Can primordial black holes form without fine-tuning?

2304.01997; JCAP **2023(08)** (2023) 031

Andrew Gow
(+Pippa Cole, Chris Byrnes, Subodh Patil)

Paris PBHs & GWs, 27 November 2023

Overview

PBHs from inflation

- Overdensities seeded by inflation

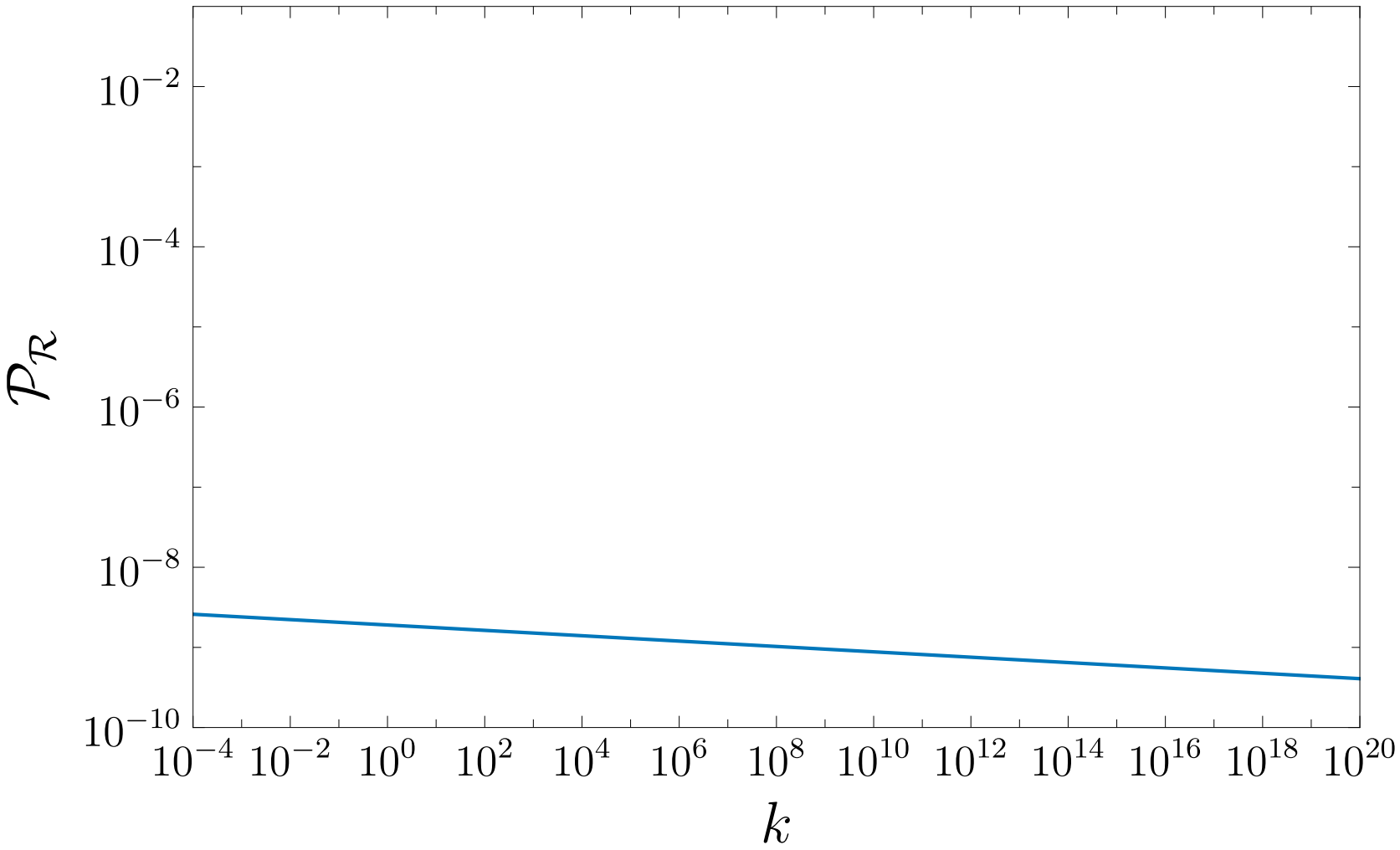
PBHs from inflation

- Overdensities seeded by inflation
- Slow roll inflation explains CMB

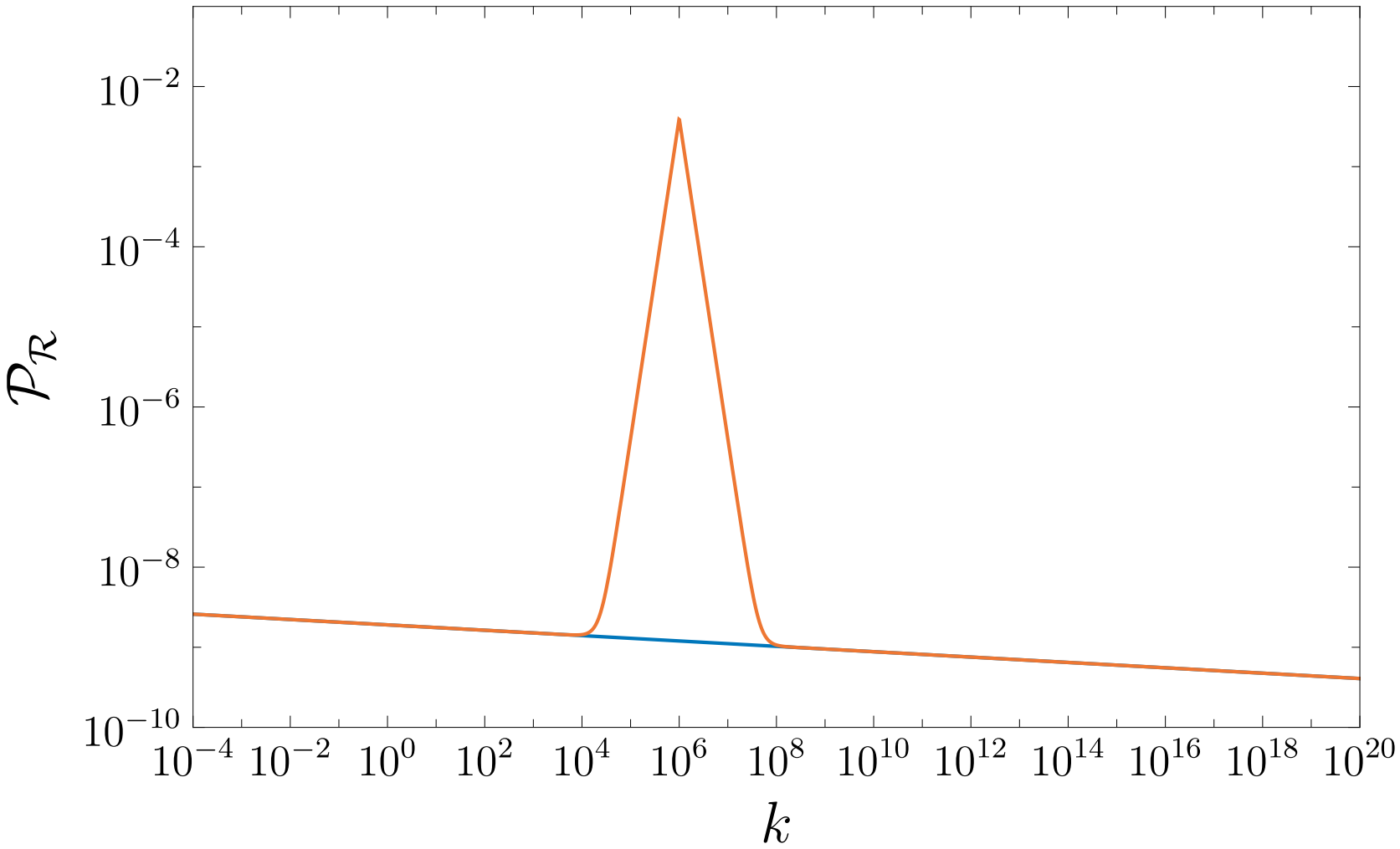
PBHs from inflation

- Overdensities seeded by inflation
- Slow roll inflation explains CMB
- Nearly scale-invariant power spectrum

PBHs from inflation



PBHs from inflation



Inflaton potential

- Inflation driven by scalar field ϕ

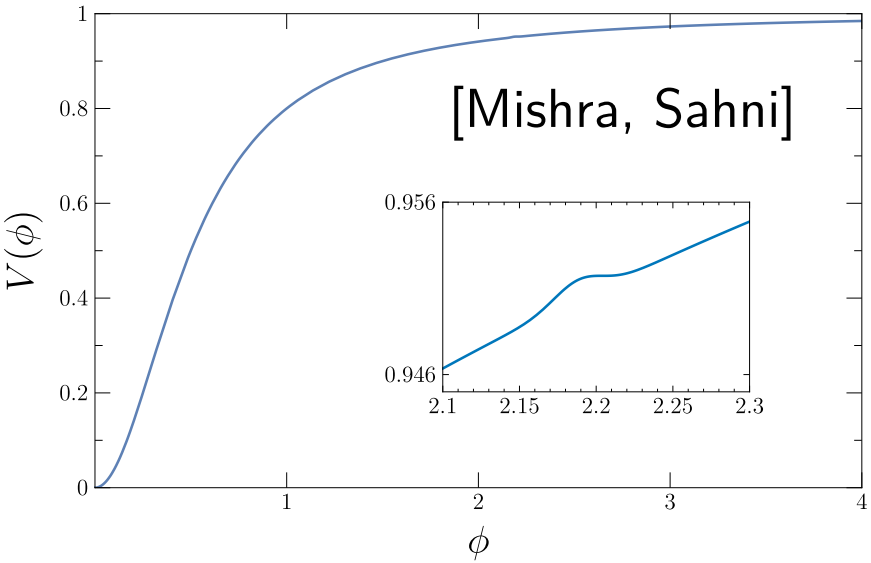
Inflaton potential

- Inflation driven by scalar field ϕ
- Governed by potential $V(\phi)$

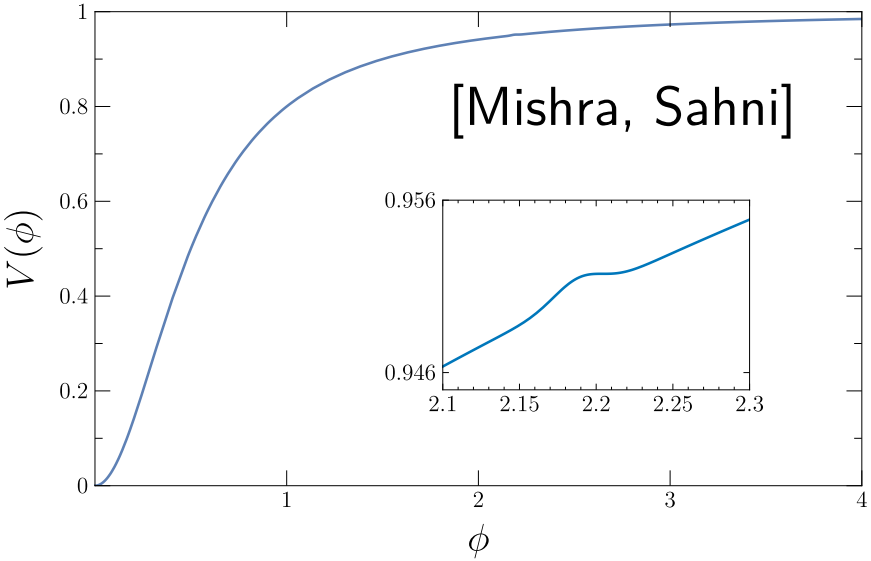
Inflaton potential

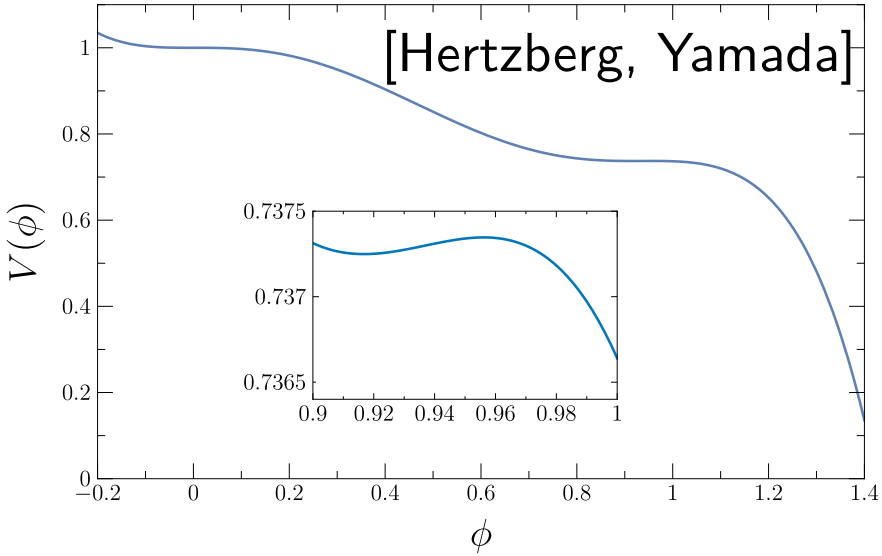
- Inflation driven by scalar field ϕ
- Governed by potential $V(\phi)$
- Need some feature in potential

Potential features

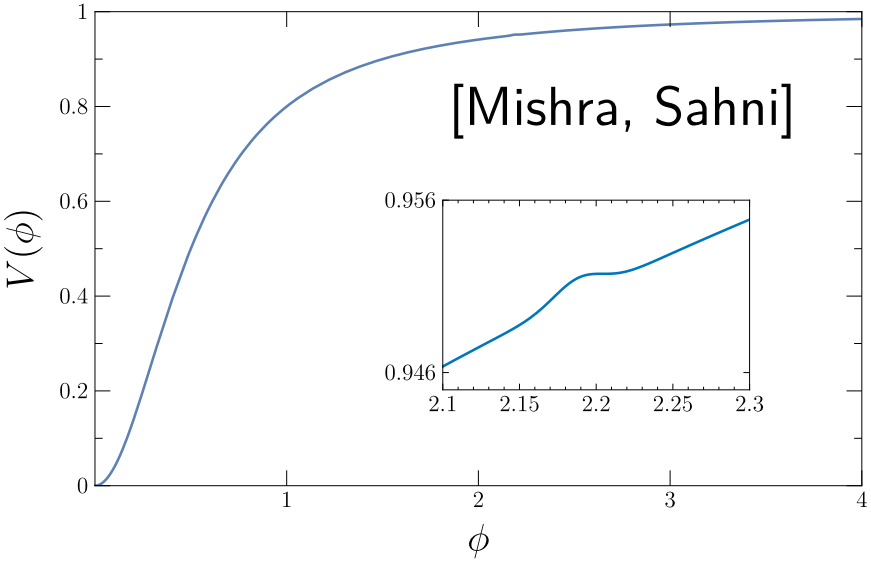


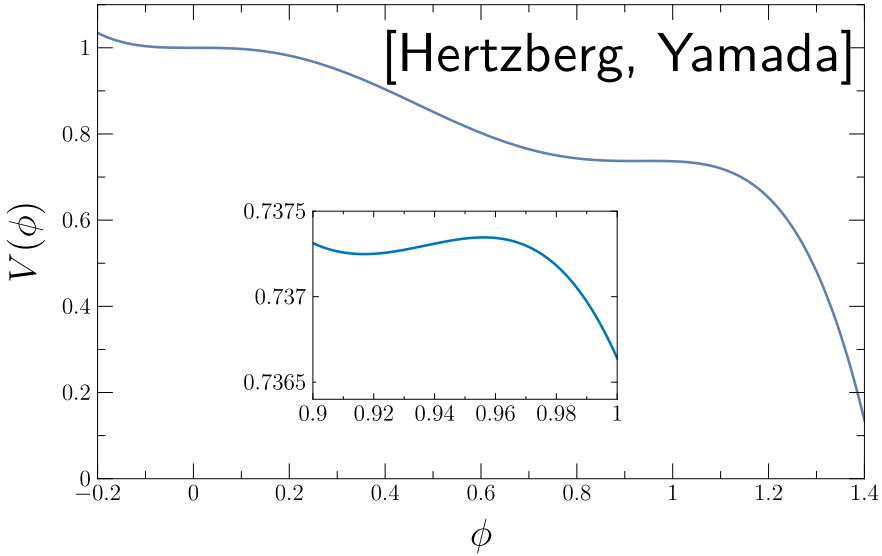
Potential features

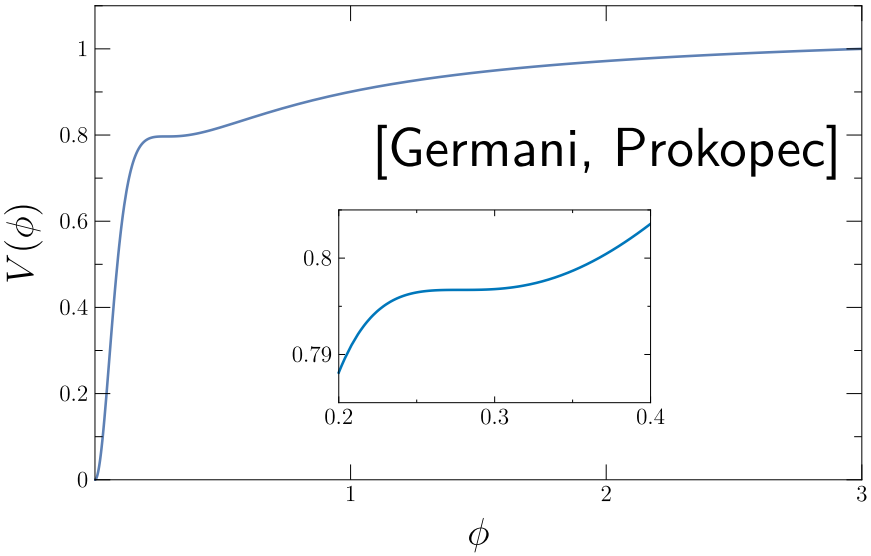




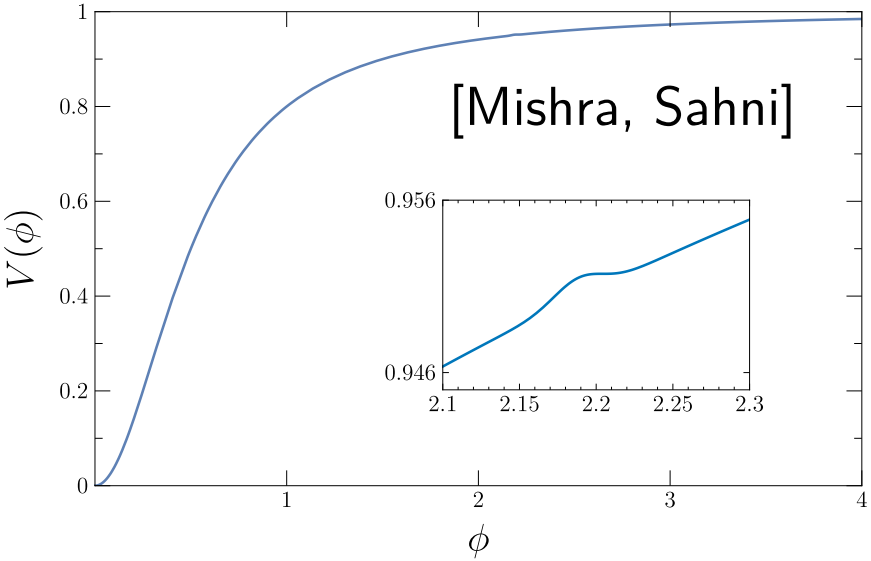
Potential features

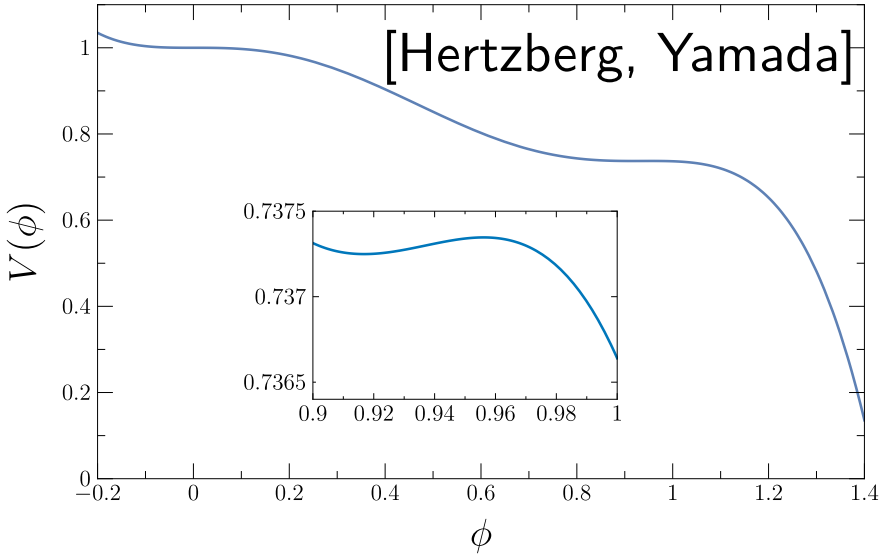


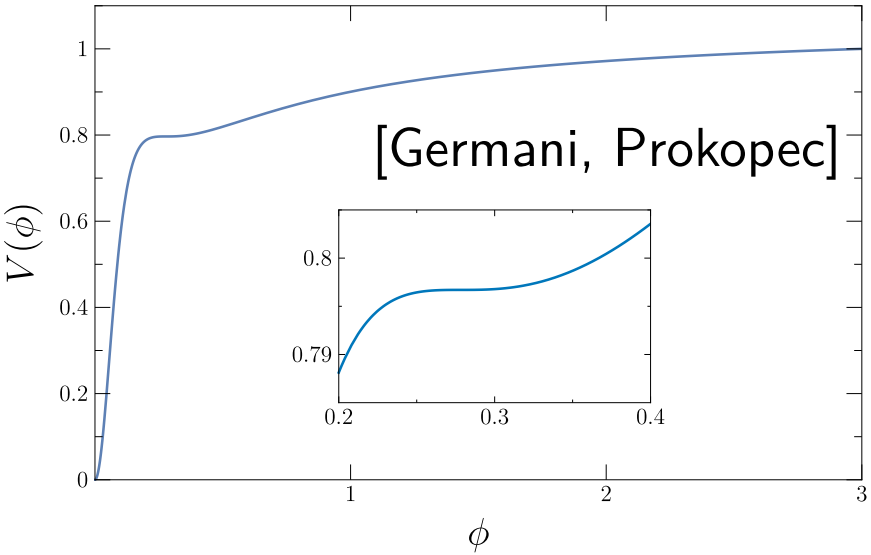


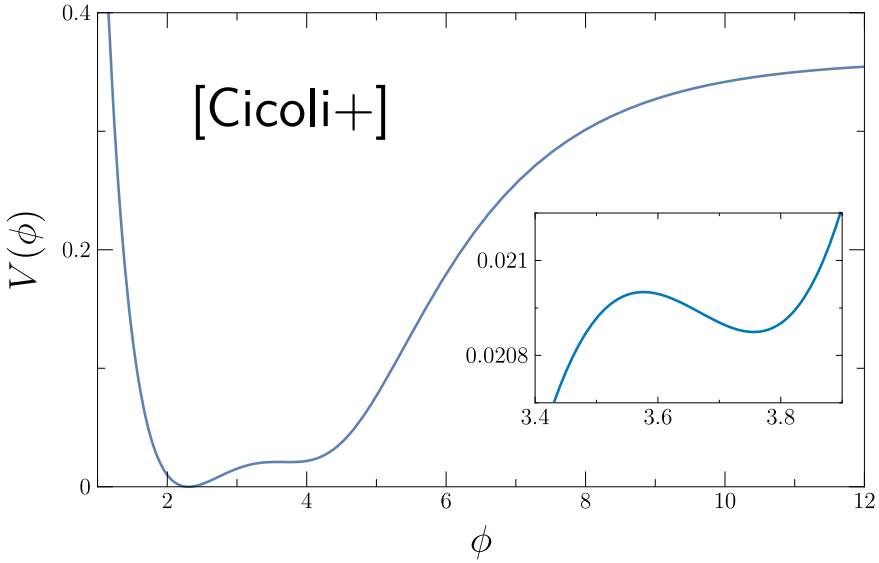


Potential features









Agreement with the CMB

	n_s	r
Mishra & Sahni	0.9648	0.0026
Hertzberg & Yamada	0.9820	4.8×10^{-7}
Germani & Prokopec	0.9567	0.0063
Cicoli *et al.*	0.9400	0.018

Planck constraint:

- $n_s = 0.9649 \pm 0.0042$
- $r < 0.032$

Overview

PBHs from inflation

Fine-tuning

Conclusions

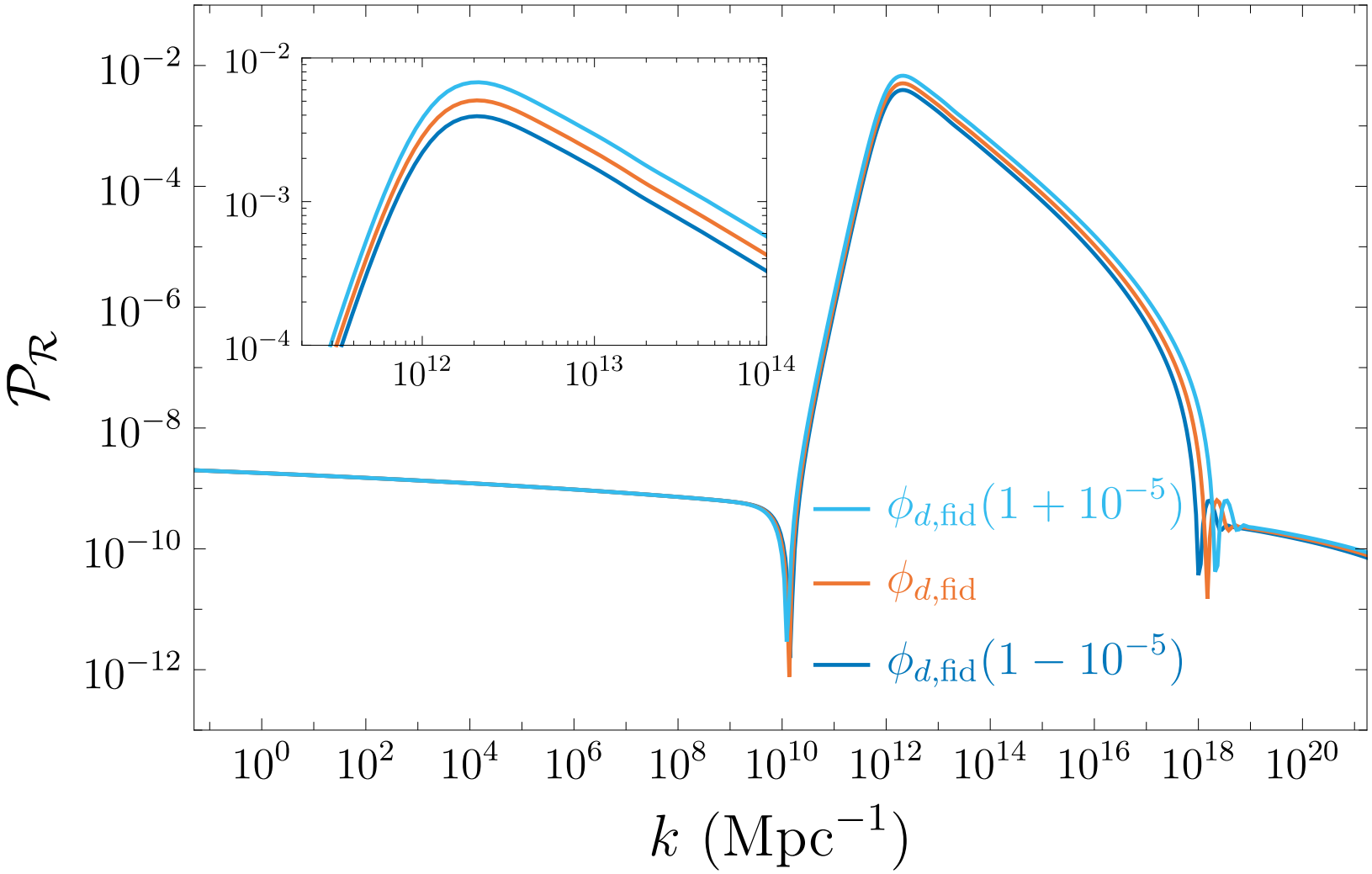
Power spectrum fine-tuning

- Solve Mukhanov–Sasaki equation for each potential

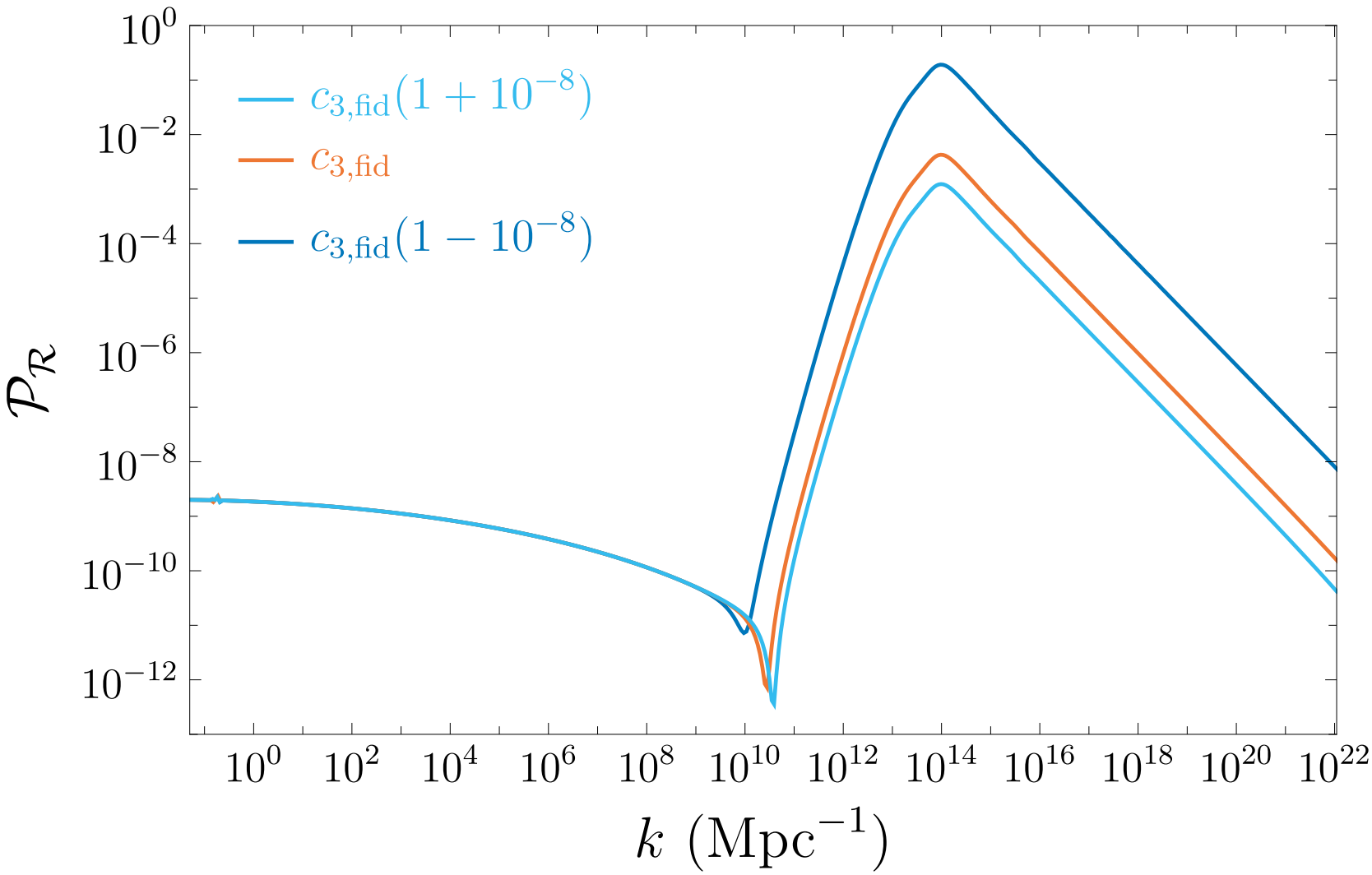
Power spectrum fine-tuning

- Solve Mukhanov–Sasaki equation for each potential
- Perturb potential parameters and compare power spectra

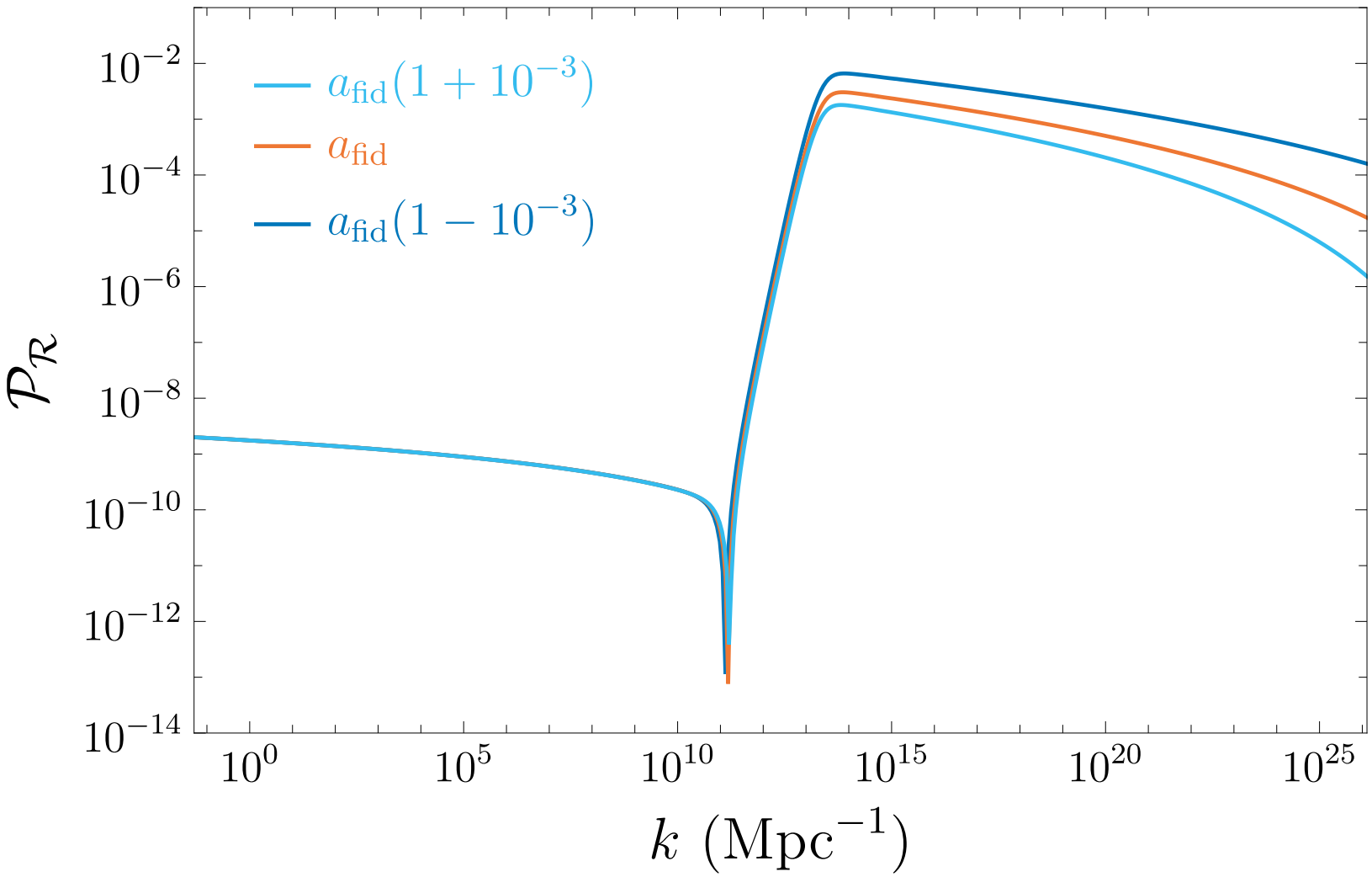
Power spectrum fine-tuning



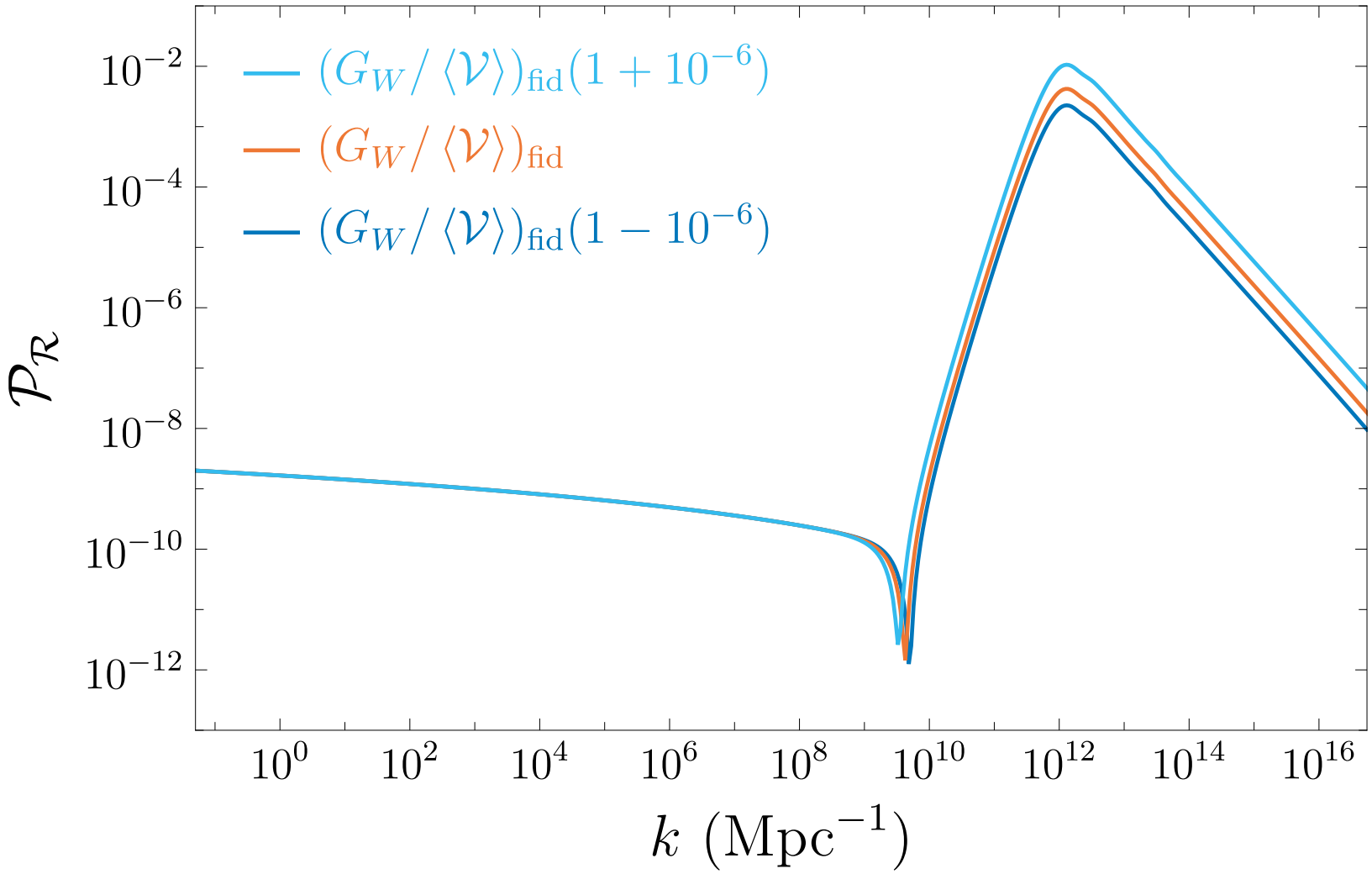
Power spectrum fine-tuning



Power spectrum fine-tuning



Power spectrum fine-tuning



Fine-tuning measure

- Quantify fine-tuning using differential measure [Azhar, Loeb]

$$\epsilon_{\mathcal{O}} = \frac{\mathrm{d}\log\mathcal{O}}{\mathrm{d}\log p}$$

Fine-tuning measure

- Quantify fine-tuning using differential measure [Azhar, Loeb]

$$\epsilon_{\mathcal{O}} = \frac{\mathrm{d} \log \mathcal{O}}{\mathrm{d} \log p}$$

Model	$\epsilon_{\mathcal{P}_{\mathrm{peak}}}$	$\epsilon_{f_{\mathrm{PBH}}}$	ρ
Superposed	2.7×10^{4}	6.2×10^{5}	23
Polynomial	-1.8×10^{8}	-4.7×10^{9}	27
Non-exponential	-6.0×10^{2}	-2.2×10^{4}	37
Exponential	7.5×10^{5}	2.2×10^{7}	29

Conclusions

- PBHs from single-field inflation require a potential feature

Conclusions

- PBHs from single-field inflation require a potential feature
- Might be difficult to explain from particle physics

Conclusions

- PBHs from single-field inflation require a potential feature
- Might be difficult to explain from particle physics
- Typical potentials seem to be quite fine-tuned

Conclusions

- PBHs from single-field inflation require a potential feature
- Might be difficult to explain from particle physics
- Typical potentials seem to be quite fine-tuned
- Total PBH fine-tuning actually dominated by power spectrum fine-tuning

Conclusions

- PBHs from single-field inflation require a potential feature
- Might be difficult to explain from particle physics
- Typical potentials seem to be quite fine-tuned
- Total PBH fine-tuning actually dominated by power spectrum fine-tuning
- Could we be saved by non-Gaussianity?

2304.01997; JCAP **2023(08)** (2023) 031