



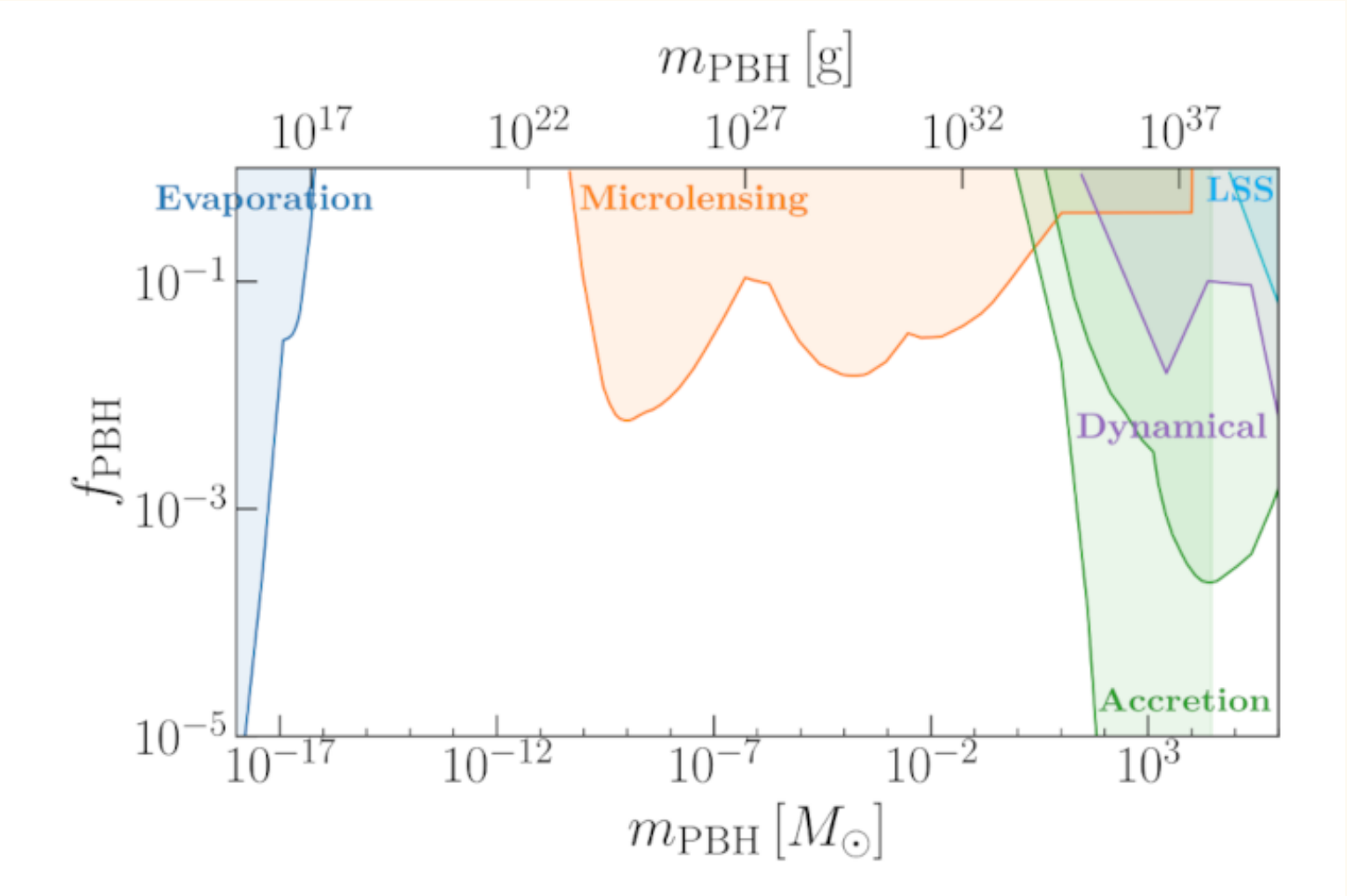
Primordial Black Holes from Resonances in the Running-Mass-Inflation Model

Mindaugas Karčiauskas

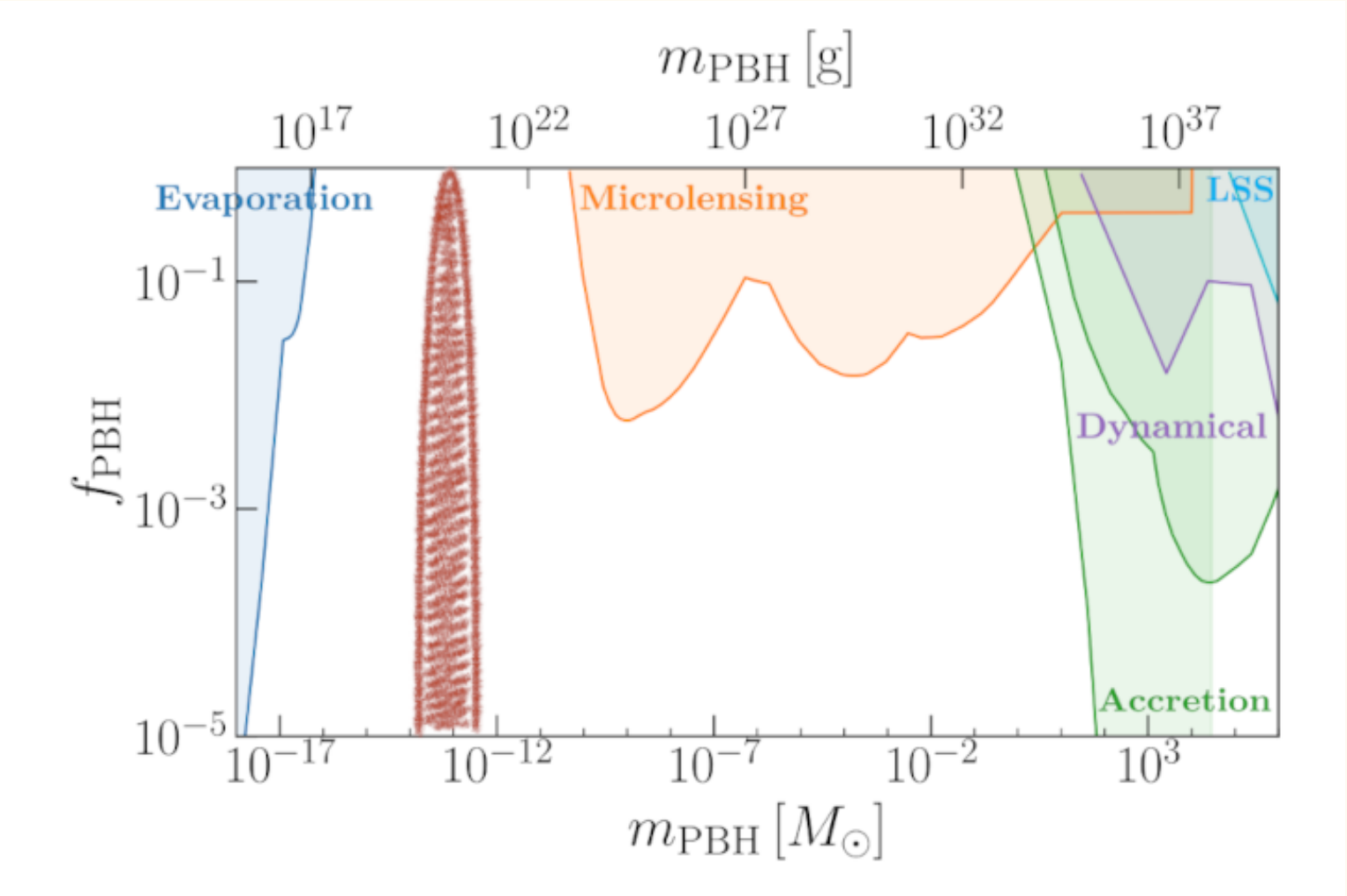
Center for Physical Sciences and Technology,
Vilnius, Lithuania

Furuta, **Karčiauskas**, Kohri, Sáez JCAP08 (2026) (arXiv:2511.23182)

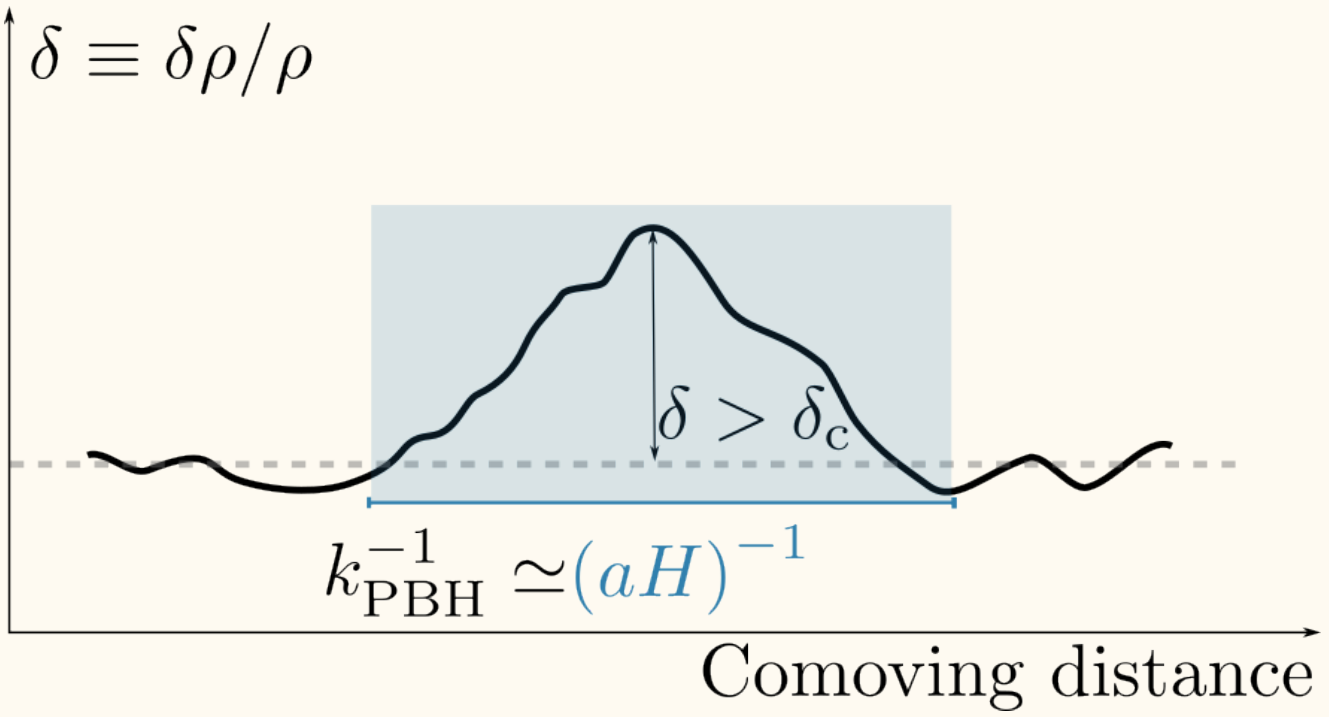
Primordial Black Holes as Dark Matter



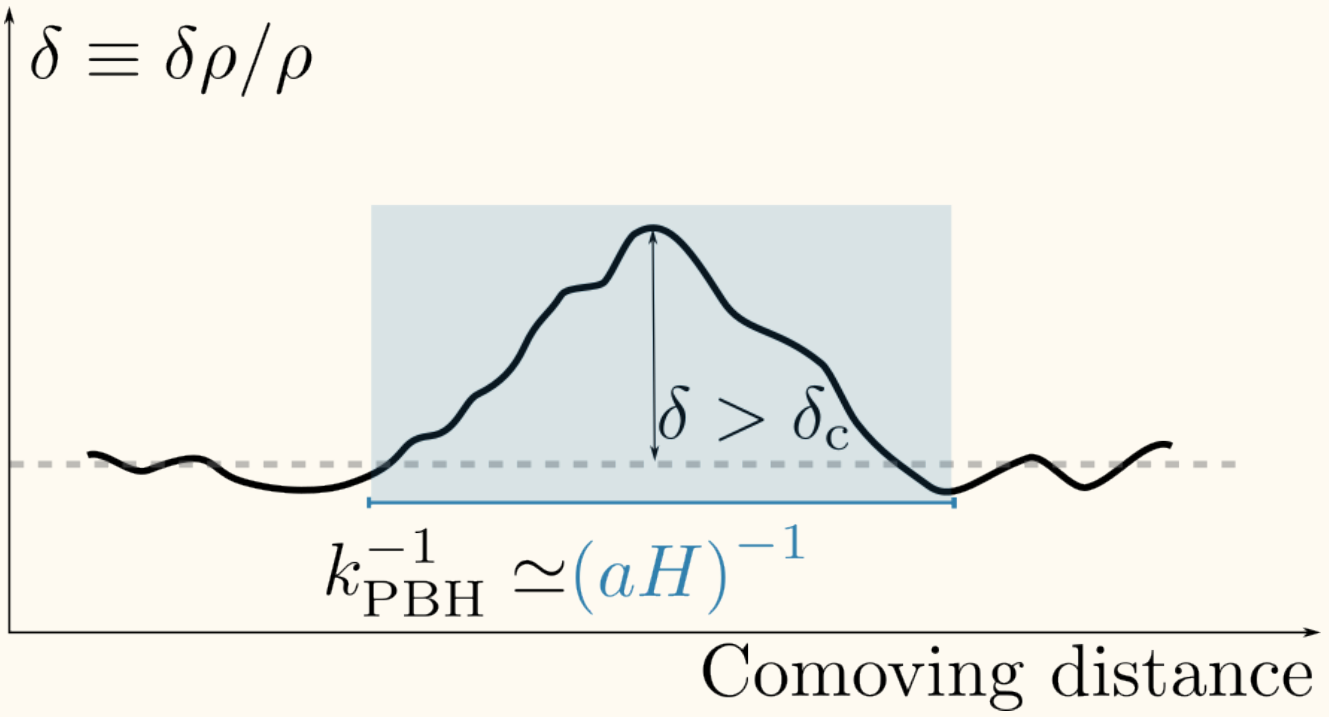
Primordial Black Holes as Dark Matter



Overdensities into Black Holes



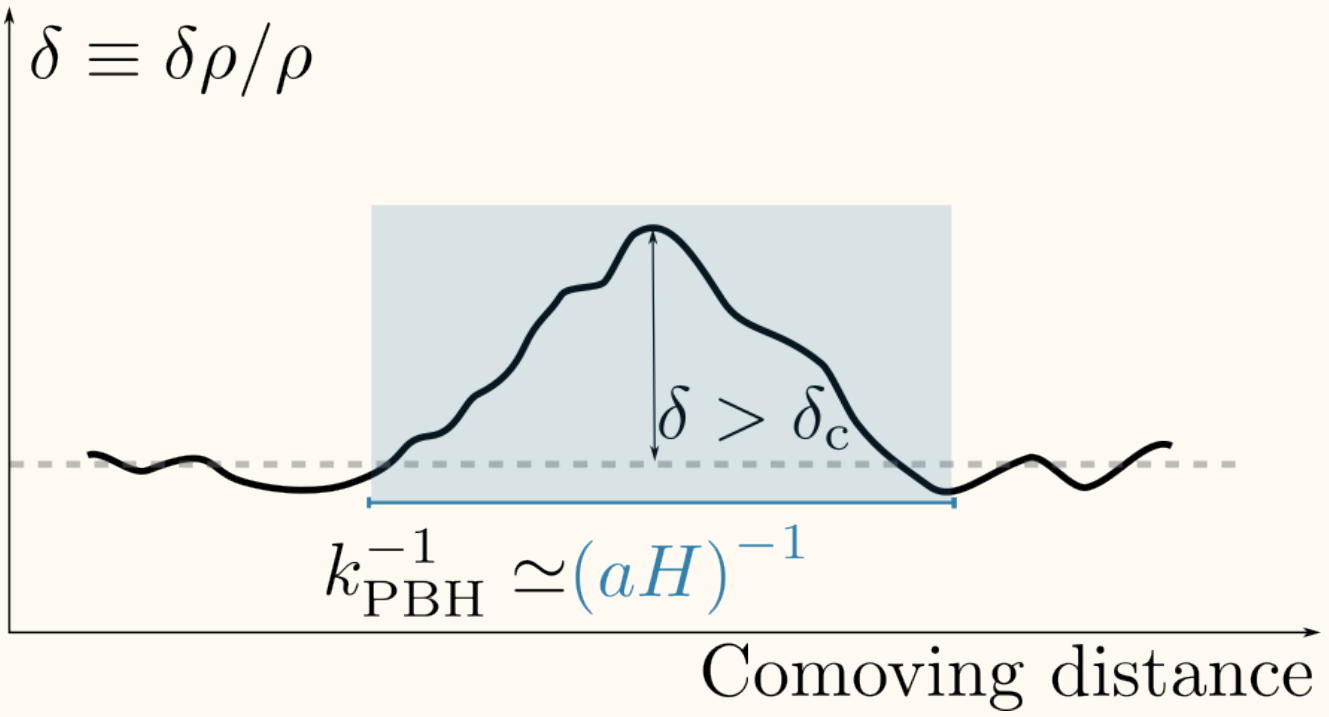
Overdensities into Black Holes



Musco (2019), Escrivà (2022)

$$0.4 < \delta_c < 0.66$$

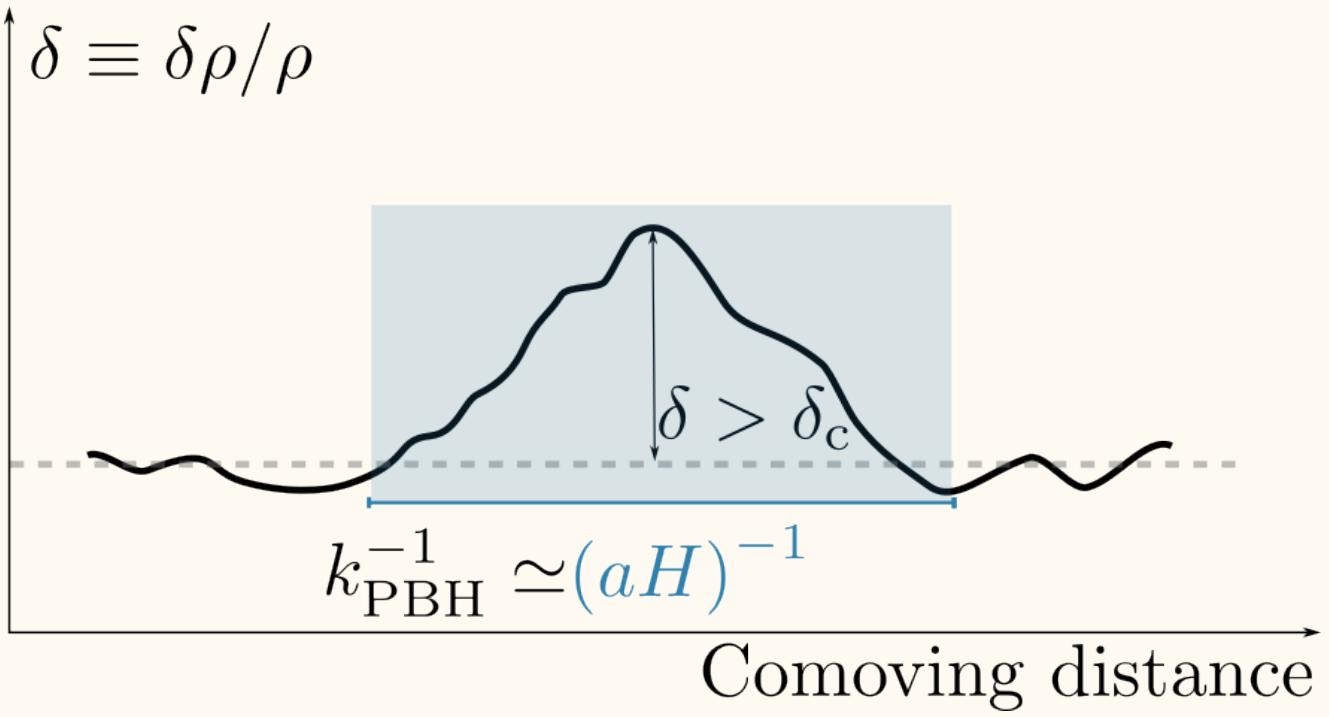
Overdensities into Black Holes



$$m_{\rm PBH}\left(k_{\rm PBH}\right) \simeq \gamma M_H\left(k_{\rm PBH}\right)$$

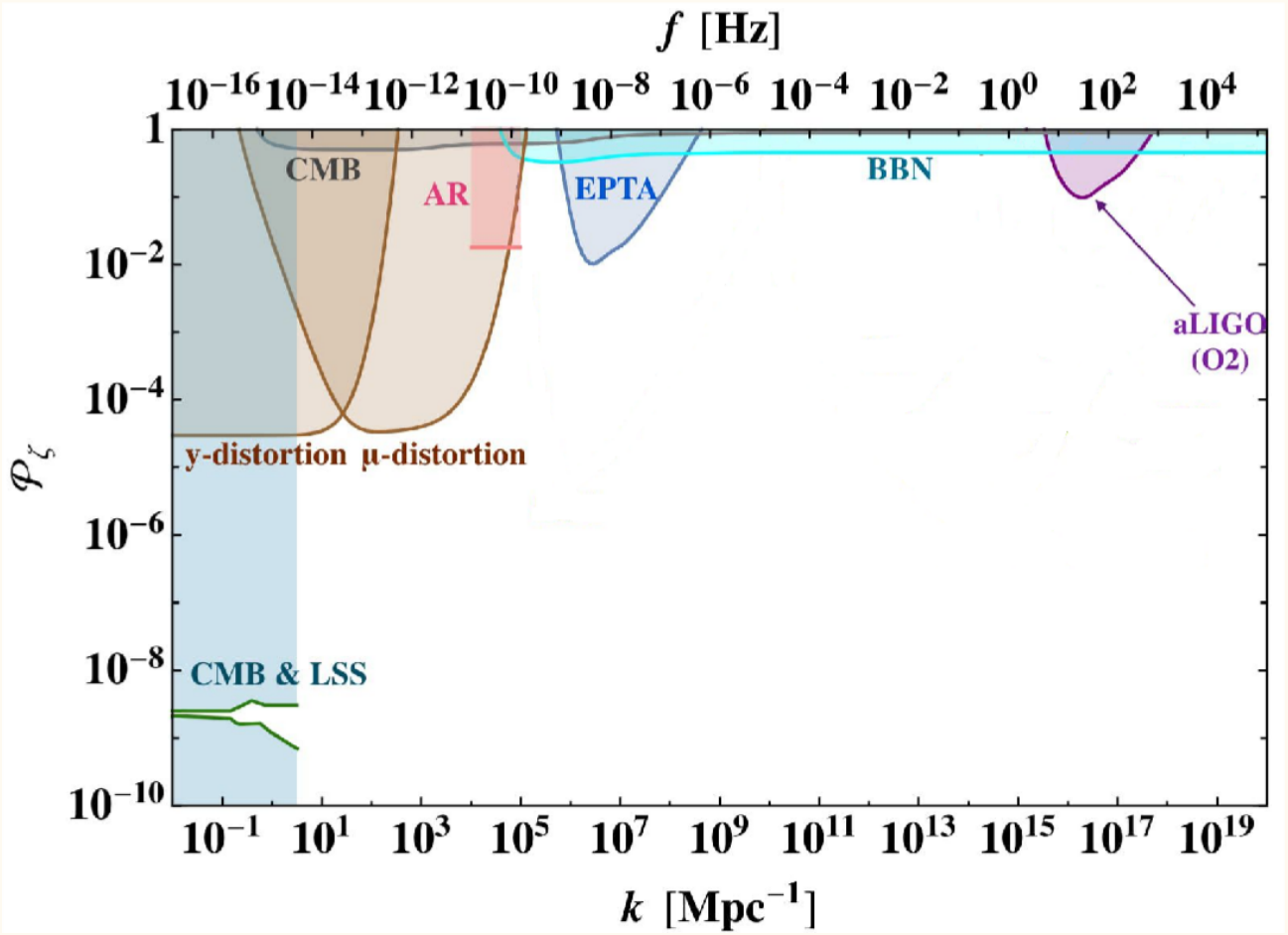
where $\gamma = \mathcal{O}\left(0.1\right)$

Overdensities into Black Holes



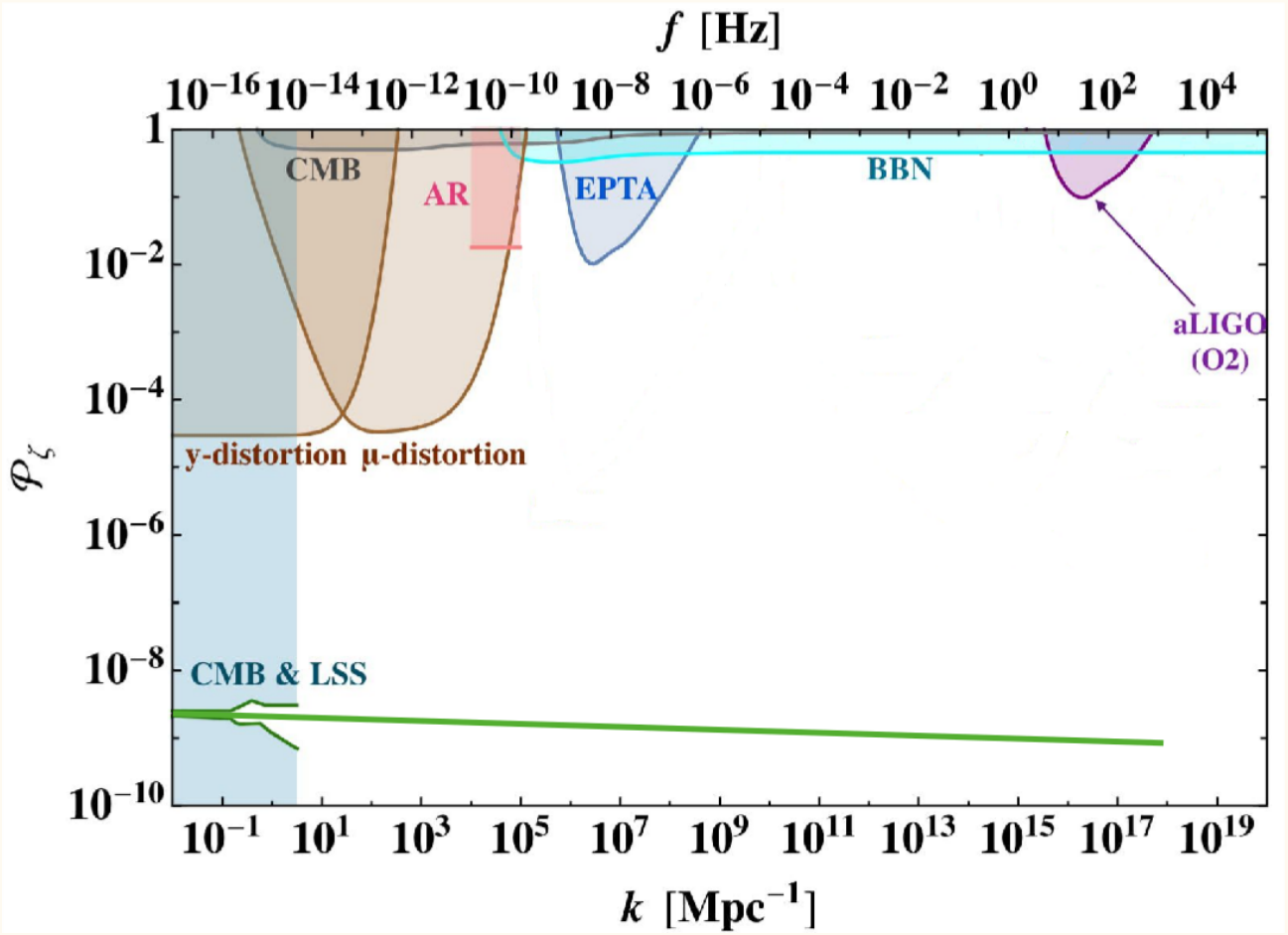
$k_{\rm PBH} \Longleftrightarrow m_{\rm PBH}$

Primordial Perturbation Spectrum



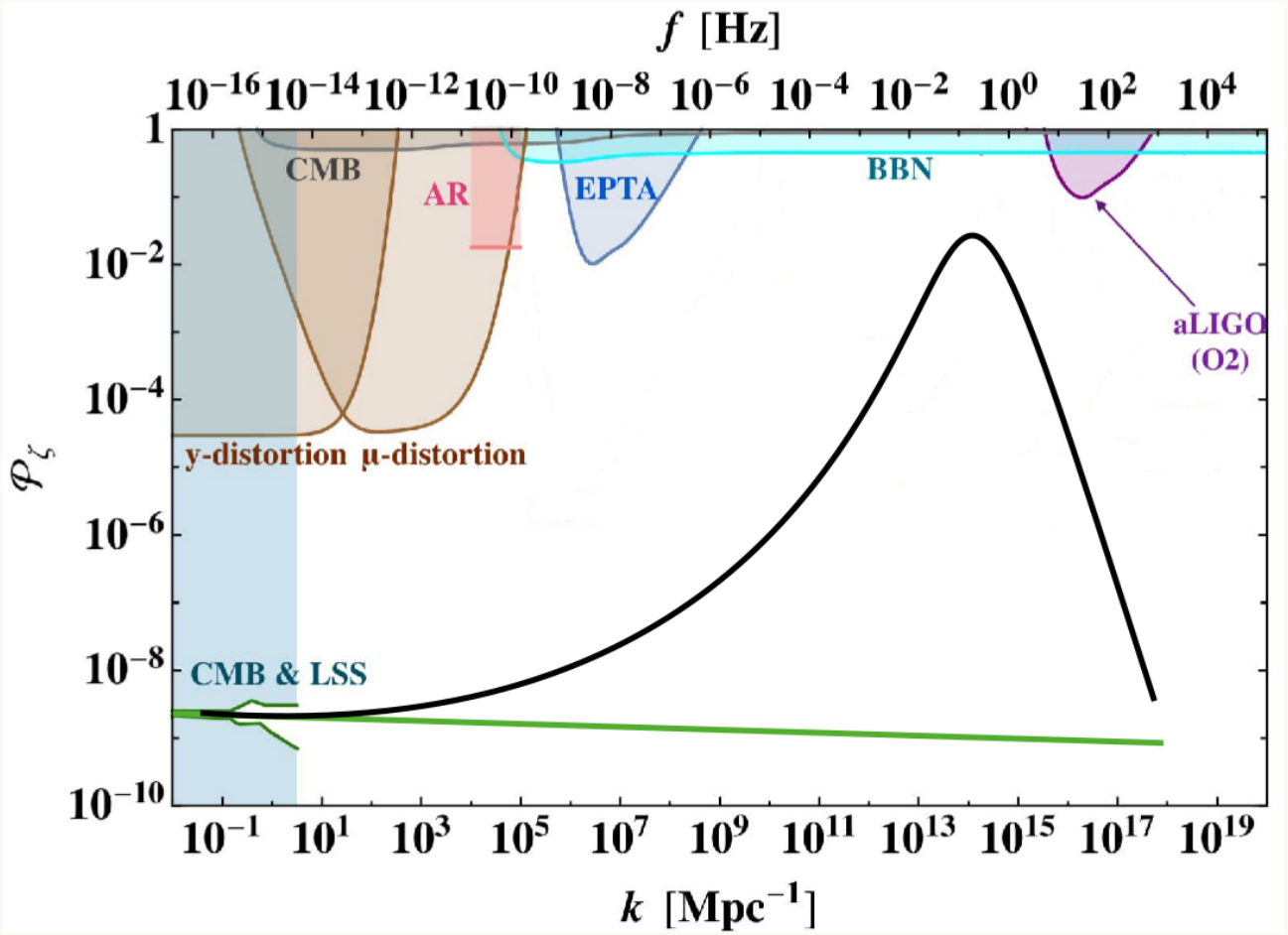
Adapted from Inomata and Nakama (2019)

Primordial Perturbation Spectrum



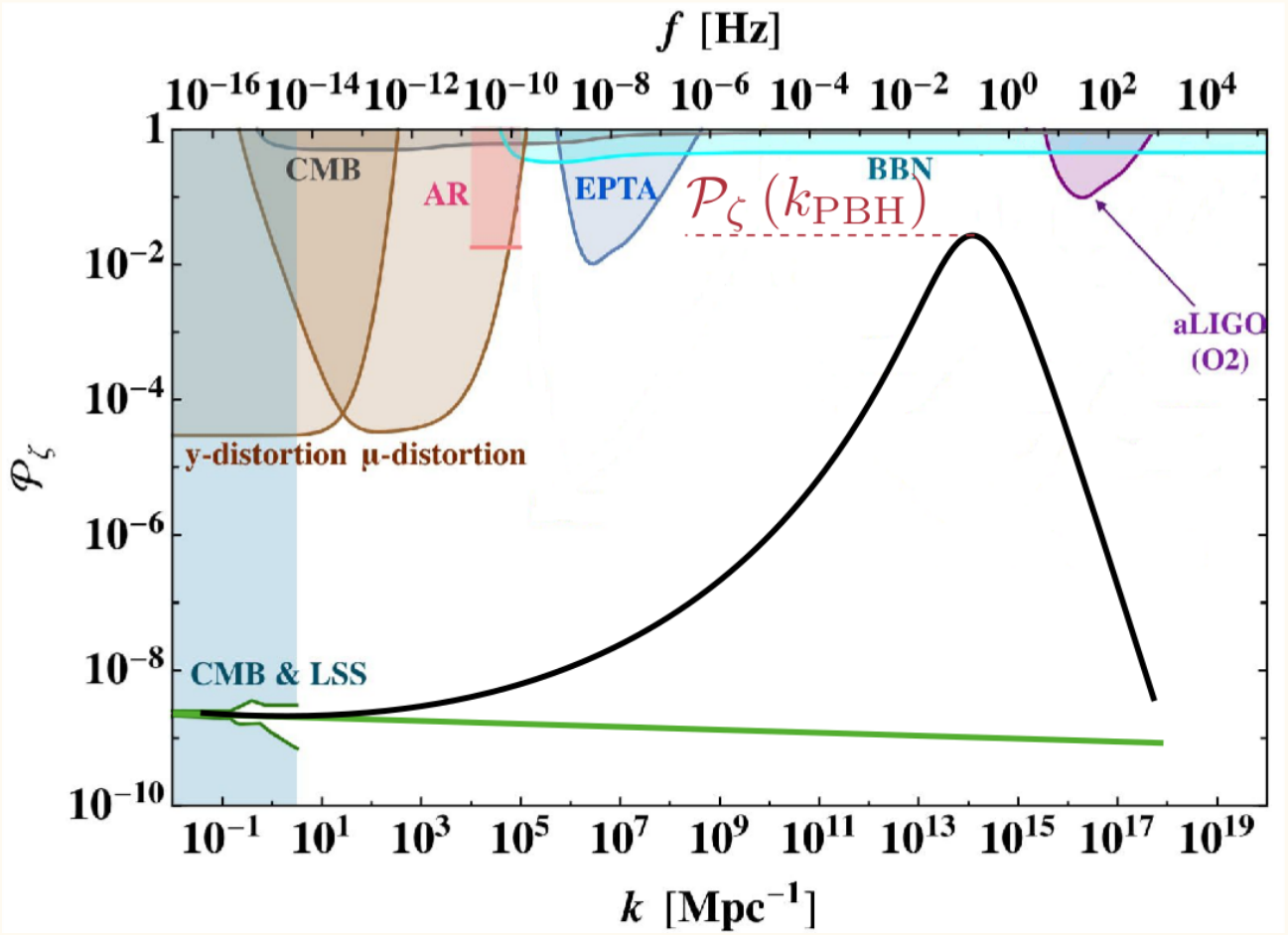
Adapted from Inomata and Nakama (2019)

Primordial Perturbation Spectrum



Adapted from Inomata and Nakama (2019)

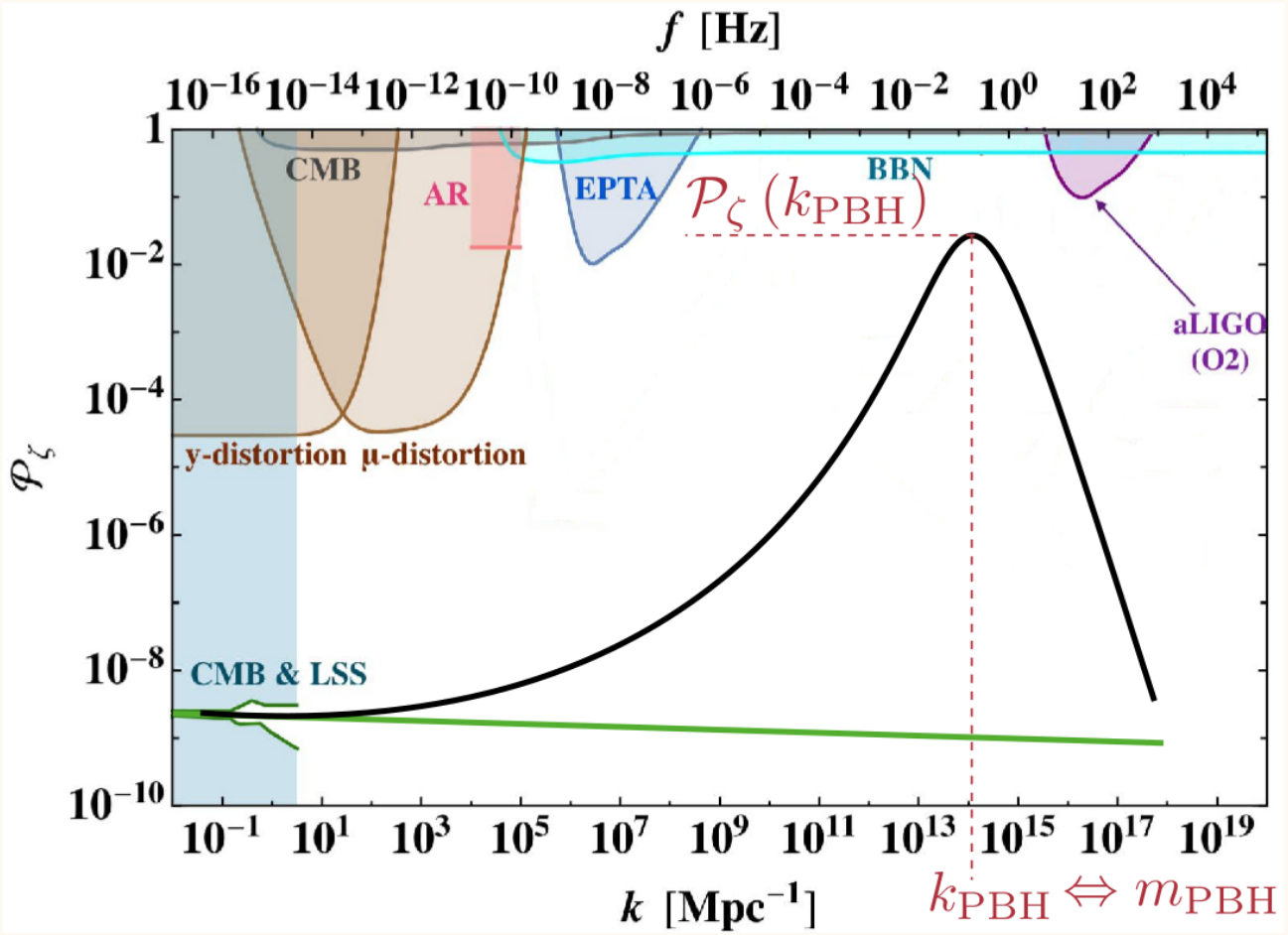
Primordial Perturbation Spectrum



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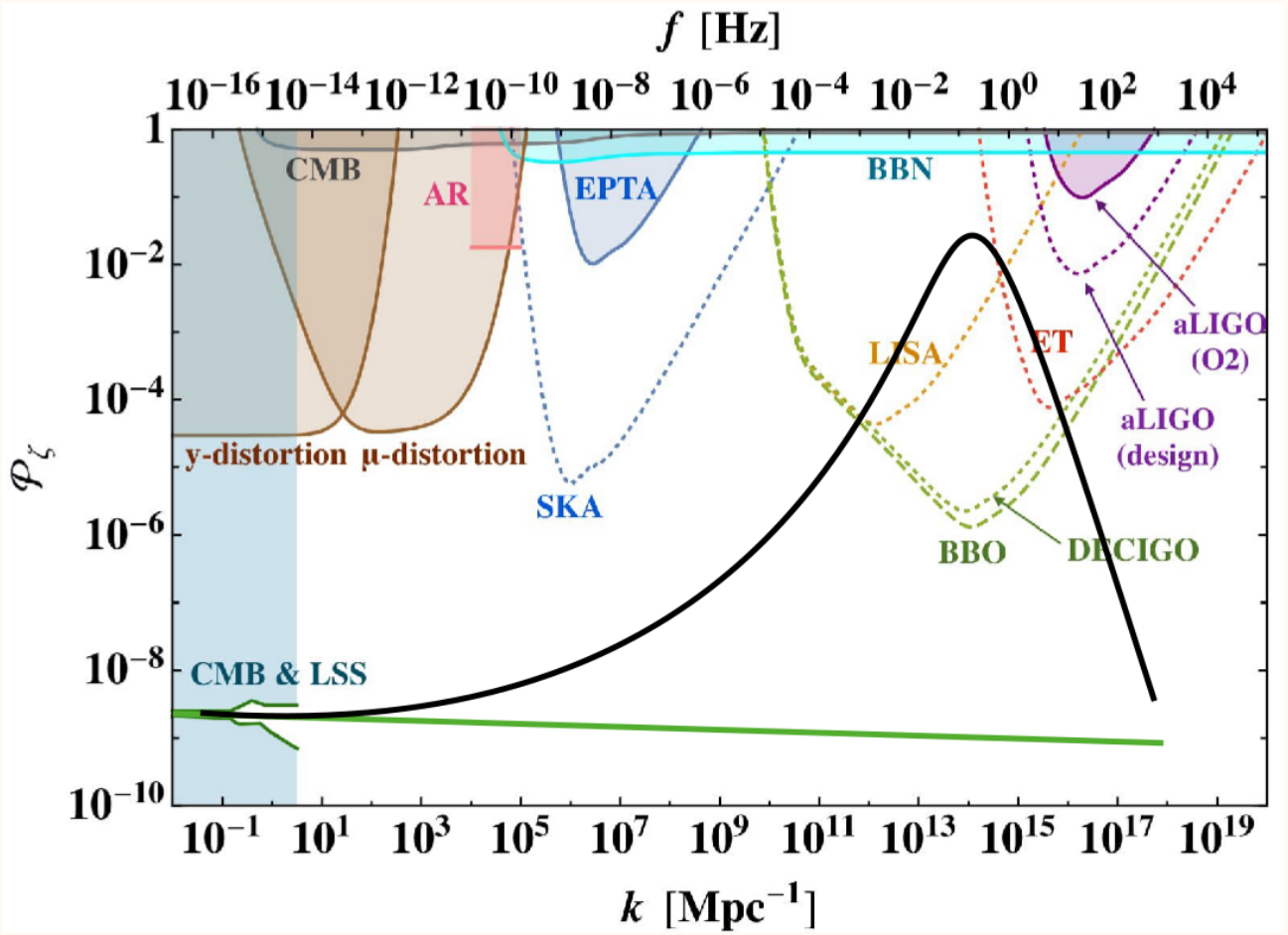
$\mathcal{P}_{\zeta \max} \simeq 10^{-1.5}$ at $\sim 30 - 35$ e-folds after the pivot scale exits the horizon.

Primordial Perturbation Spectrum



Adapted from Inomata and Nakama (2019)

Primordial Perturbation Spectrum



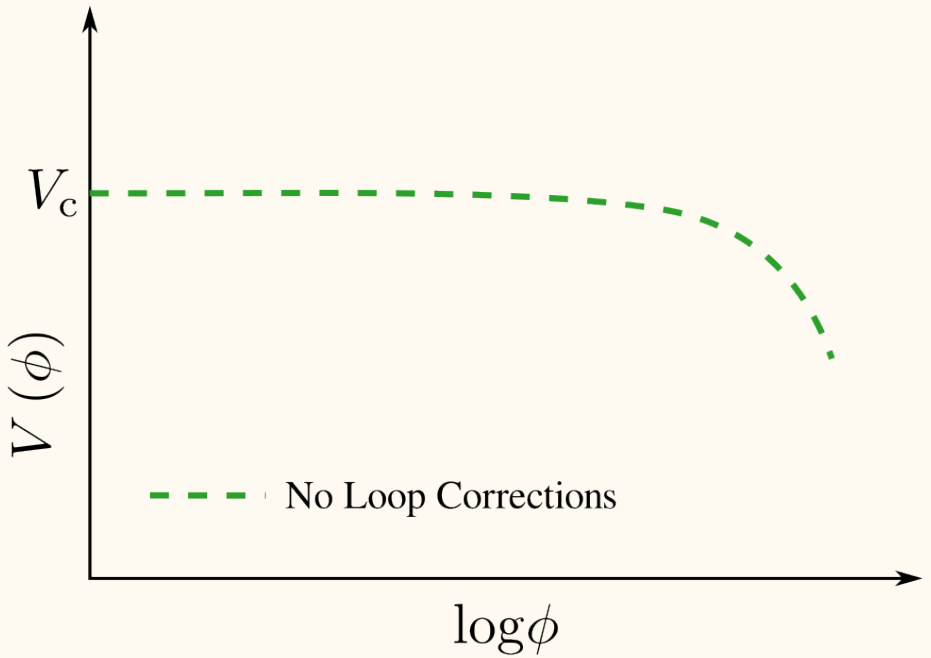
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Running-Mass-Inflation

Running-Mass Inflation

Stewart (1997), Covi+ (1999, 2004), Leach+ (2000), Alabidi+ (2006, 2009, 2012)

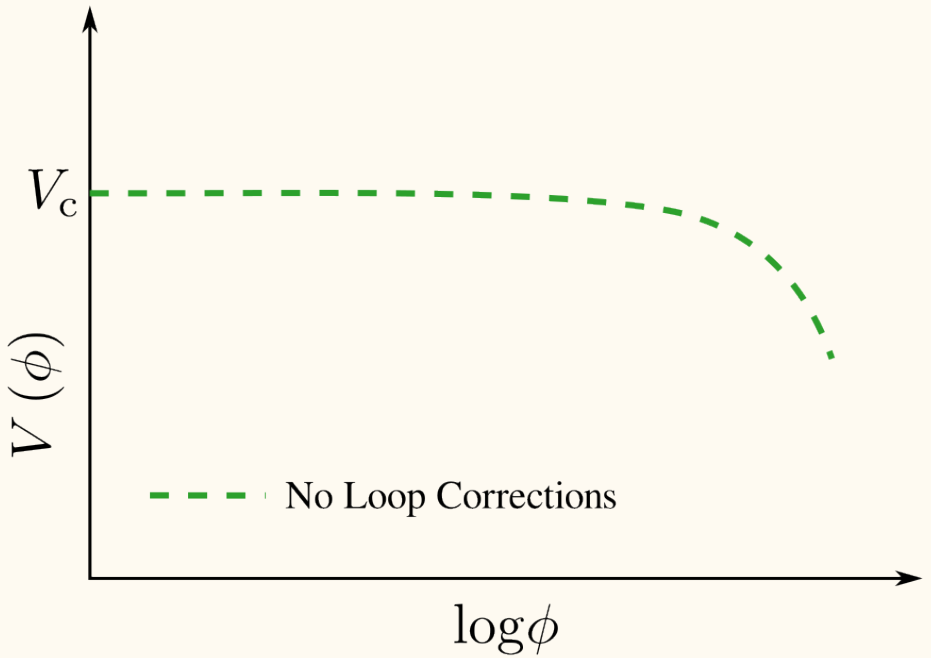
$$V \simeq V_{\rm c}\left[1-\frac{1}{2}\mu^2\frac{\phi^2}{m_{\rm Pl}^2}+\ldots\right]$$



Running-Mass Inflation

Stewart (1997), Covi+ (1999, 2004), Leach+ (2000), Alabidi+ (2006, 2009, 2012)

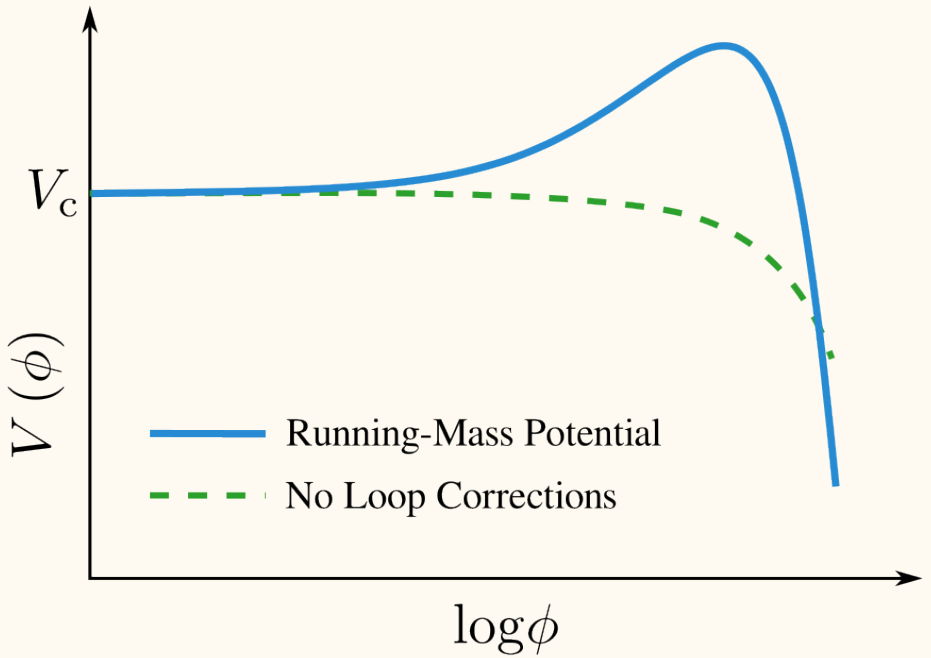
$$\mu = \mu\left[\mu_0, A, \alpha \ln \frac{\phi}{m_{\rm Pl}}\right]$$



Running-Mass Inflation

Stewart (1997), Covi+ (1999, 2004), Leach+ (2000), Alabidi+ (2006, 2009, 2012)

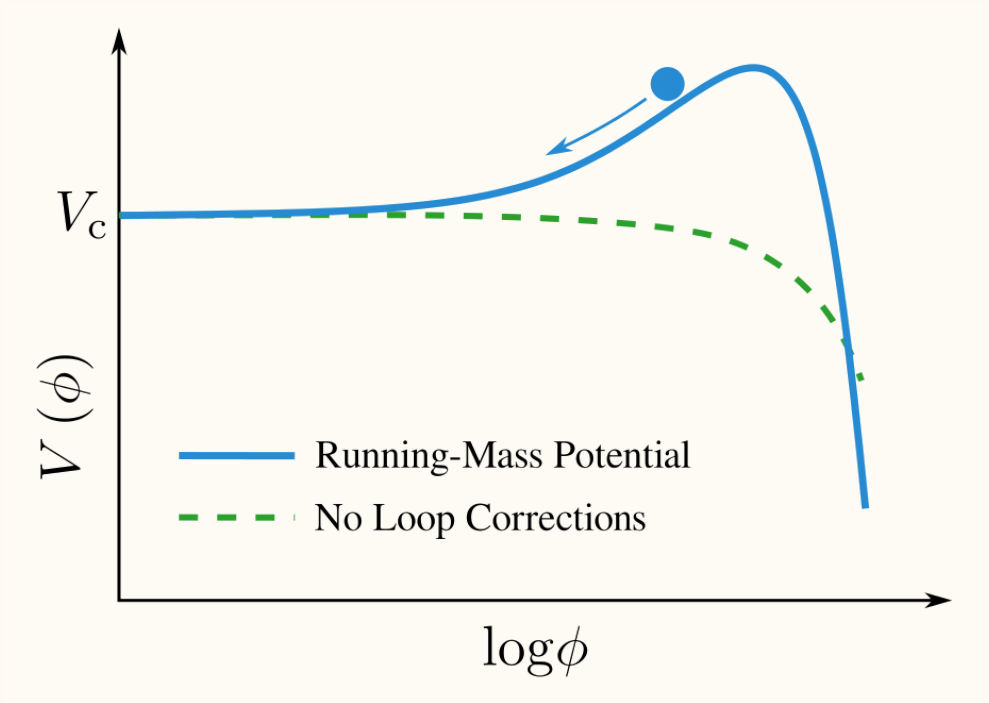
$$V(\phi) = V_{\rm c}\left[1 - \frac{1}{2}\frac{\phi^2}{m_{\rm Pl}^2}\left(B - \frac{A}{\left(1+\alpha\ln\frac{\phi}{m_{\rm Pl}}\right)^2}\right)\right]$$



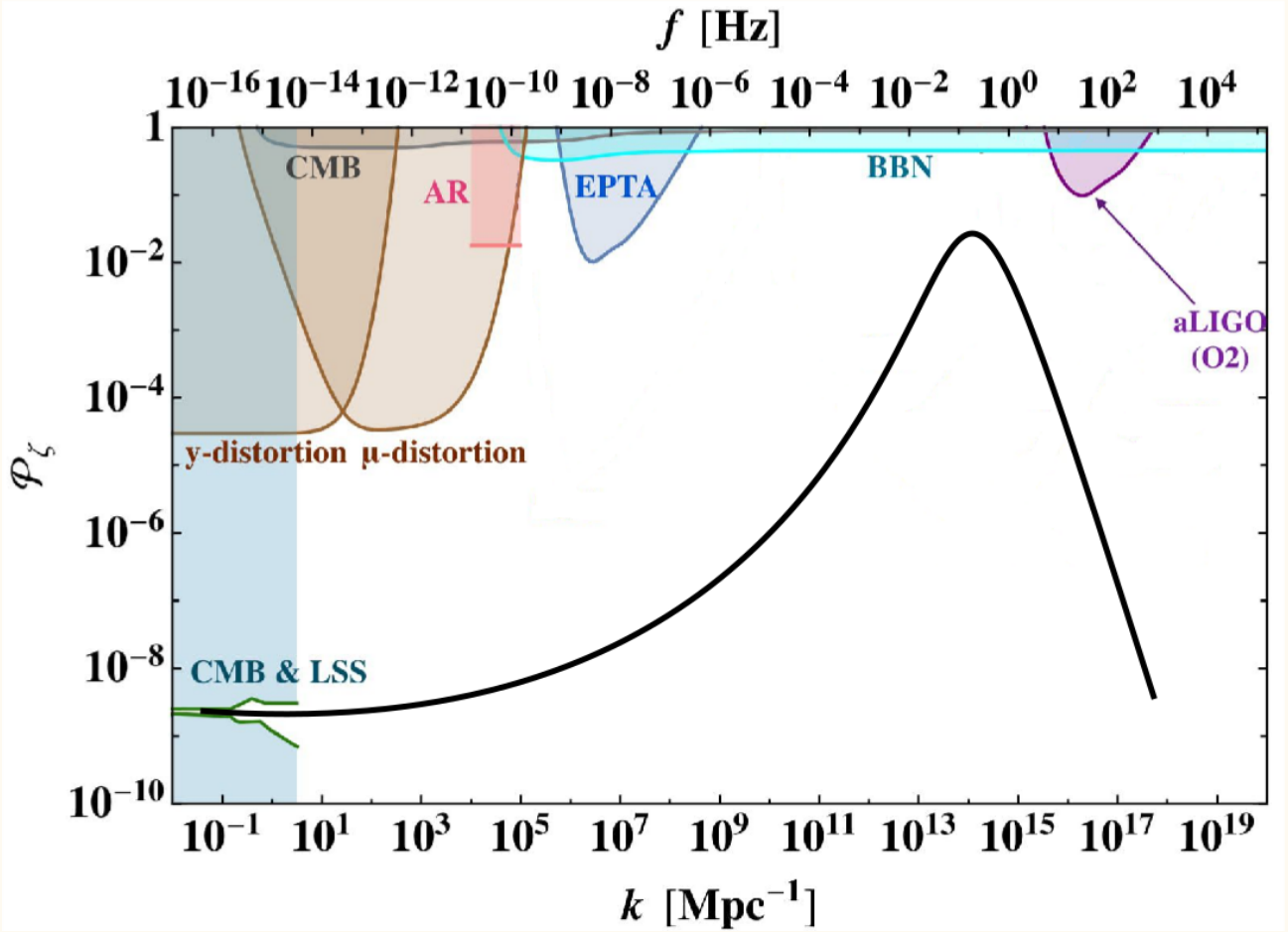
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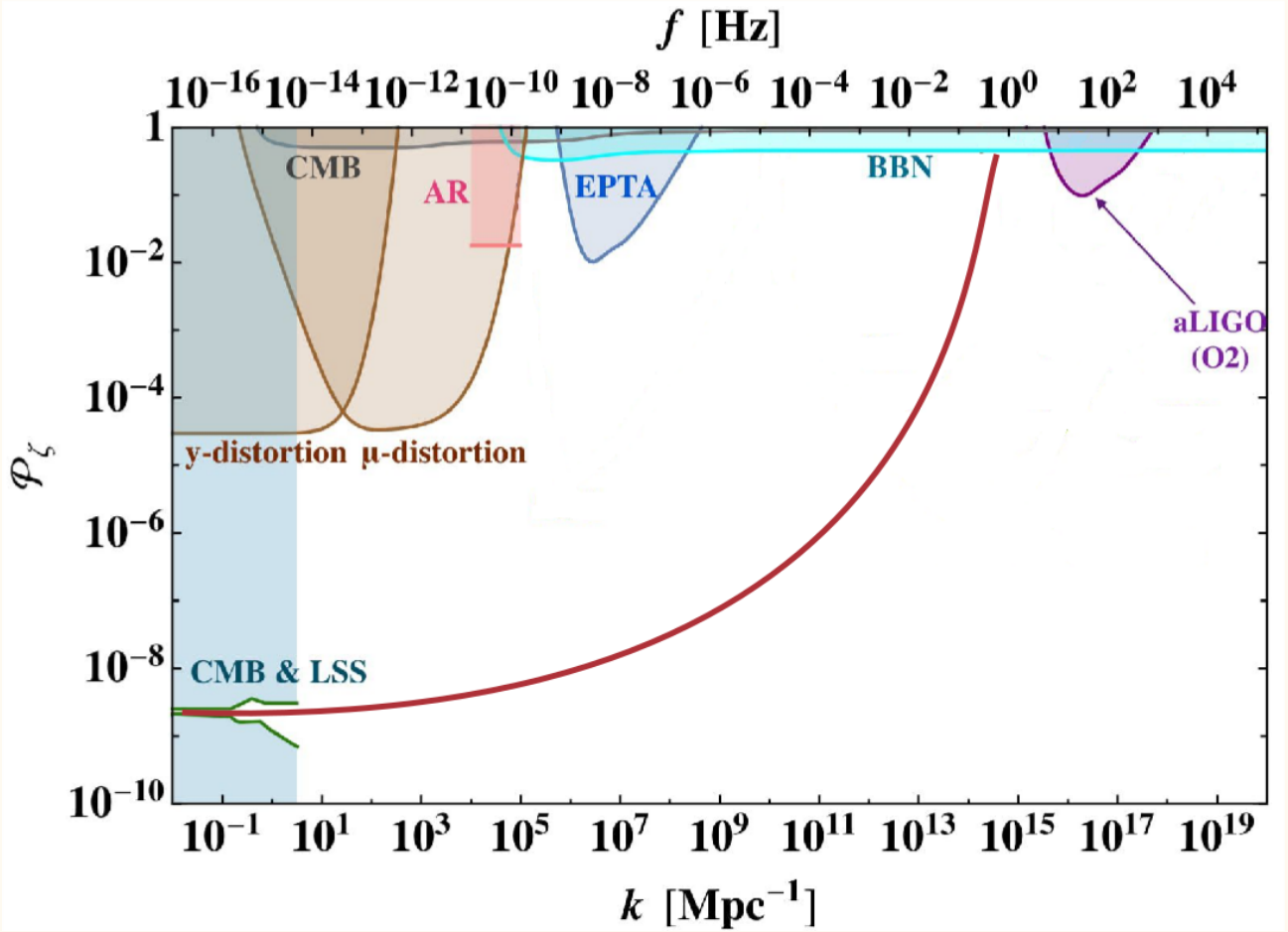
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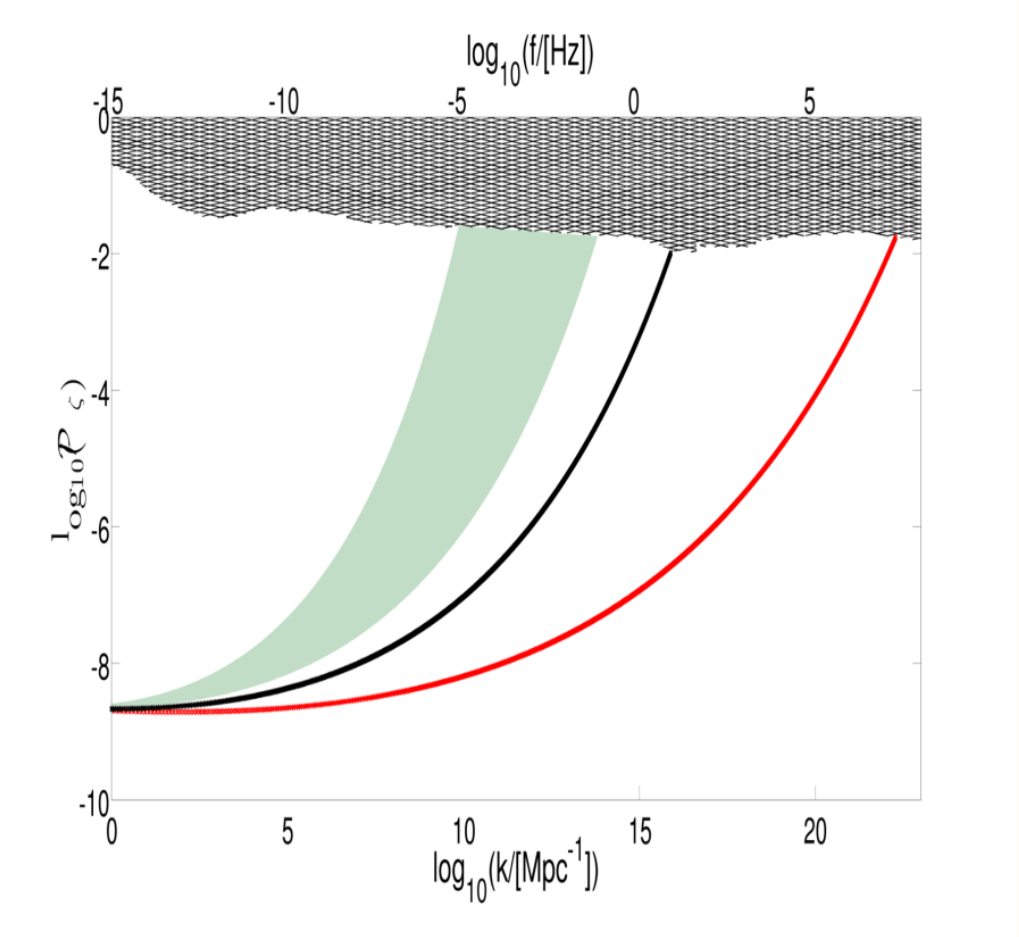
PBH Overproduction and Graceful Exit



PBH Overproduction and Graceful Exit



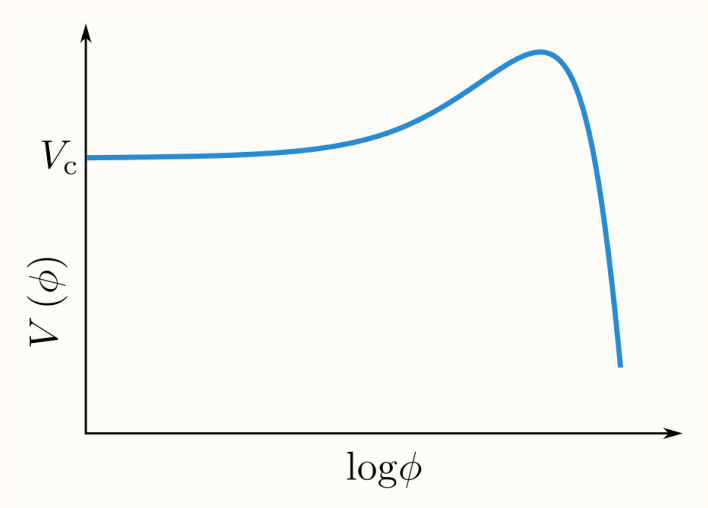
PBH Overproduction and Graceful Exit



Alabidi, Kohri, Sasaki, Sendouda (2012)

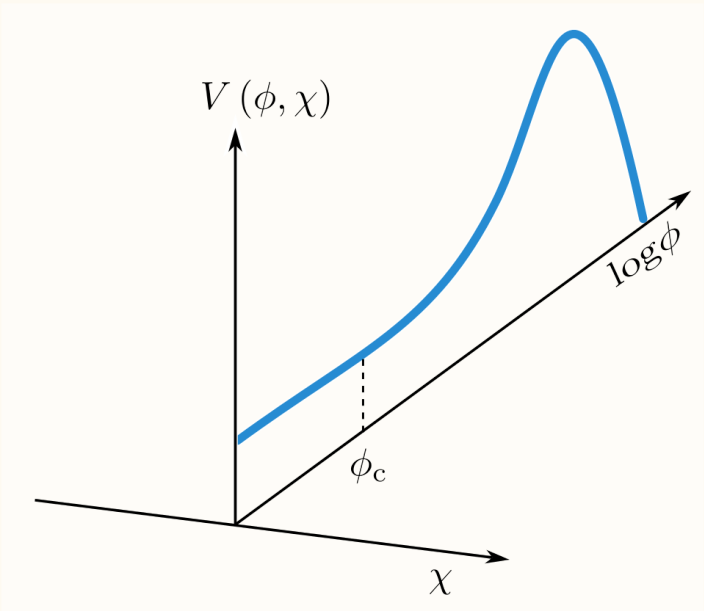
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$$V(\phi) = V_c \left[1 - \frac{1}{2} \frac{\phi^2}{m_{\rm Pl}^2} \left(B - \frac{A}{\left(1 + \alpha \ln \frac{\phi}{m_{\rm Pl}} \right)^2} \right) \right]$$



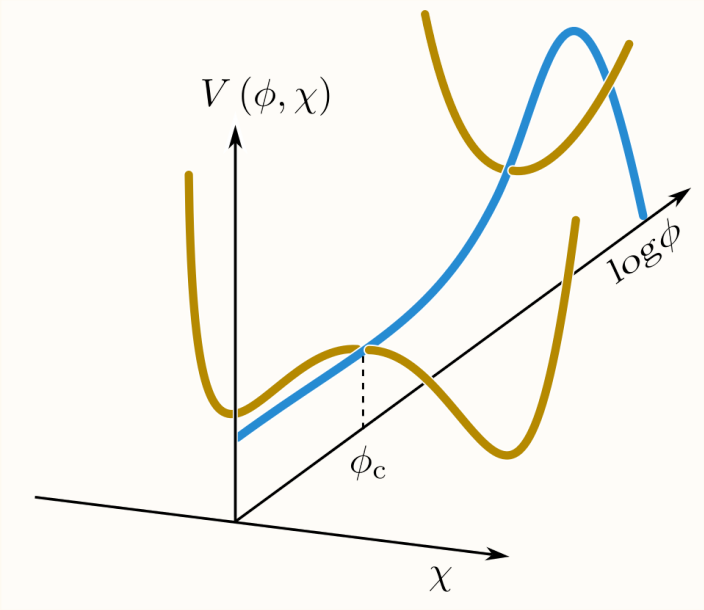
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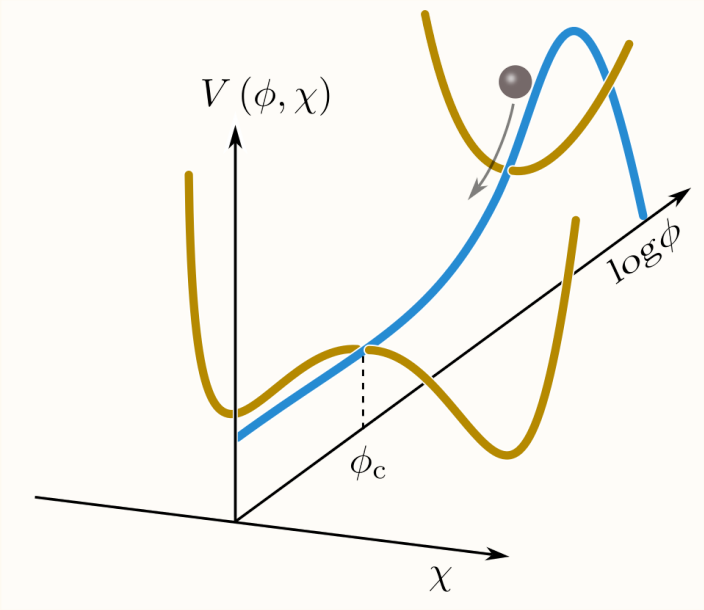
PBH Overproduction and Graceful Exit

$$V(\phi,\chi) \quad = \quad V(\phi) - \frac{1}{2}m^2\chi^2 + \frac{1}{2}g^2\chi^2(\phi-\phi_c)^2 + \lambda\chi^4$$



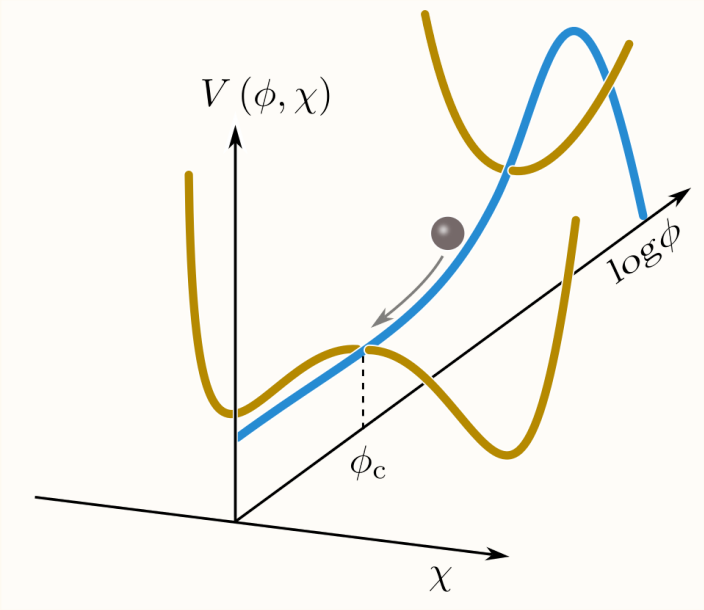
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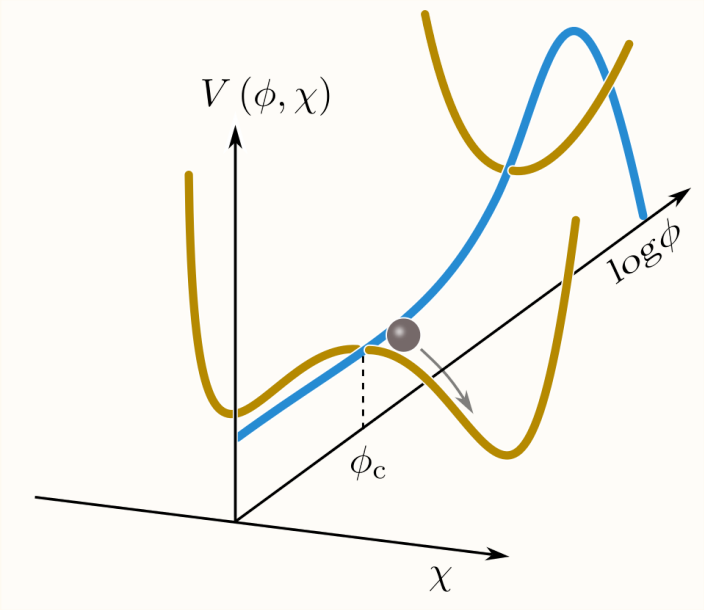
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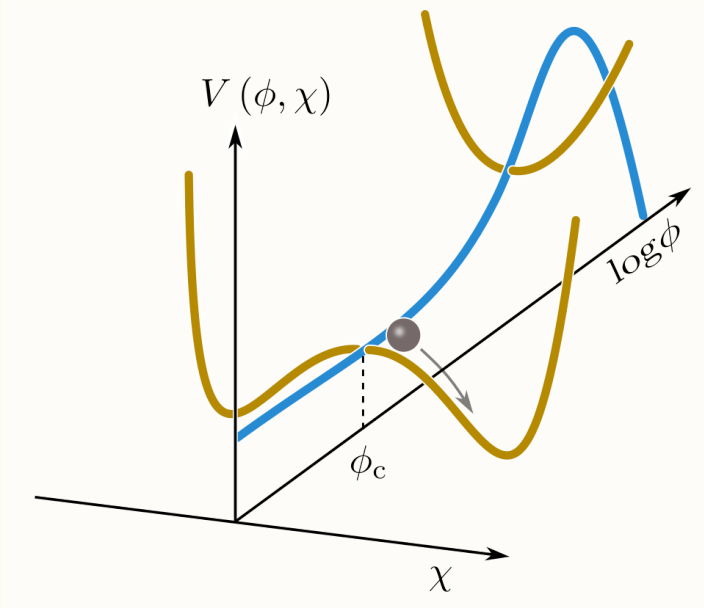
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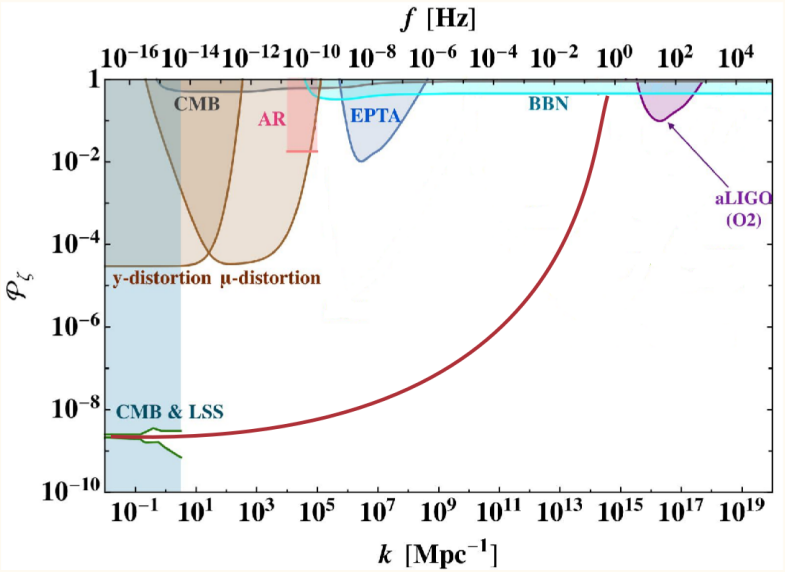
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PBH Overproduction and Graceful Exit

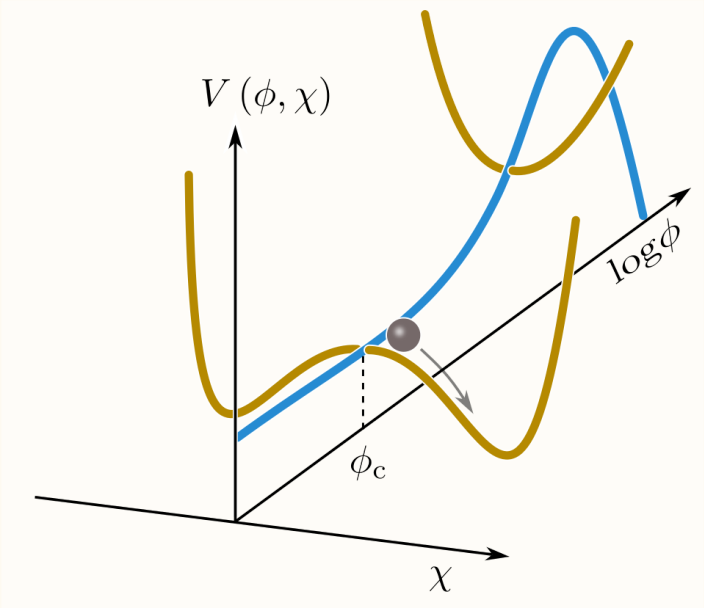
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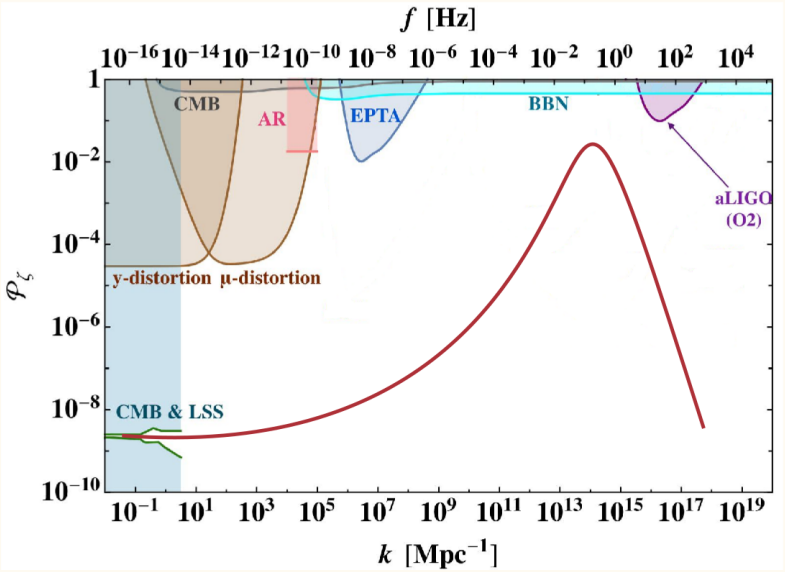




PBH Overproduction and Graceful Exit

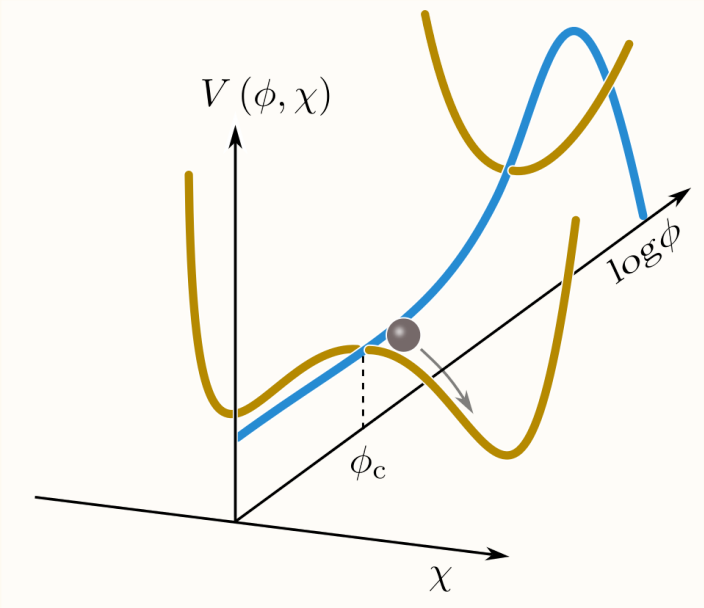
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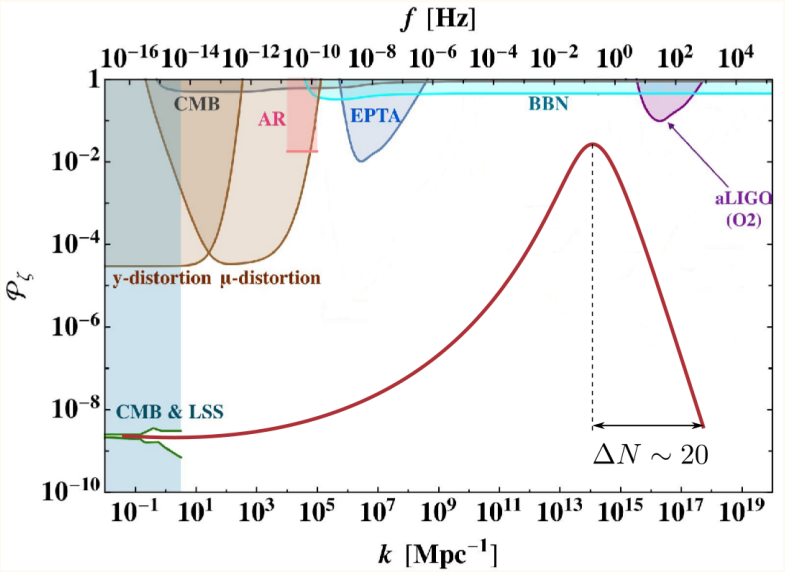




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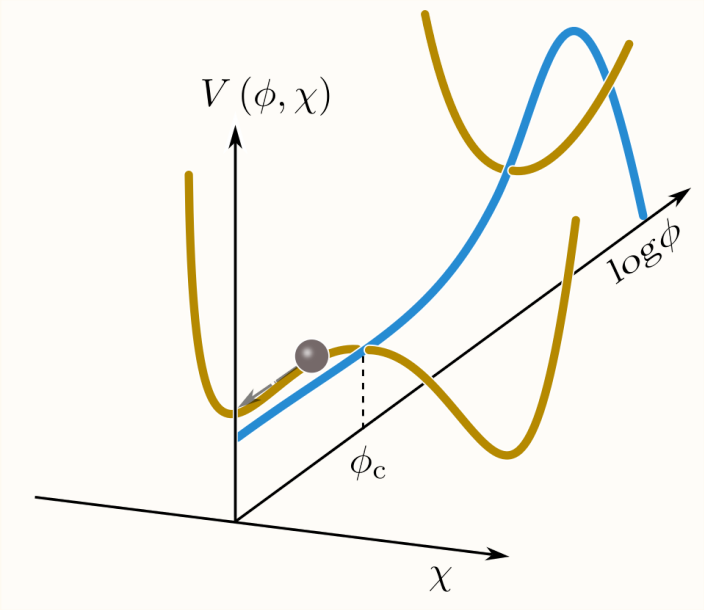
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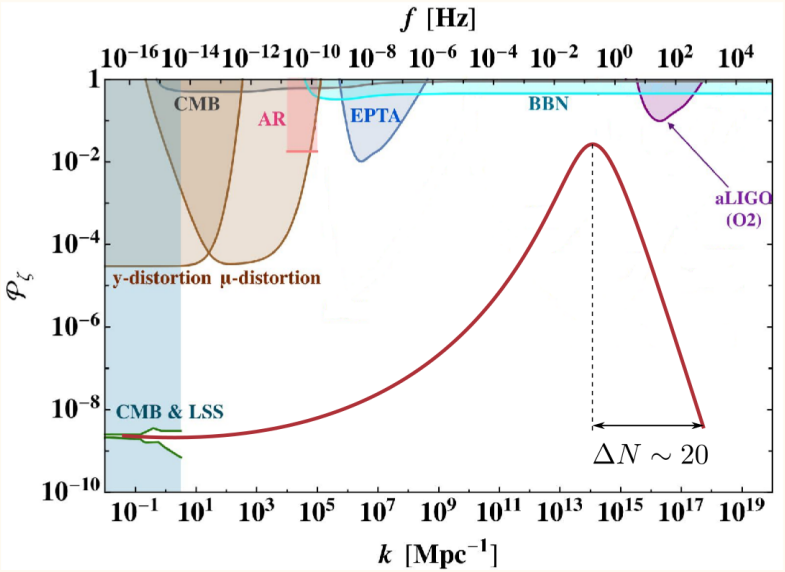




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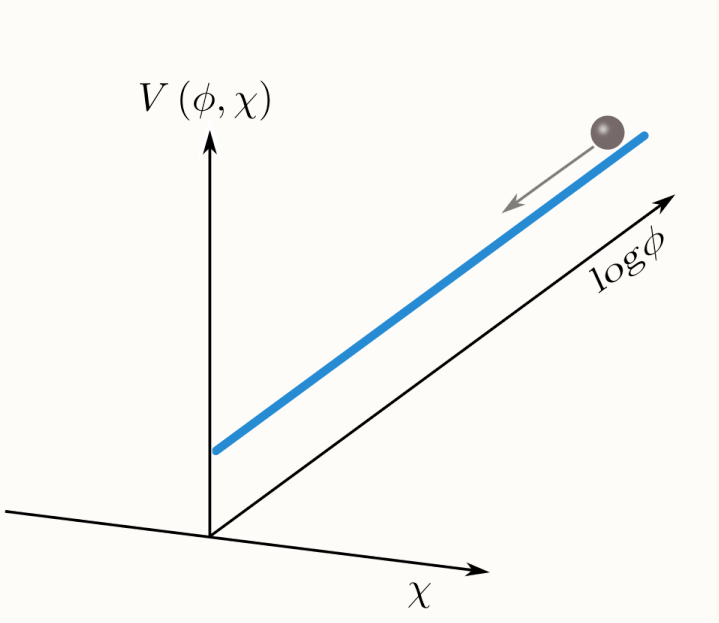


Tachyonic Trap

Beauty is Attractive

Kofman, Linde, Liu, Maloney, McAllister, Silverstein,
"Beauty is attractive: Moduli trapping at enhanced symmetry points" (2004)

$$\mathcal{L} = -\partial_\mu \phi \partial^\mu \phi + V_c$$

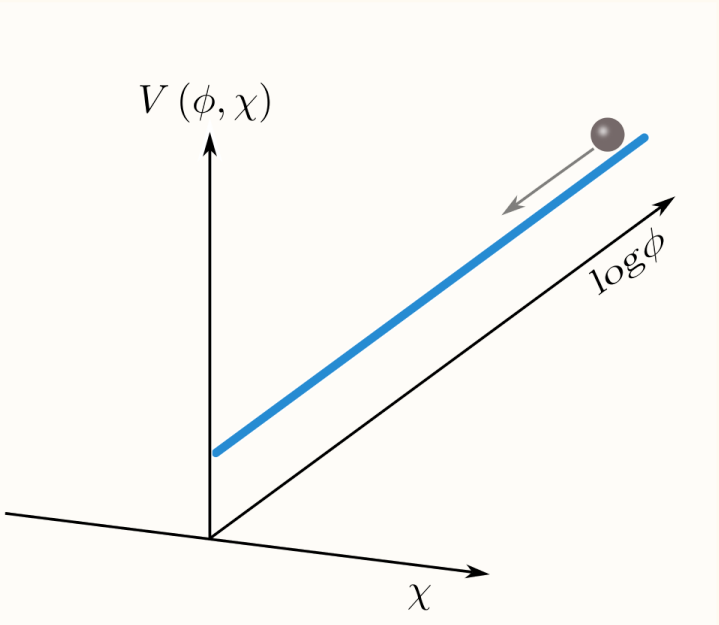


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$$\phi \simeq \dot{\phi}_c t$$

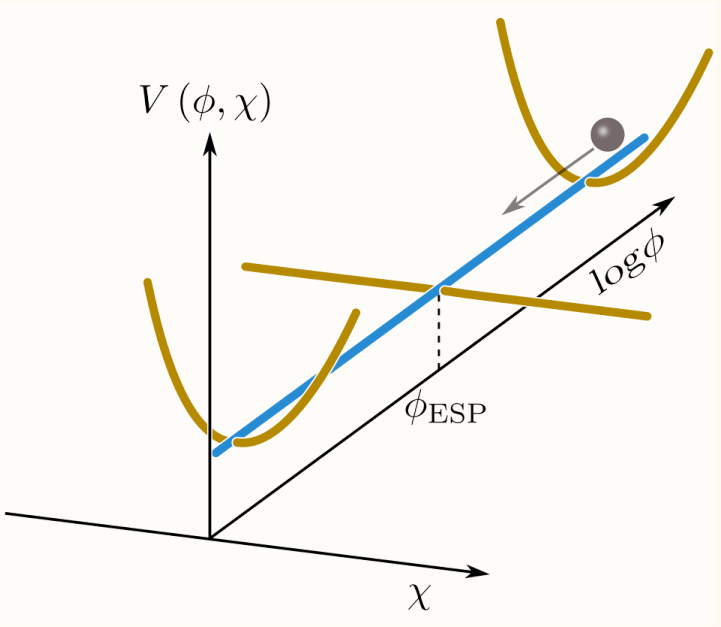


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$$\mathcal{L} = -\partial_\mu \phi \partial^\mu \phi + V_c - \partial_\mu \chi \partial^\mu \chi - \frac{1}{2} g^2 \chi^2 (\phi - \phi_{\rm ESP})^2$$

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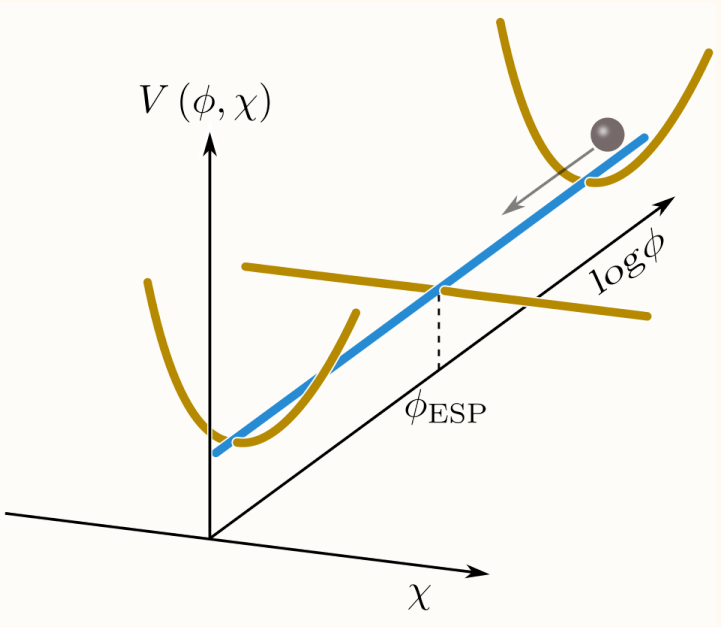


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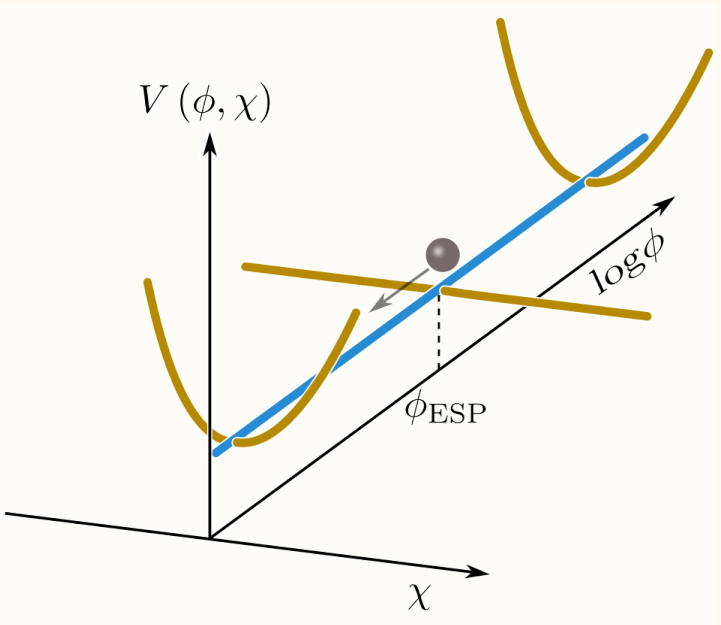


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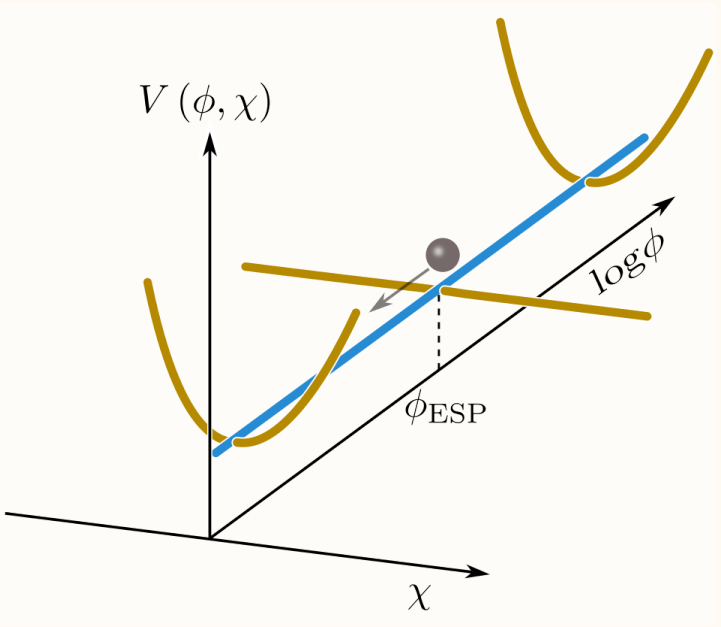


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$$\delta\ddot{\chi}_k + \omega_k^2 \delta\chi_k = 0; \qquad \omega_k^2 = k^2 + g^2 (\phi - \phi_{\rm SBP})^2$$

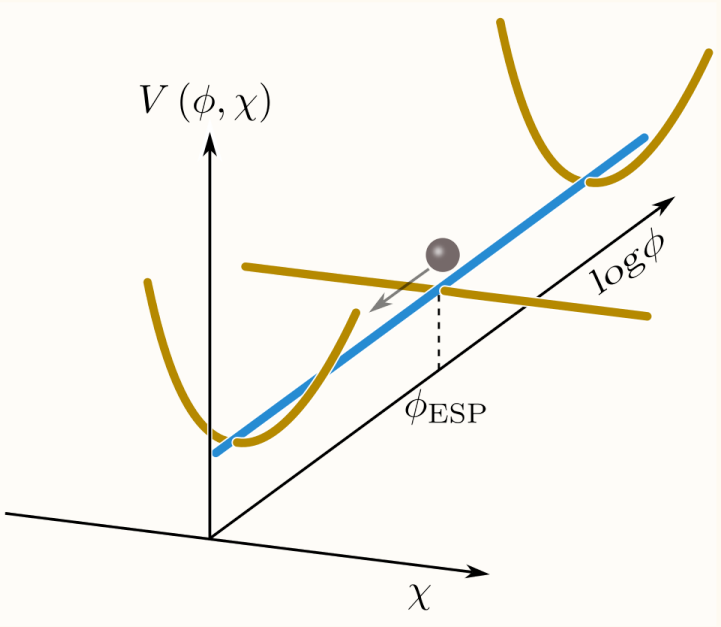


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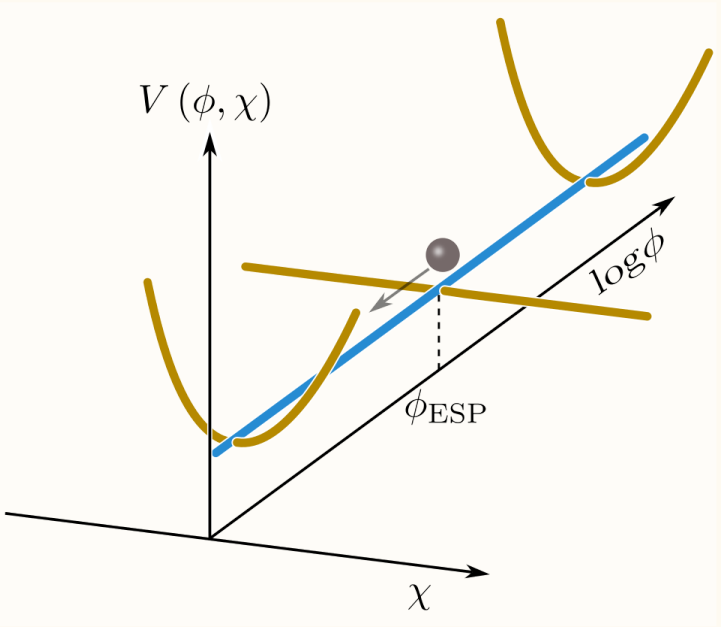


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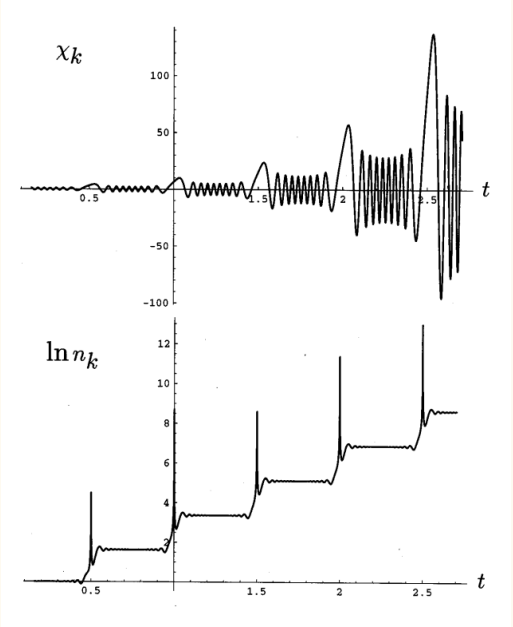


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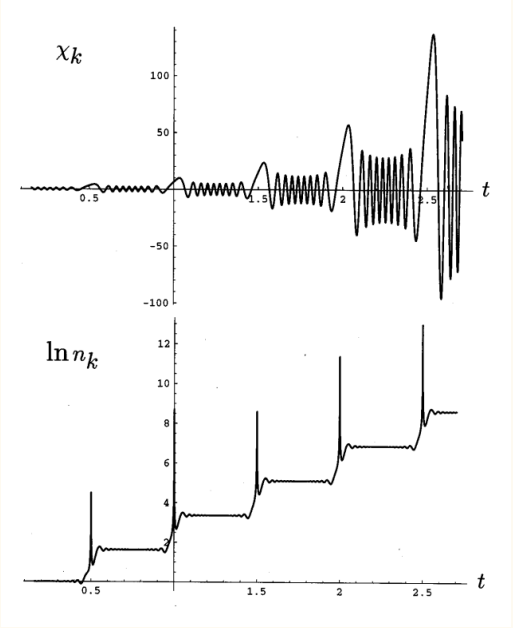
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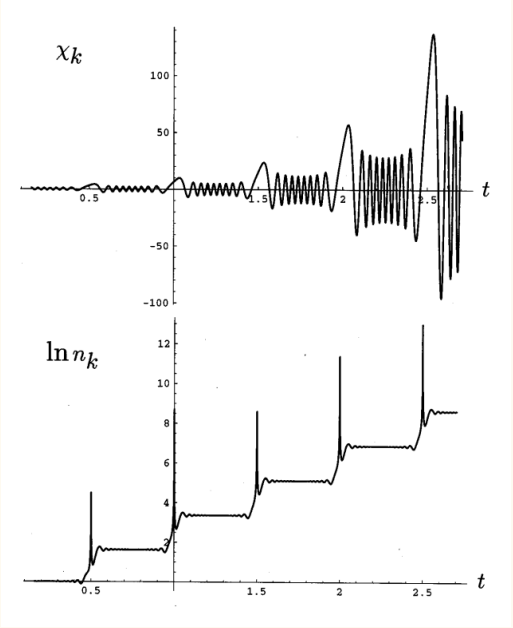
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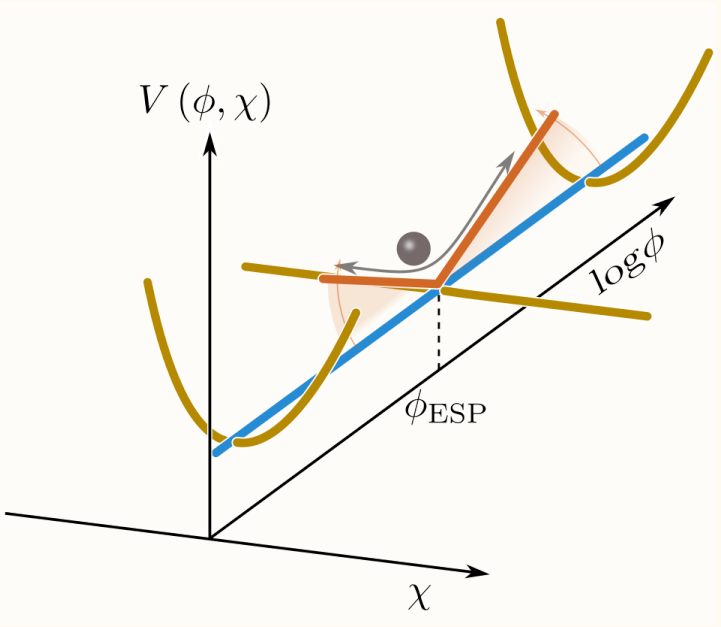
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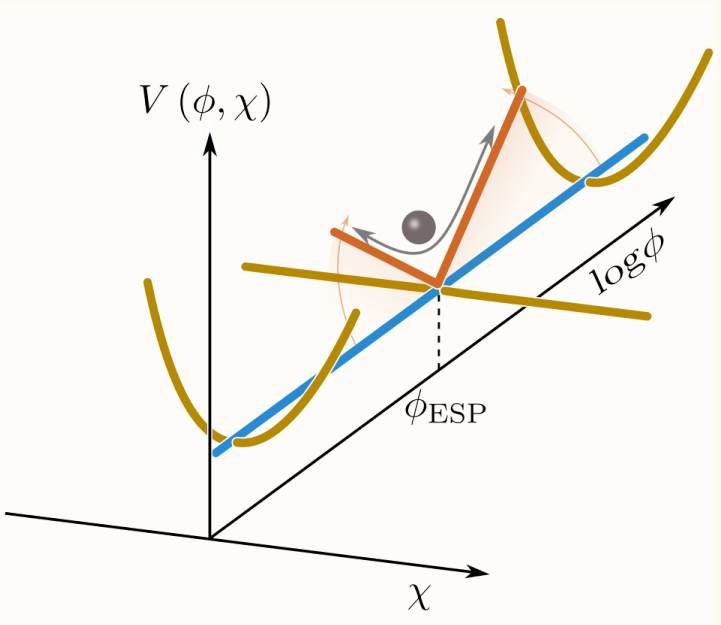


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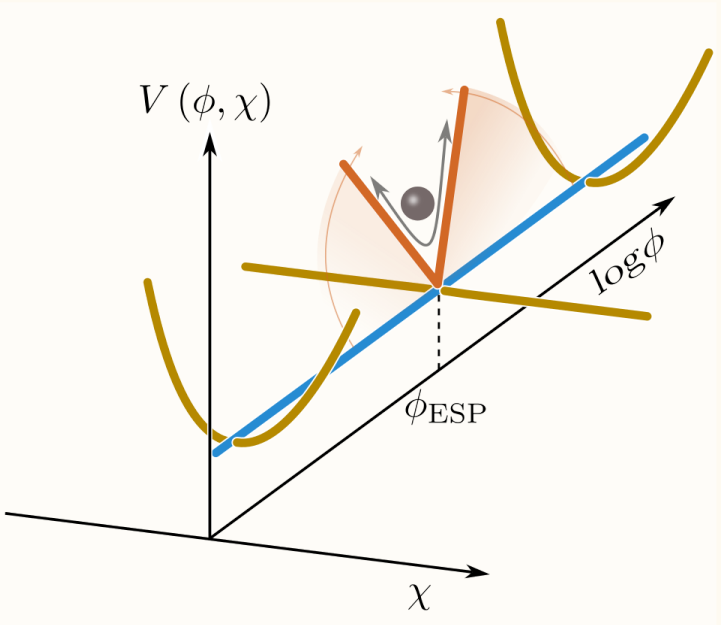


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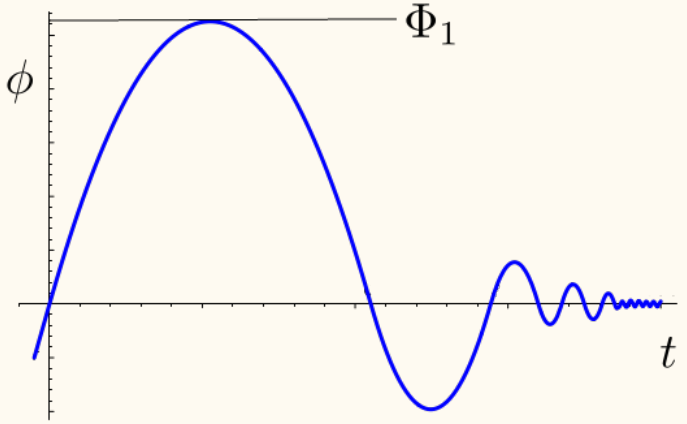


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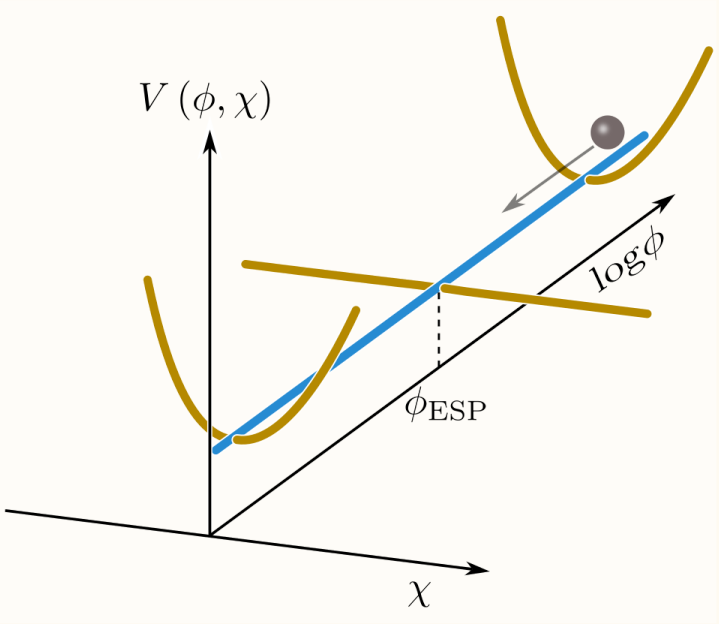
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Tachyonic Trap

Dimopoulos, MK, Owen (2019), MK, Rusak, Saez (2022)

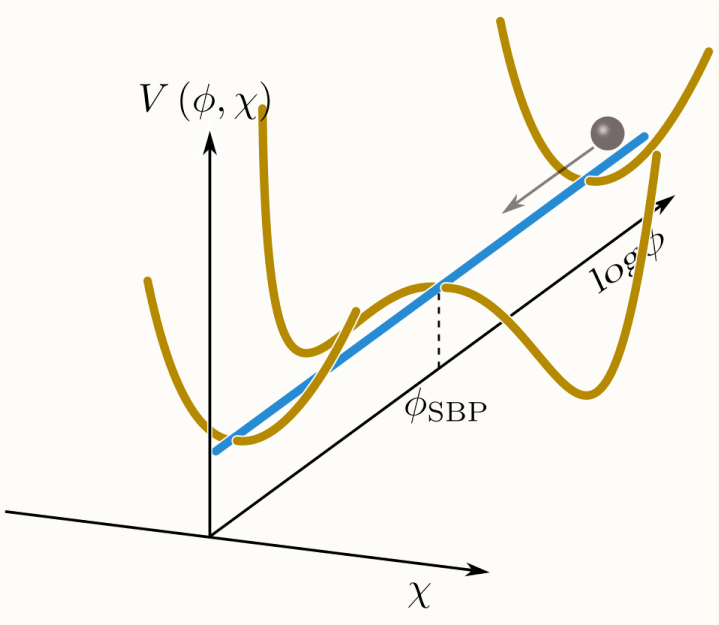
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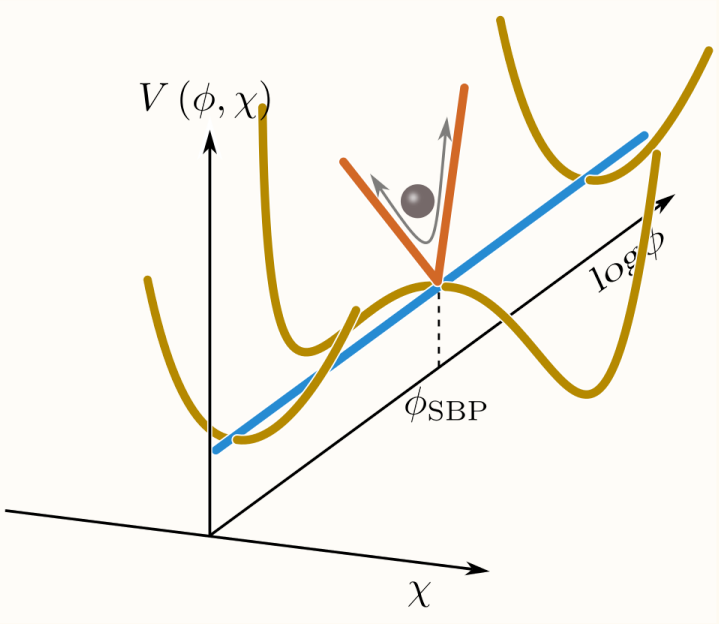
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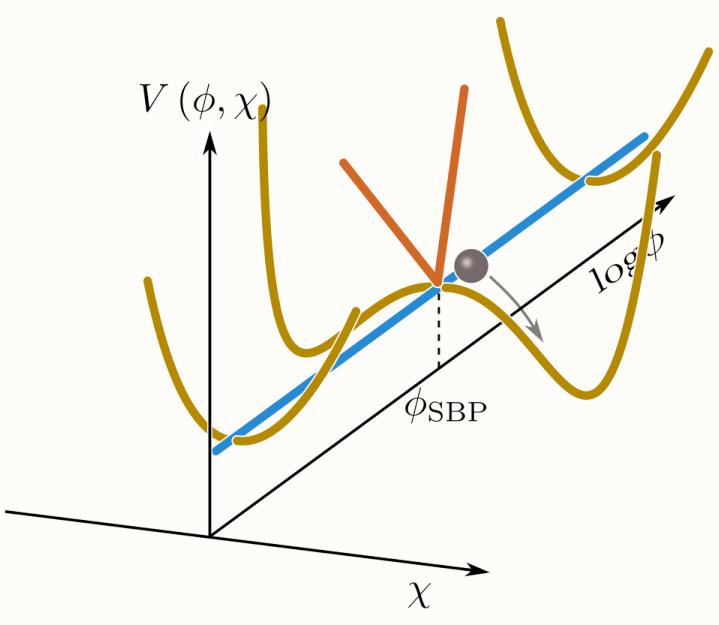
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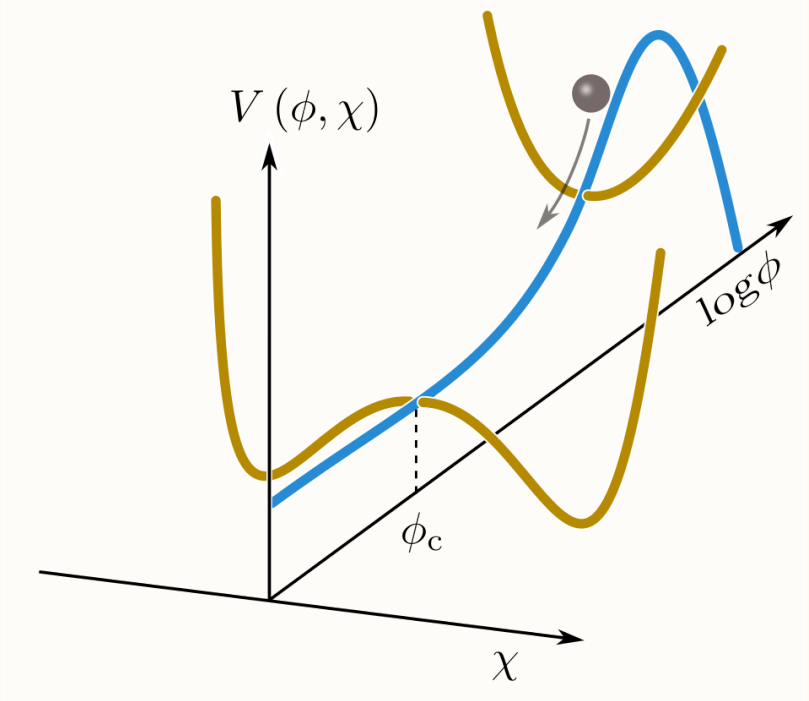
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Running-Mass-Inflation

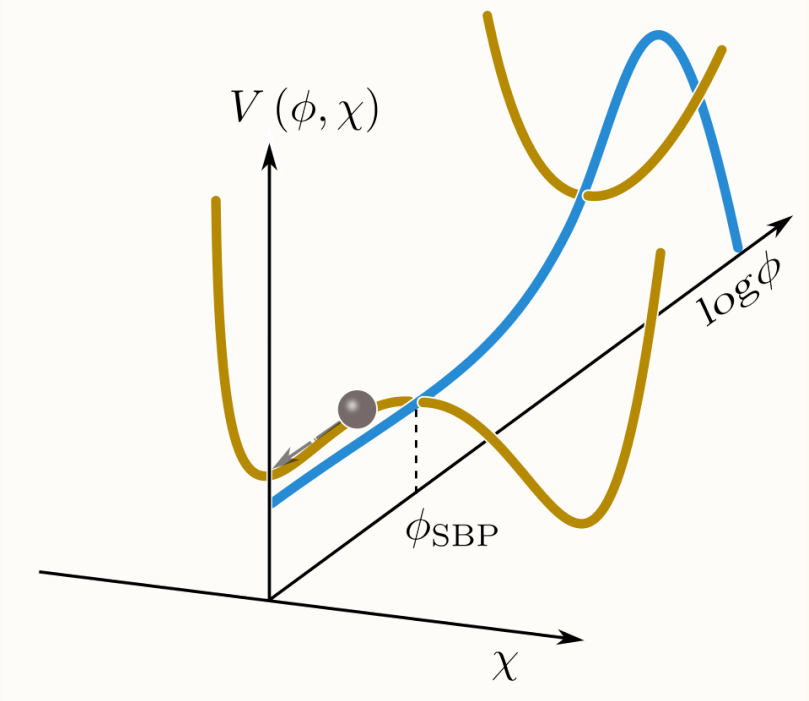
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$$V(\phi,\chi) \quad = \quad V(\phi) - \frac{1}{2}m^2\chi^2 + \frac{1}{2}g^2\chi^2(\phi-\phi_c)^2 + \lambda\chi^4$$



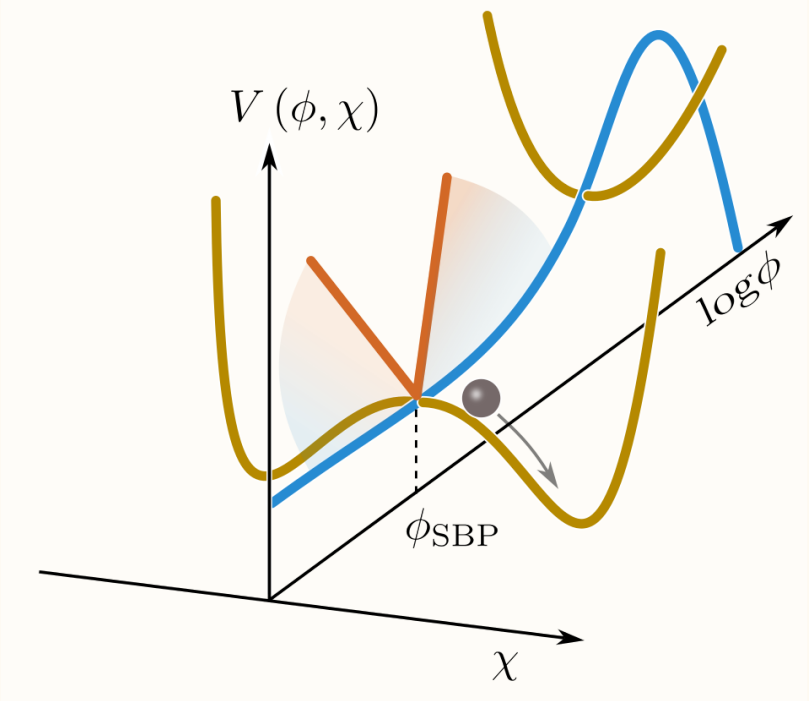
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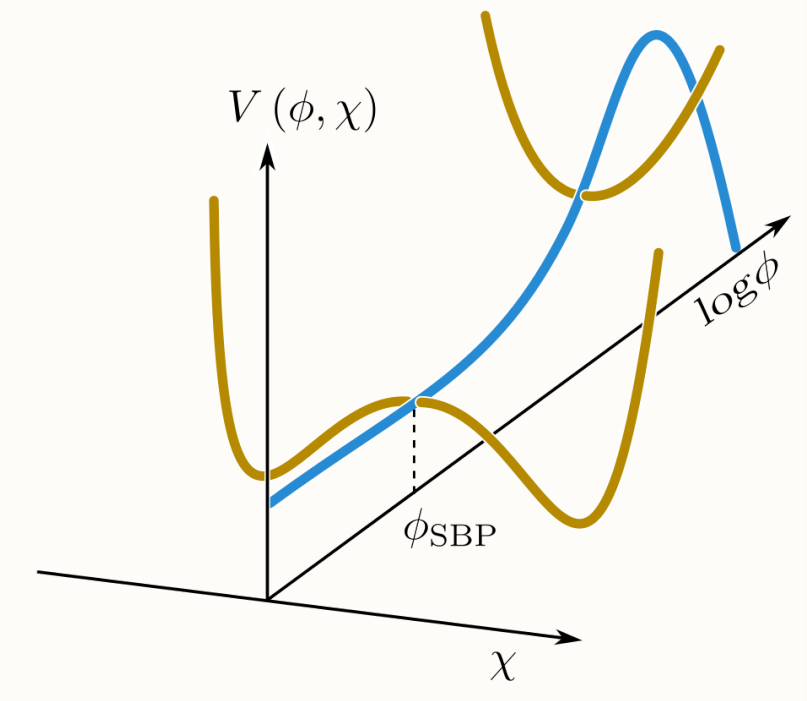
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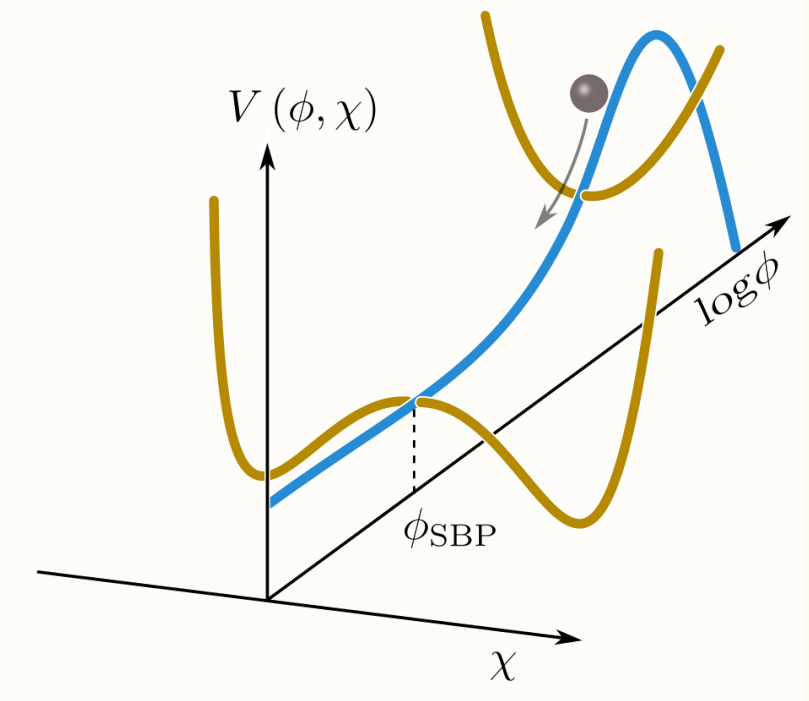
The Plan

1. Find models consistent with CMB observations;
2. Find parameters for PBHs



CMB Constraints

$$V(\phi_*) \quad = \quad V_c \left[1 - \frac{1}{2} \frac{\phi_*^2}{m_{\rm Pl}^2} \left(B - \frac{A}{\left(1 + \alpha \ln \frac{\phi_*}{m_{\rm Pl}} \right)^2} \right) \right]$$



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Scalar spectrum:

$$\mathcal{P}_\zeta = A_{\rm s} \left(\frac{k}{k_*} \right)^{n_{\rm s} - 1 + \frac{1}{2}\alpha_{\rm s} (\ln k/k_*) + \frac{1}{6}\beta_{\rm s} (\ln k/k_*)^2}$$

where (Akrami+ (2020))

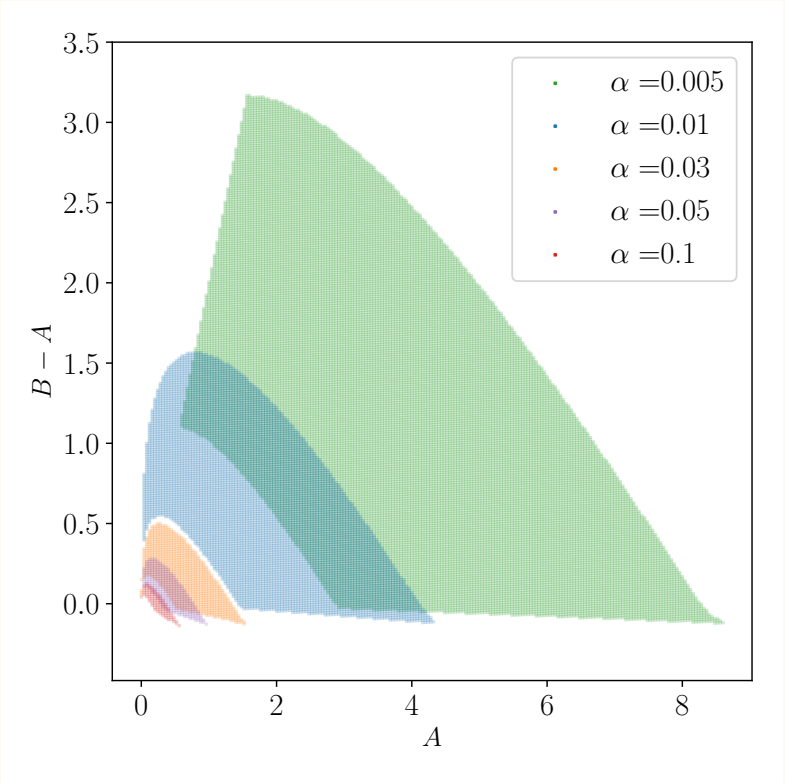
$$\begin{aligned} A_{\rm s} &= 3.044 \\ n_{\rm s} &= 0.9587 \pm 0.0056 \\ \alpha_{\rm s} &= 0.013 \pm 0.012 \\ \beta_{\rm s} &= 0.022 \pm 0.012 \end{aligned}$$

and (Ade+ (2021))

$$r < 0.036$$

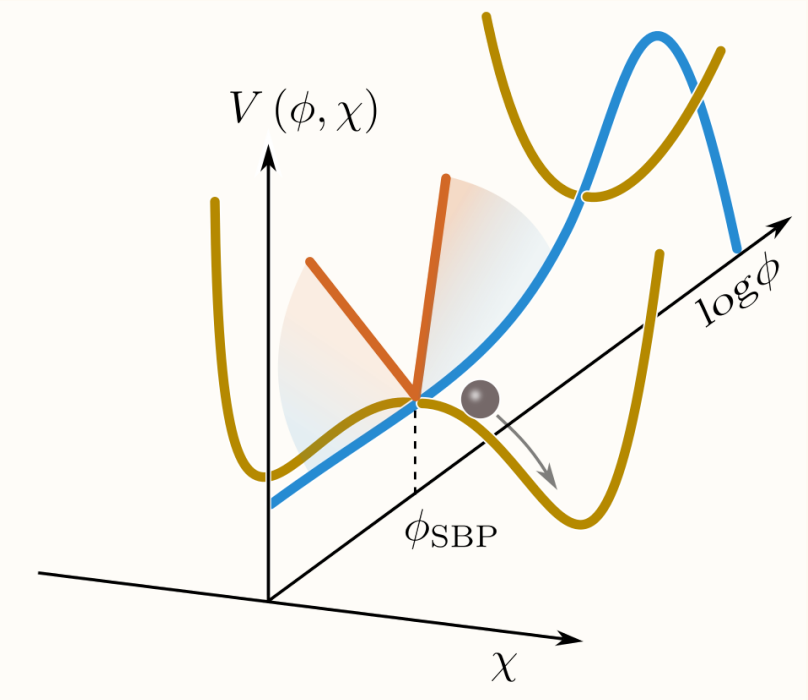
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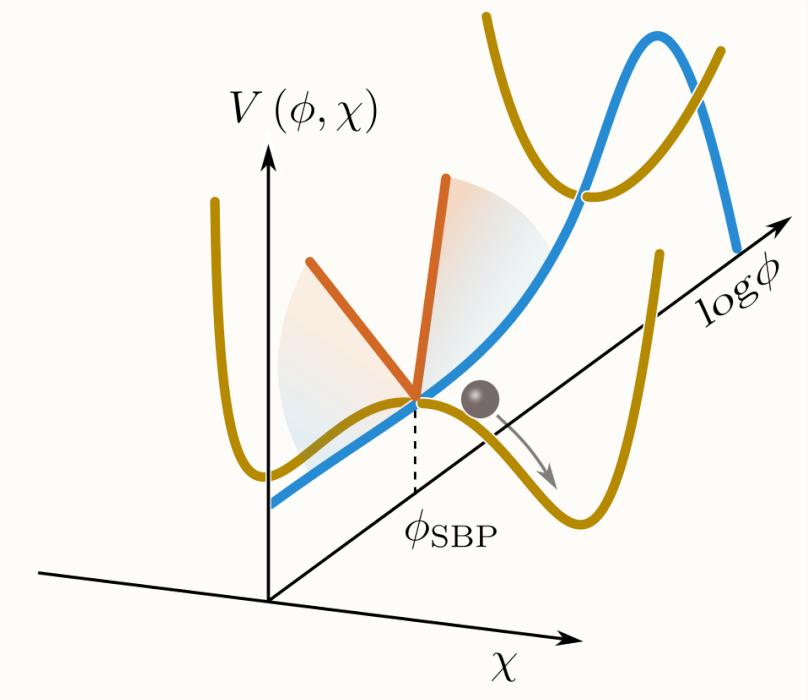
Resonance Parameters

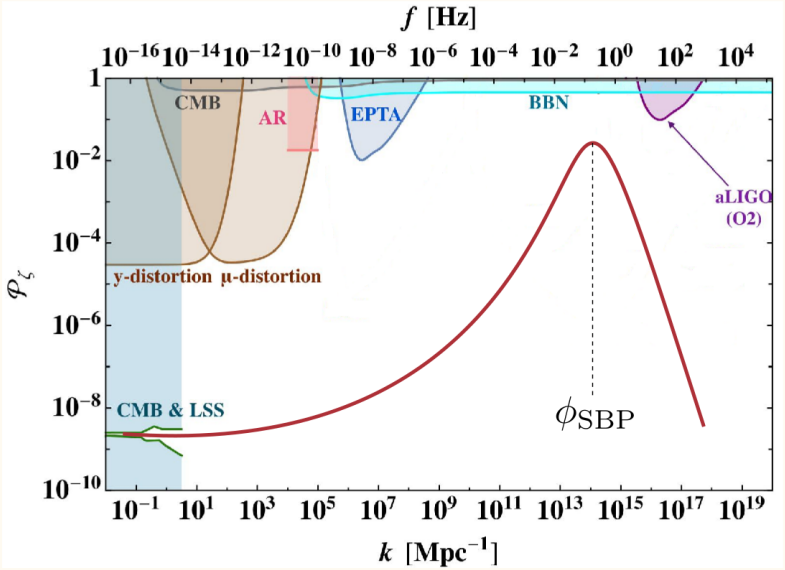
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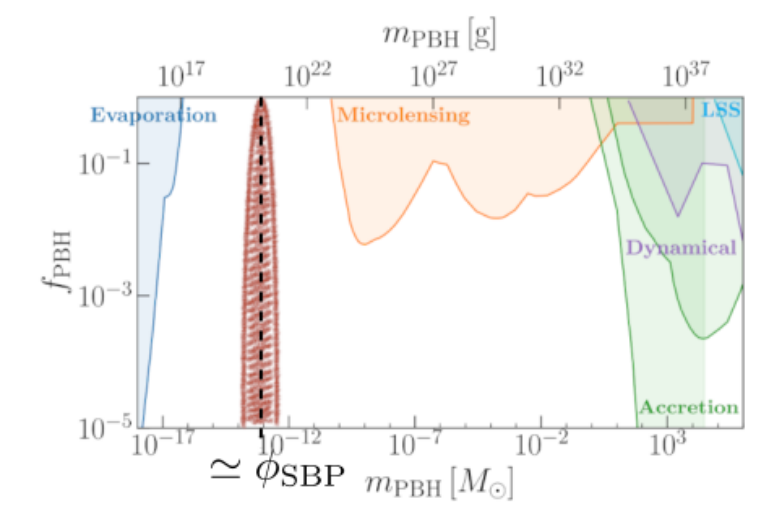
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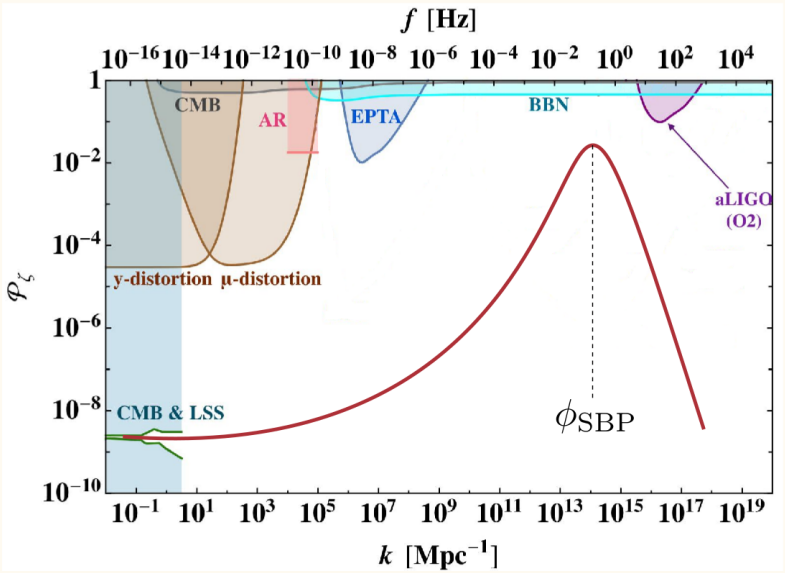




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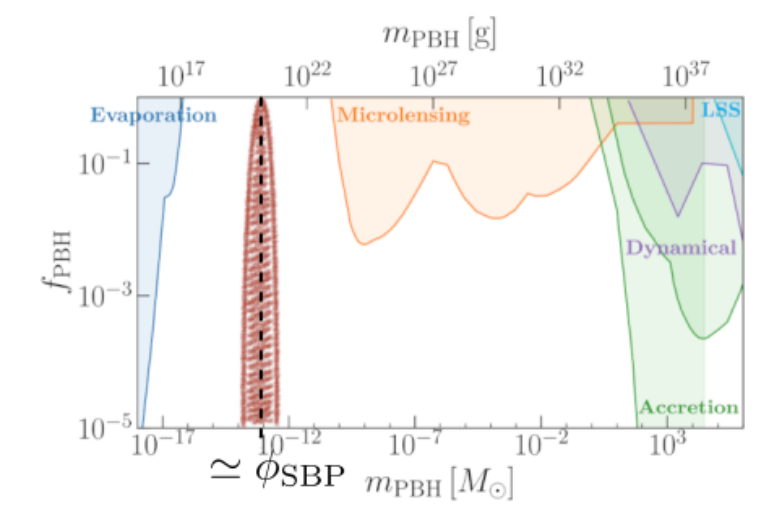
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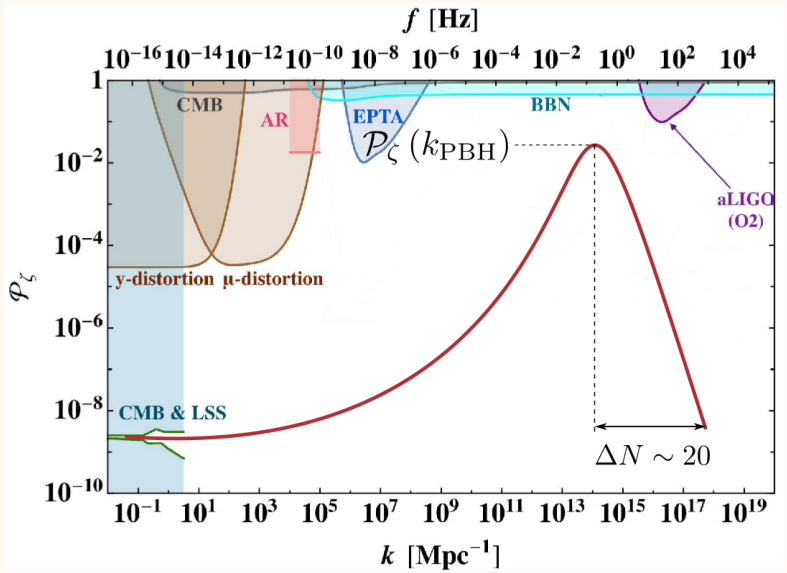




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Perturbations

Newtonian gauge:

$$\mathrm{d}s^2 = -\left(1+2\Phi\right)\mathrm{d}t^2 + a^2\left(t\right)\left(1+2\Phi\right)\delta_{ij}\mathrm{d}x^i\mathrm{d}x^j$$

Perturbations:

$$\delta\ddot{\phi}_k + 3H\delta\dot{\phi}_k + \left(\frac{k^2}{a^2} + V_{,\phi\phi}\right)\delta\phi_k = 2\left(2\dot{\phi}\dot{\Phi}_k - V_{,\phi}\Phi_k\right) - V_{,\phi\chi}\delta\chi_k$$

$$\delta\ddot{\chi}_k + 3H\delta\dot{\chi}_k + \left(\frac{k^2}{a^2} + V_{,\chi\chi}\right)\delta\chi_k = 2\left(2\dot{\chi}\dot{\Phi}_k - V_{,\chi}\Phi_k\right) - V_{,\phi\chi}\delta\phi_k$$

$$\dot{\Phi}_k + H\Phi_k = \frac{1}{2}\left(\dot{\phi}\delta\phi_k + \dot{\chi}\delta\chi_k\right)$$

Hartree approximation

$$\chi^2 \quad \rightarrow \quad \langle\chi^2\rangle$$

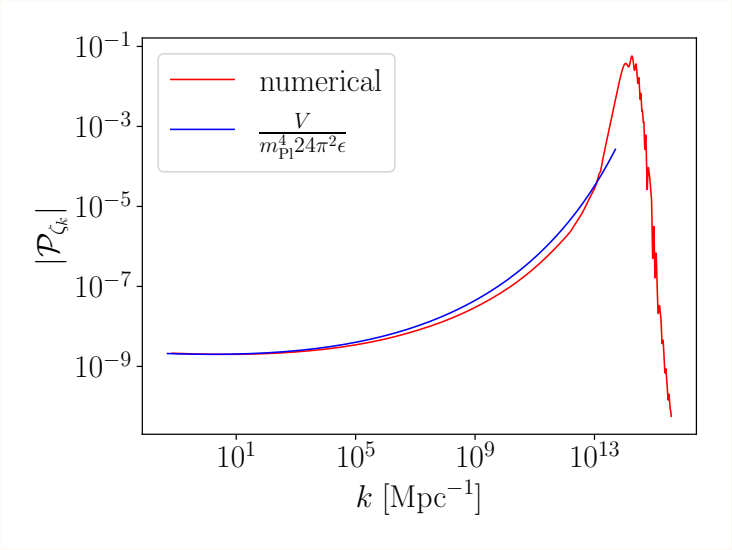
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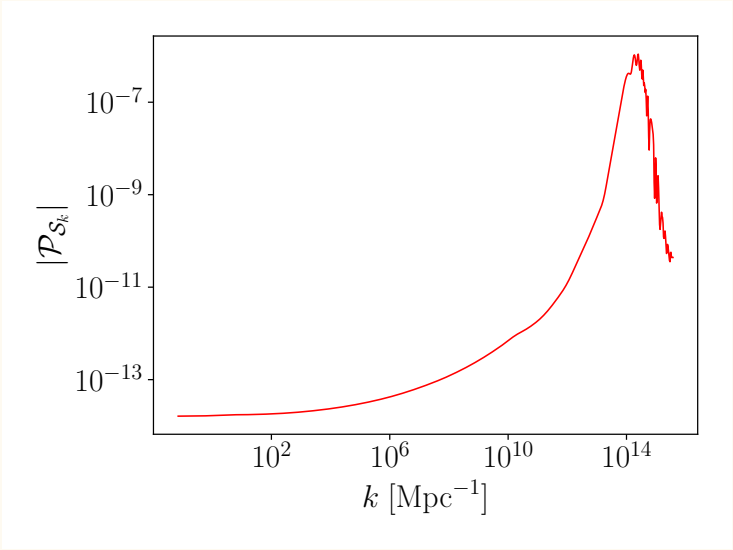
Curvature and isocurvature perturbations:

$$\zeta_k = \Phi_k + 2H\frac{\dot{\Phi}_k + H\Phi_k\left(1+\frac{1}{3}\frac{k^2}{a^2H^2}\right)}{\dot{\phi}^2+\dot{\chi}^2}$$

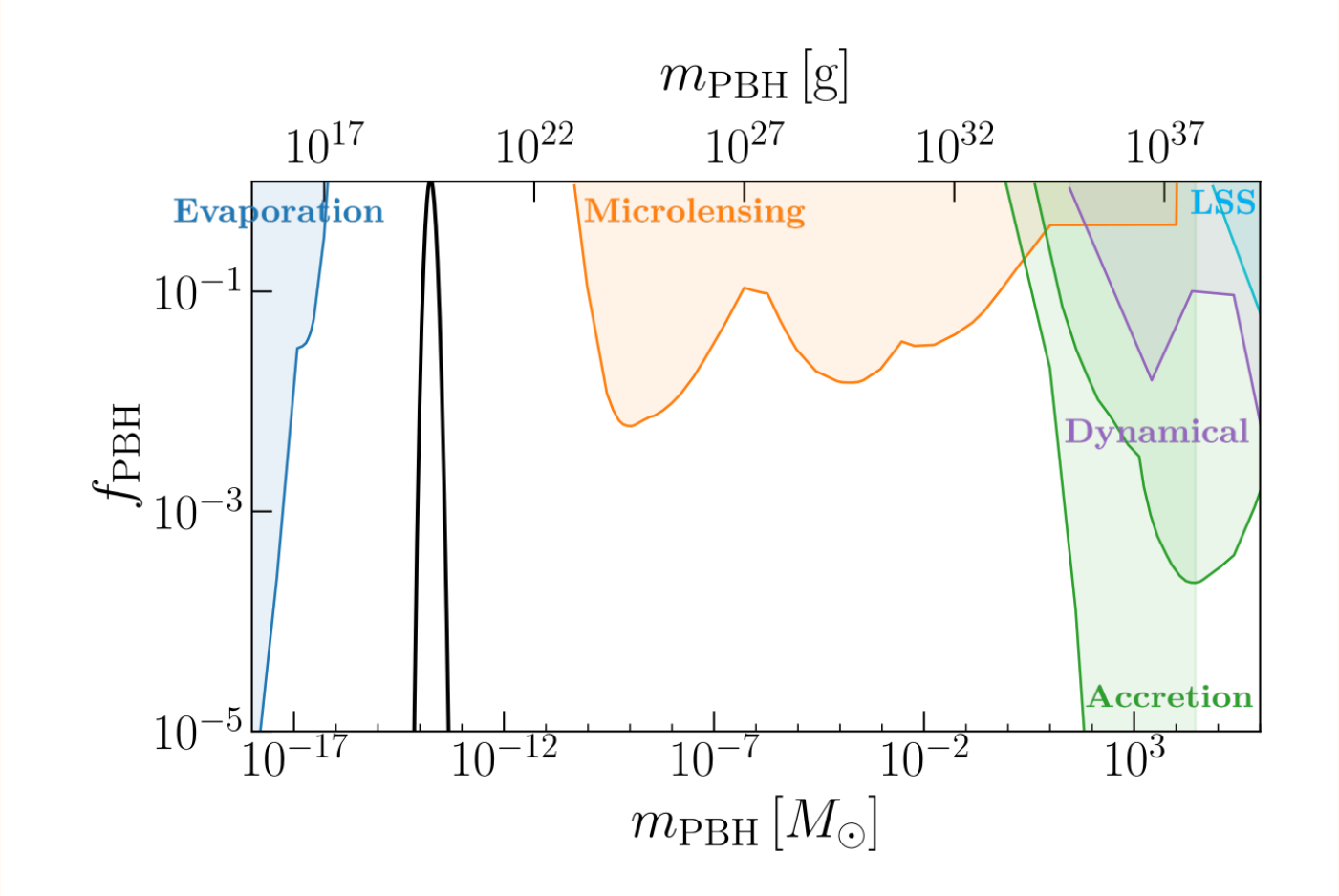
$$\mathcal{S}_k = \frac{2}{3}\frac{\delta V\left[3H\left(\dot{\phi}^2+\dot{\chi}^2\right)+\dot{V}\right]+\left[\dot{\phi}\delta\dot{\phi}_k+\dot{\chi}\delta\dot{\chi}_k+\Phi_k\left(\dot{\phi}^2+\dot{\chi}^2\right)\right]\dot{V}}{\left(\dot{\phi}^2+\dot{\chi}^2\right)\left[3H\left(\dot{\phi}^2+\dot{\chi}^2\right)+2\dot{V}\right]}$$

Simulation Results



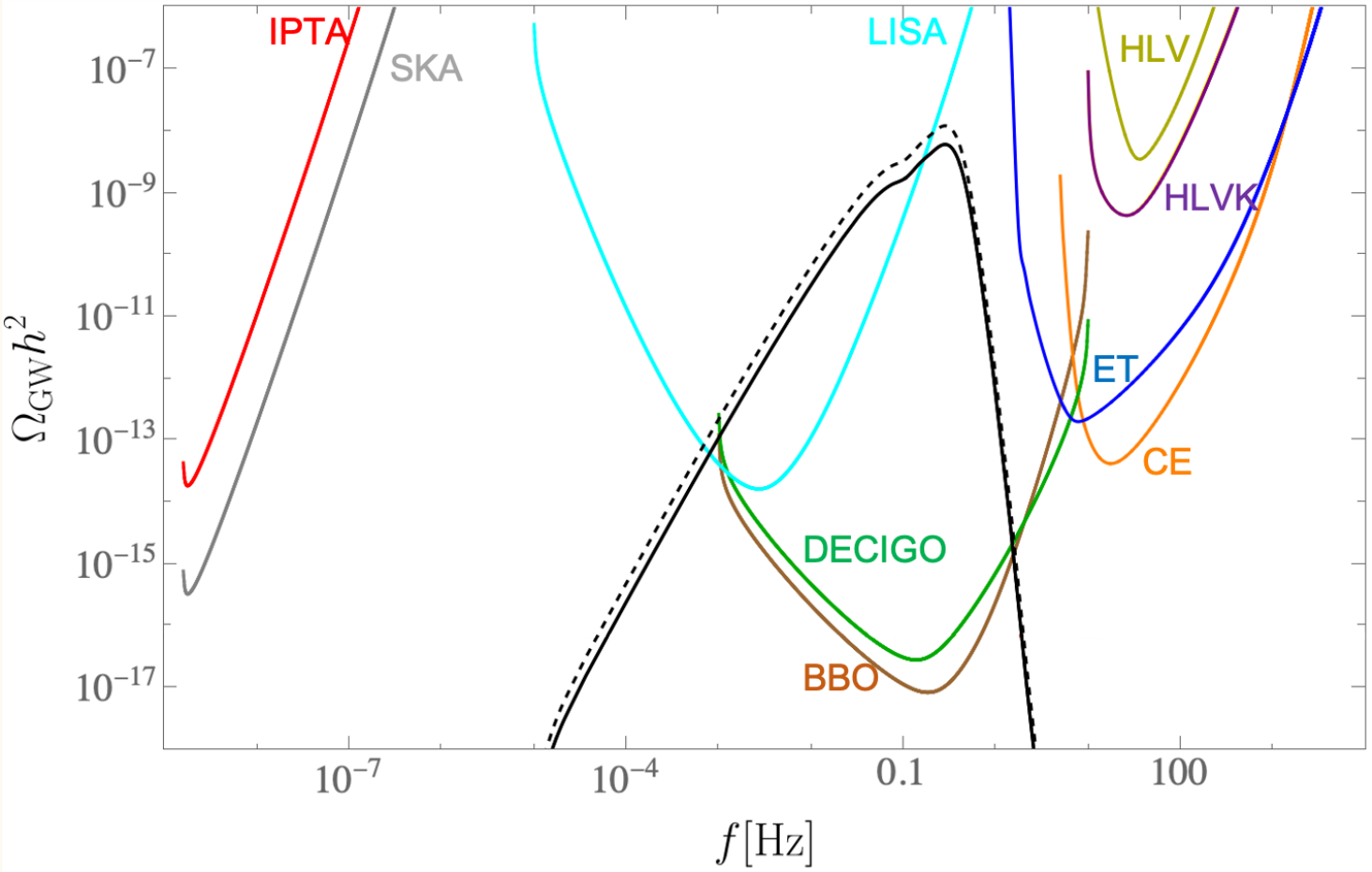


Simulation Results



Gravitational Waves

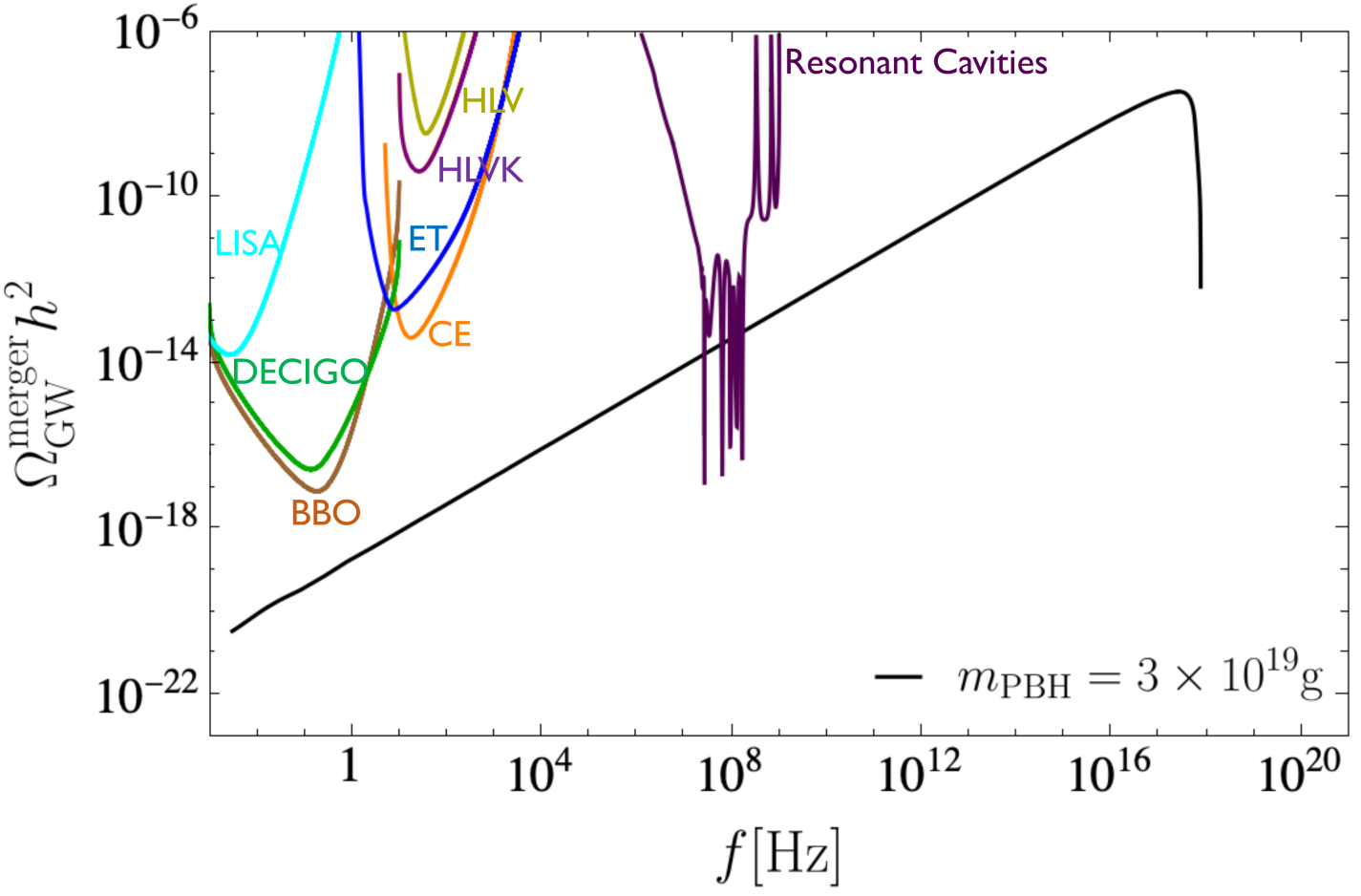
Induced Gravitational Waves



Binary Mergers

Merging PBH binaries produce a stochastic GW background

Sasaki+ (2018), Wang+ (2020), Kohri+ (2025)



Summary

- Running-mass-inflation naturally gives a large running of the spectrum $\Rightarrow$ PBHs
- Non-perturbative processes at SBP provide:
  - grateful exit
  - the viable spectrum for PBH formation
- Observable **gravitational waves**:
  - Scalar induced
  - Black Hole mergers

Furuta, **Karčiauskas**, Kohri, Sáez JCAP08 (2026) (arXiv:2511.23182)

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$$- \frac{1}{2}m^2\chi^2 + \frac{1}{2}g^2\chi^2(\phi-\phi_{\rm c})^2 + \lambda\chi^4$$

$$\mu_0^2 = B - A = m_{\rm Pl}^2; \quad A = 4.849; \quad \alpha = 0.005;$$
$$m = 3\times10^{-13}m_{\rm Pl}; \quad g^2 = 0.81; \quad \lambda = 10^{-24}$$

