Stochastic effects and PBH production in uphill inflation

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- Based on : 2301.09336 (JCAP)
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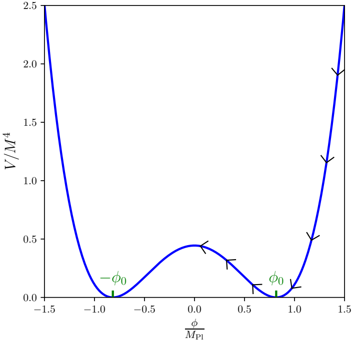
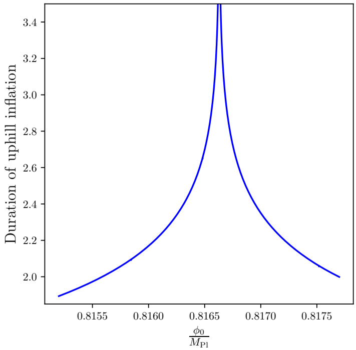
Stochastic effects in uphill inflation

$$V(\phi) = M^4 \left[\left(\frac{\phi}{M_{\mathrm{Pl}}} \right)^2 - \left(\frac{\phi_0}{M_{\mathrm{Pl}}} \right)^2 \right]^2$$





Yokoyama (1998), Karam et al (2023)

Stochastic inflation and stochastic-δN formalism

Stochastic inflation

- Effective field theory of the IR part of the inflaton
- Captures quantum features at large scale
- Stochastic equations instead of operator equations

δN formalism

- Relates curvature perturbation to the amount of expansion
- Stochastic version considers the expansion as stochastic
- Relates observables to first-passage time statistics

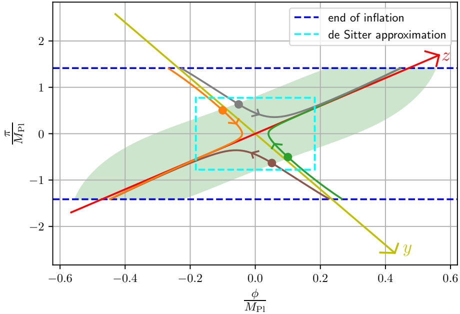
$$P\left(\zeta_R\right) = \int \mathrm{d}x_* \mathrm{d}y_* P_{\mathrm{BW}}\left[x_*, y_* | N_{\mathrm{BW}}(R)\right] \times P_{\mathrm{FPT}\, x_{\mathrm{in}}, y_{\mathrm{in}} \to x_*, y_*}\left[\zeta_R - \left\langle \mathcal{N} \right\rangle (x_*, y_*) + \left\langle \mathcal{N} \right\rangle (x_{\mathrm{in}}, y_{\mathrm{in}})\right]$$

$$\beta_{\mathrm{f}}\left(M\right) = \int_{\zeta_{\mathrm{c}}}^{\infty} P\left(\zeta_R\right) \mathrm{d}\zeta_R \int_{N_{\mathrm{BW}}(R)}^{\infty} P_{\mathrm{FPT}}(\mathcal{N} \big| z_{\mathrm{in}}) \mathrm{d}\mathcal{N}$$

Tada, Vennin (2022)

Stochastic-δN formalism in uphill inflation

Phase space analysis

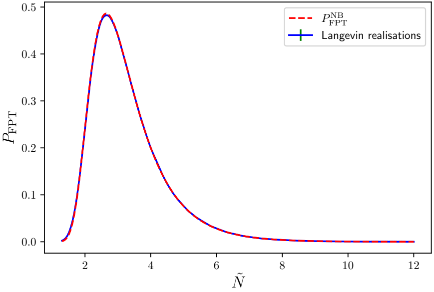


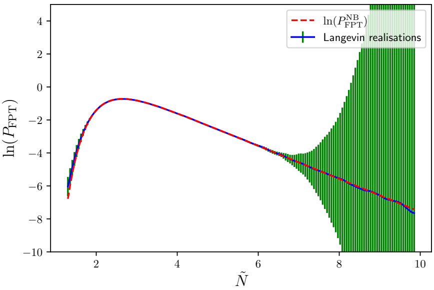
$$\frac{\mathrm{d}z}{\mathrm{d}\widetilde{N}} = z + \xi(\widetilde{N})$$

$$\frac{\mathrm{d}y}{\mathrm{d}\widetilde{N}} = -\frac{\nu_0 + \frac{3}{2}}{\nu_0 - \frac{3}{2}}\, y$$

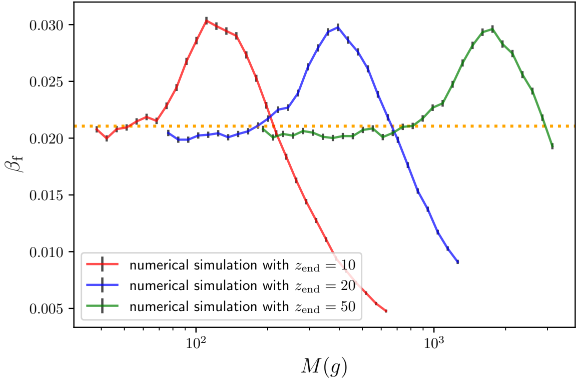
Stochastic-δN formalism in uphill inflation

First-passage time





PBH abundance and phenomenology



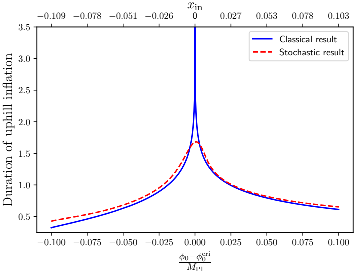
$$\simeq \mathrm{erf}\left[\frac{1}{2}e^{-\left(\nu_0-\frac{3}{2}\right)\zeta_{\rm c}-\frac{\gamma_{\rm E}}{2}}\right]$$

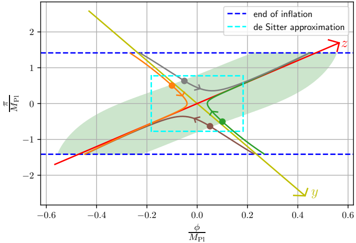
$$z_{\rm end}\propto\frac{M_{\rm Pl}}{H}$$

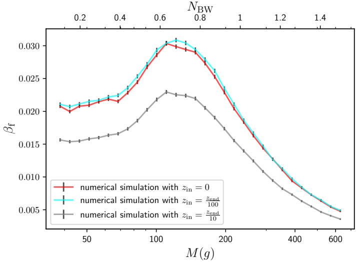
$$\nu_0\approx 4.5$$

$$\beta_{\rm f}\left(M\right)=\int_{\zeta_{\rm c}}^{\infty}P\left(\zeta_R\right)\mathrm{d}\zeta_R\int_{N_{\rm BW}(R)}^{\infty}P_{\rm FPT}(\mathcal{N}\,|\,z_{\rm in})\mathrm{d}\mathcal{N}$$

Fine tuning of the model







Conclusion

- A new regime where all three terms in Klein-Gordon are of the same order, where analytical solutions can be found (extension to a generic CR scenario made by Eemeli).
- Using the stochastic-δN formalism, we have computed the abundance of PBHs.
- Our model does not need that much fine tuning.

At the technical level :

- We have used an approximation on the boundary conditions which may be broadly used to get analytical results.
- We have described a simple numerical procedure to compute the curvature perturbation in stochastic inflation.