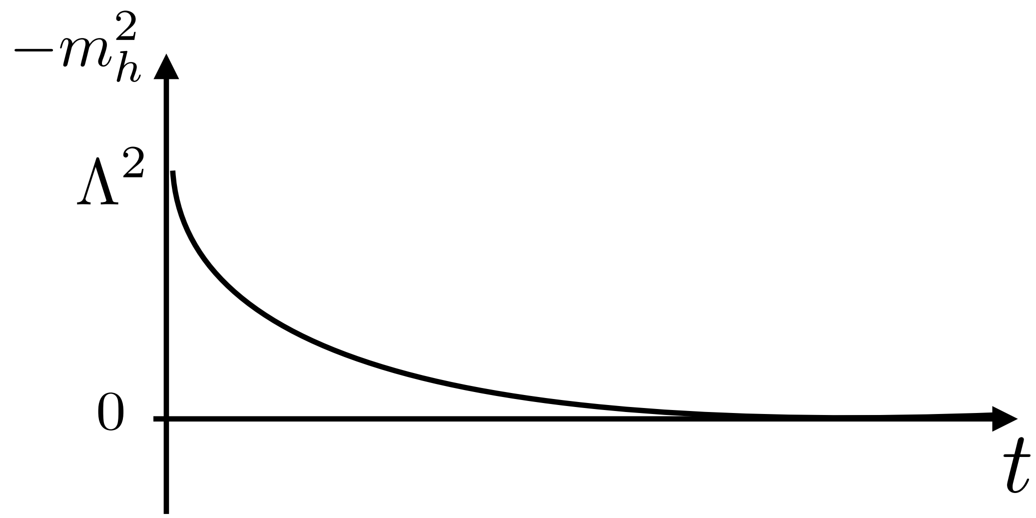
- Higgs mass time evolution



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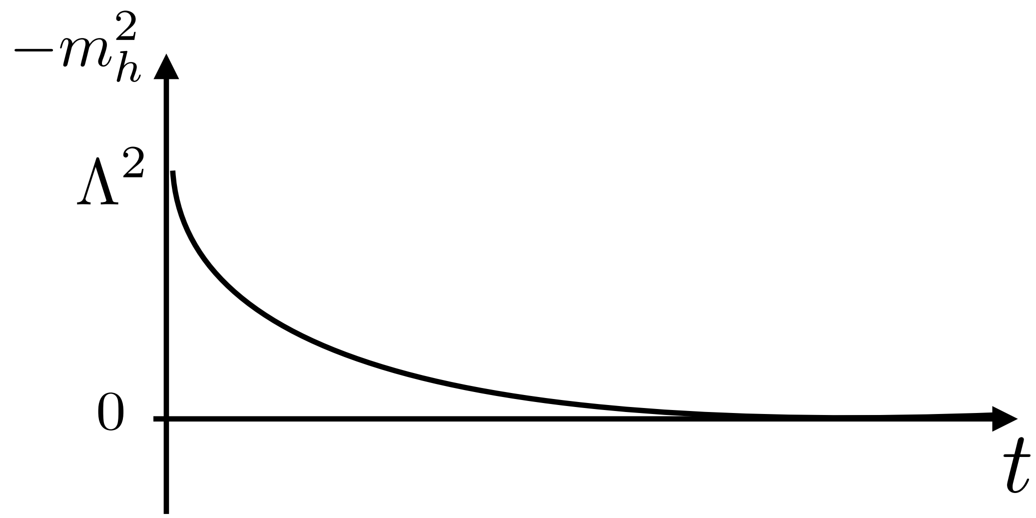
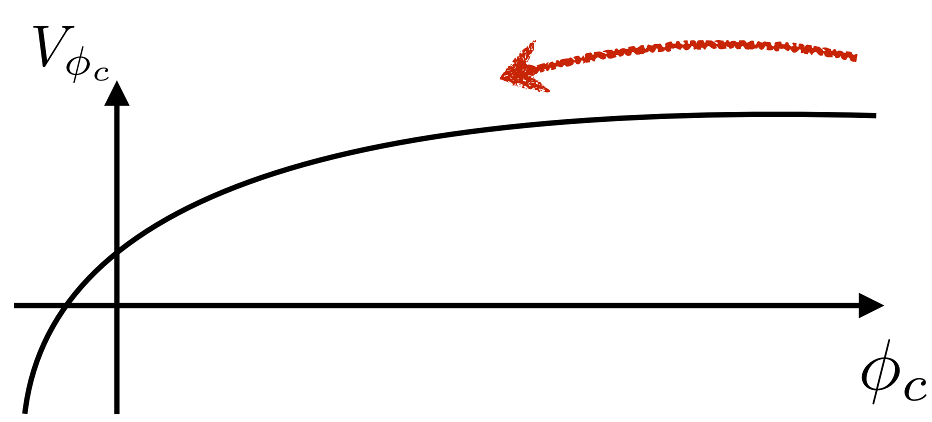


- Reminiscent of pole inflation



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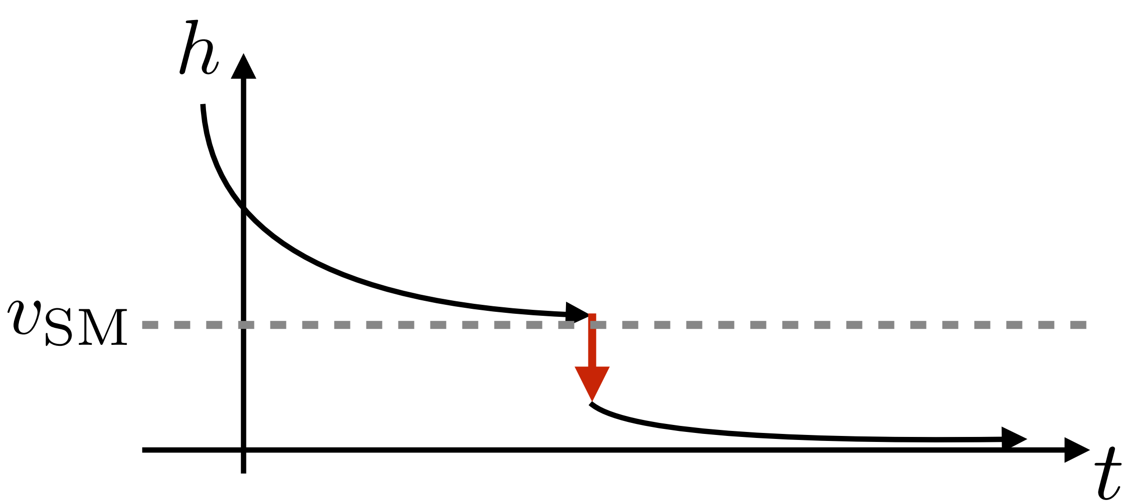

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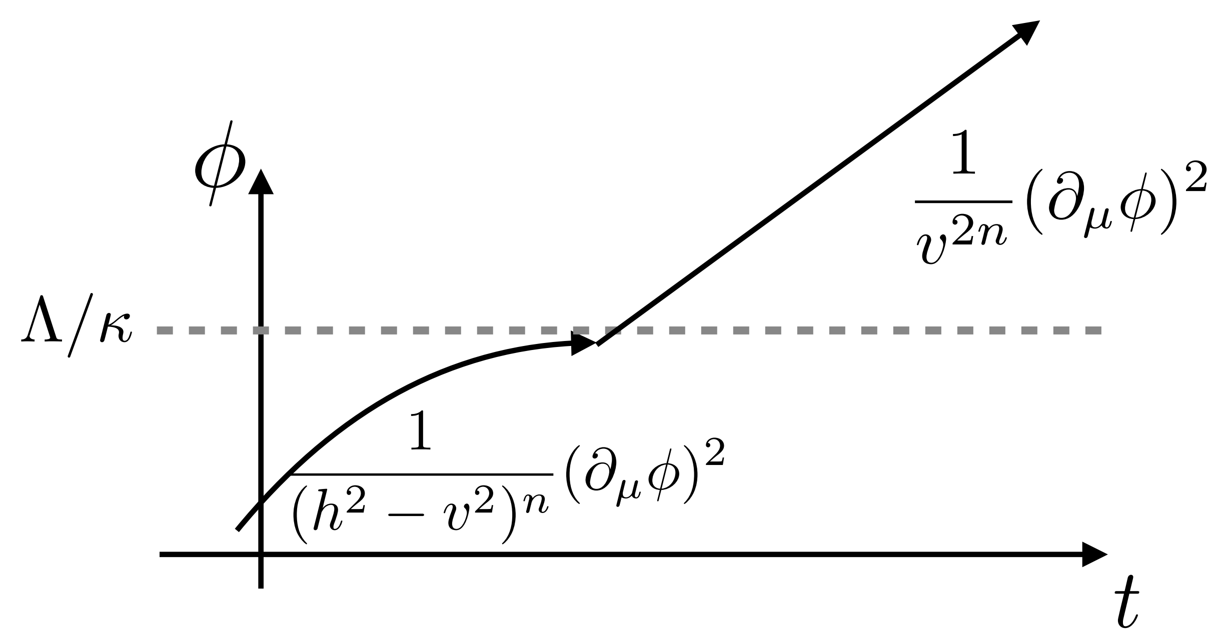

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- Introduce a new SM singlet scalar giving a pole

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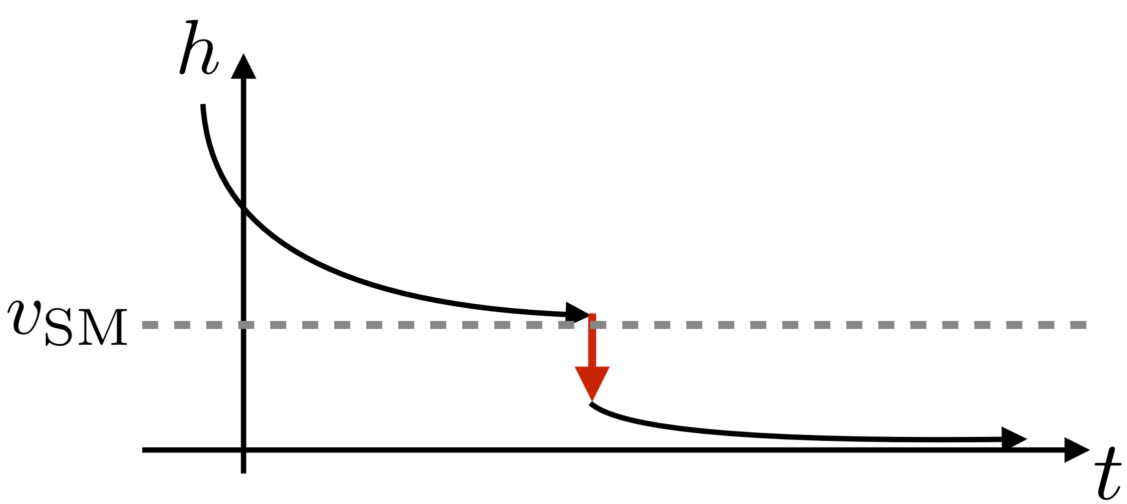

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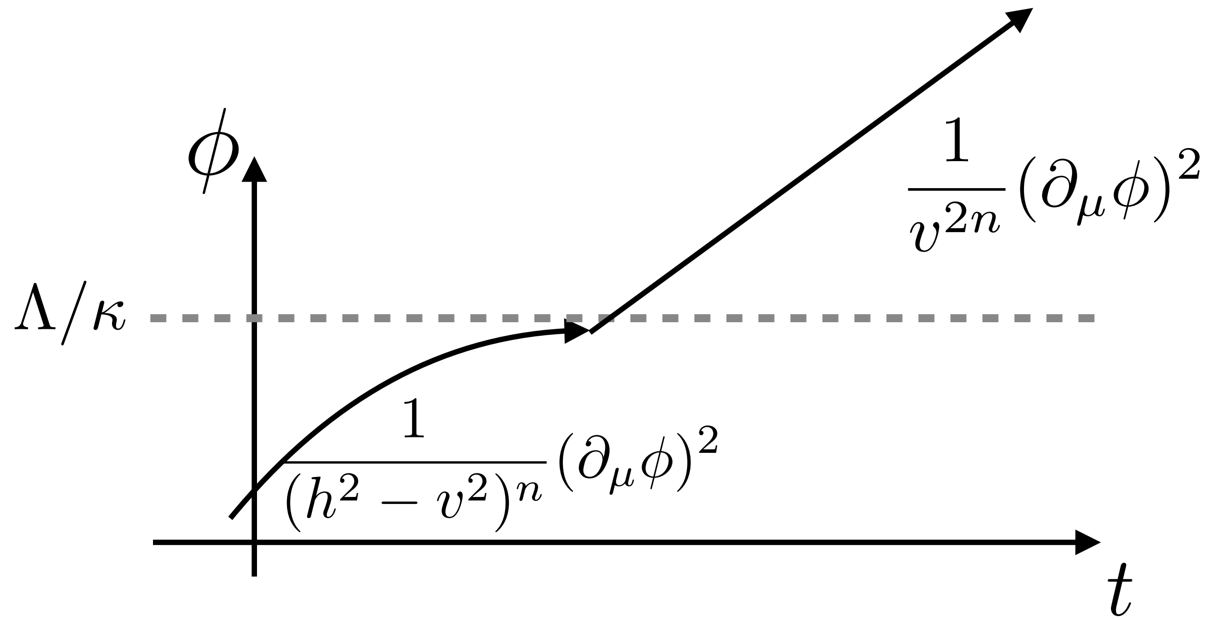

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- Make the ρ kinetic term non-canonical as well

$$\frac{1}{\rho^2}(\partial_\mu \rho)^2$$

Towards a Realistic Set-Up

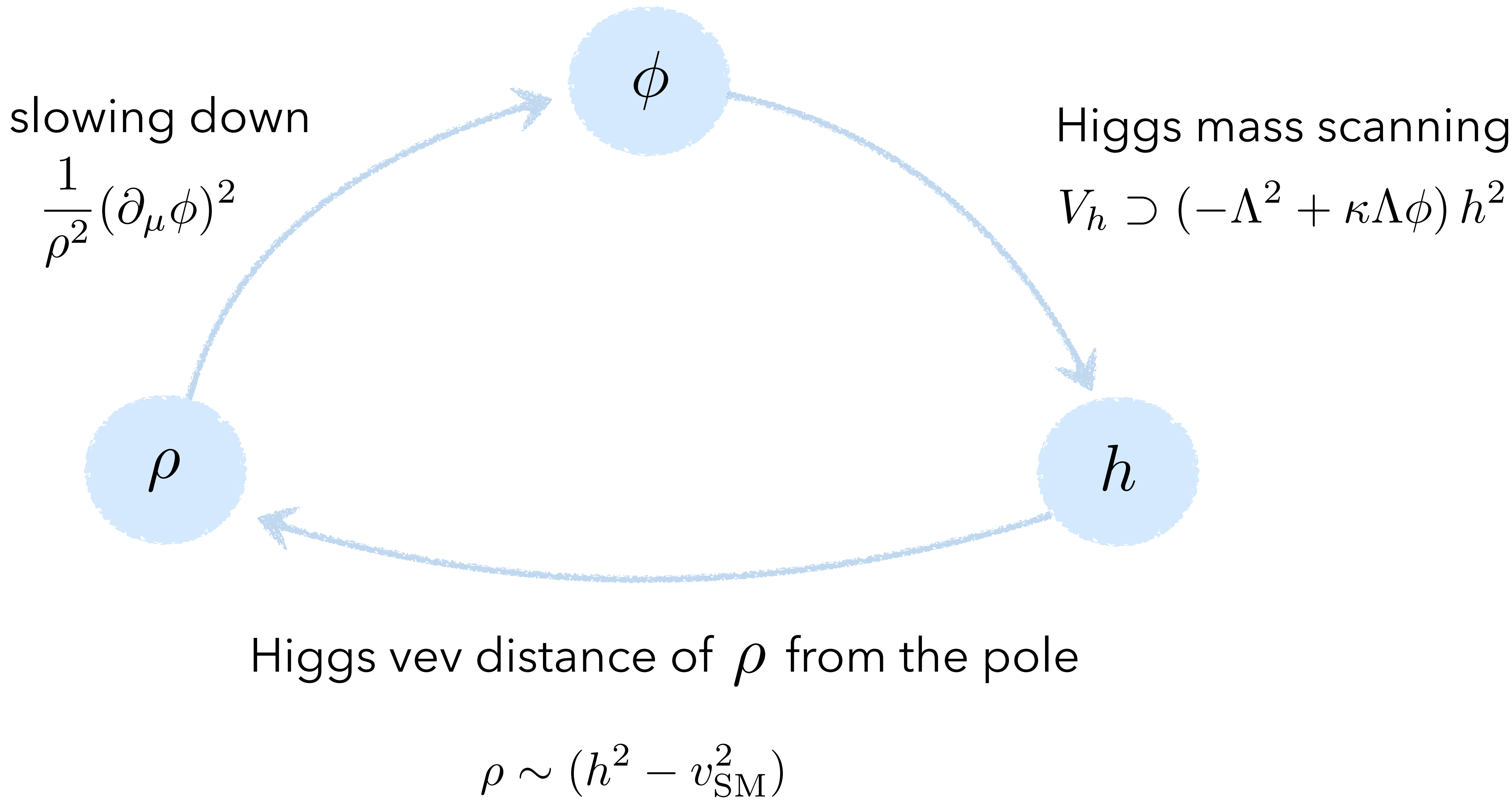
- Again analogy with pole inflation, which can be generated in SUGRA e.g. by a Kahler potential

$$K = -3\alpha \log[T + \bar{T}]$$

$$\mathrm{Re}[T] \sim \rho$$
$$\mathrm{Im}[T] \sim \phi$$

Towards a Realistic Set-Up

- Relations in the scalar sector



Towards a Realistic Set-Up: sensitivity to the Higgs

- The ρ value has to shift to zero as the Higgs vev approaches the SM value.

- Simplest (?) but not unique (?) realisation:

$$V_\rho = \gamma(h^2 - \Delta^2)\rho + \Lambda^2\rho^2$$

$$\rho_{\rm min} \sim (h^2 - \Delta^2)$$

- Not stable under quantum corrections

$$\gamma h^2 \rho \to \gamma \tilde{\Lambda}^2 \rho$$

- UV completion at $\tilde{\Lambda} \ll \Lambda$: 2HDM

Towards a Realistic Set-Up: sensitivity to the Higgs

- 2HDM with $SU(2)_R$ (inspired by Espinosa et al [1506.09217])

  protected linear term

$$\gamma h^2 \rho \to \gamma (h_1 h_2^\dagger) \rho$$

  almost simultaneous scanning

$$\kappa \Lambda \phi h^2 \to \kappa \Lambda \phi (h_1^2 + h_2^2)$$

  provided by approx symmetry

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- predictions

$$m_{h_2}^2 \simeq \frac{y_t^2 g_1^2}{(4\pi)^2}\Lambda^2$$

$$v_{\rm SM}^2 \simeq \frac{\log[\Lambda^2/m_{h_2}^2]}{(4\pi)^2} m_{h_2}^2$$

→

$$m_{h_2} \sim \mathcal{O}(\mathrm{TeV})$$

$$\Lambda \sim 10^3 \mathrm{TeV}$$

Towards a Realistic Set-Up

- ρ behaviour
  - e.o.m. of canonically normalized field $\rho = -\alpha^{1/2} \exp[-\rho_c/\alpha^{1/2}]$

$$\ddot{\rho}_c + 3H\dot{\rho}_c = \gamma(\Delta^2 - h^2)\exp[-\rho_c/\alpha^{1/2}] + 2\alpha^{1/2}\Lambda^2 \exp[-2\rho_c/\alpha^{1/2}] + \frac{\dot{\phi}^2}{\alpha^{1/2}}\exp[2\rho_c/\alpha^{1/2}]$$

  - as ρ potential stretches rho stops following its minimum
  - ϕ kinetic energy term drives ρ to zero at low Hubble friction independently of the Higgs vev

Cosmological Evolution

- The Higgs vev is given by $h^2 \simeq \Delta^2 \pm (\kappa\Lambda)^2$ when one starts with a positive (negative) Higgs mass

- To complete the scan during inflation we require (neg init mass)

  - inflation unaffected $\Lambda^4 < H_i^2 M_{\rm Pl}^2$

  - Higgs in the minimum $H_i < m_h$

  - enough time for the full scan $N_e > \frac{10^2}{\kappa^2}\frac{\alpha}{\gamma^2}\frac{H_i^2}{(\kappa\Lambda)^2}$

  - quantum displacement unimportant $H < 10^{-1}\kappa^{1/3}(\kappa\Lambda)\left(\frac{\gamma^2}{\Lambda\alpha^{1/2}}\right)^{1/3}$

- After inflation due to a low Hubble scale the rho field is pushed to the origin, the scan is automatically blocked (result of rho kin term)

Cosmological Evolution

- Benchmark parameter set

$\Lambda\ (=\gamma)$	Δ	κ	α	H_i	N_e
$10^6\mathrm{GeV}$	$10^2\mathrm{GeV}$	10^{-4}	$(10^3\mathrm{GeV})^2$	$10\ \mathrm{GeV}$	10^2

Summary

Searches for traditional NP solving the hierarchy problem do not give results, hence still place for new approaches.

We present a model aiming at addressing the HP and belonging to the class of scenarios with a dynamically scanned Higgs mass.

The minimal implementation contains new scalars in a few-TeV range and light but very weakly interacting scanning fields.

The UV completions for the model, as well as alternative realizations of the main idea need further investigation.