Ultra Slow Roll with Non-perturbative Non-Gaussianity and Scalar Induced Gravitational Waves

work in progress

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13.06.2024

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Motivation

- inflation still best extension to base ΛCDM
- features in the inflaton potential have phenomenological consequences
- USR scenario: PBH DM and GW
- so far: PS formalism with $\zeta \sim \delta\rho/\rho$
- compaction function C and curvature perturbation ζ (Musco 2019)

$$C(r) = -\frac{2}{3} r\zeta'(r) \left[2 + r\zeta'(r)\right] \tag{1}$$

- consider NG (to all orders)
- implication for PBH DM and GW signal (esp. LISA)

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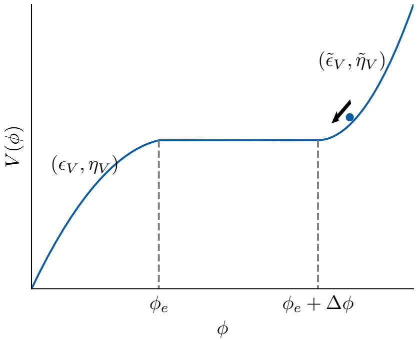
A simple model

- expand around the plateau with the SR parameters $(\tilde{\epsilon}_V, \tilde{\eta}_V), (\epsilon_V, \eta_V)$



- degeneracy in the model parameters
- CMB fixes the scale with given $\tilde{\epsilon}_V$
- choose duration ΔN, smoothness h, and e-folds left N_{togo}

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δN calculation

- a perfect plateau $V = V_0 = \text{const.}$
- solution to EOM (number of e-folds N, final field value ϕ_e and final velocity π_e)

$$\phi(N) = \frac{\pi_e}{3}\left(1 - e^{-3N}\right) + \phi_e \tag{2}$$

- invert and take variation

$$\zeta = \delta N = -\frac{1}{3}\ln(1 - 3\zeta_G) \tag{3}$$

- smoothness h
- need SR after USR: relation gets modified
- NL parameter (Cai et al. 2018)

δN calculation

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$$h = 6\frac{\sqrt{2\epsilon_V}}{\pi_e}, \; s = \sqrt{9 - 12\eta_V}, \; \alpha = \frac{-2\eta_V}{s-3}\frac{2}{2\eta_V + h} - \frac{1}{3} \tag{2}$$

- need SR after USR: relation gets modified

$$\zeta = \frac{-2}{s-3}\ln\left[1 + \frac{2\eta_V}{2\eta_V + h}\frac{\zeta_G}{\alpha}\right] - \frac{1}{3}\ln\left(1 + \frac{\zeta_G}{\alpha}\right) \tag{3}$$

- NL parameter (Cai et al. 2018)

$$f_{\mathrm{NL}} = \frac{5h(h-\eta_V)}{2(h-6)^2}; \quad f_{\mathrm{NL}}|_{h=-5} \sim 0.5, \; f_{\mathrm{NL}}|_{h=-15} \sim 1.3 \tag{4}$$

Method

- numerically solving inflaton EOM and MS equation

$$u_k'' + \left(k^2 - \frac{z''}{z}\right) u_k = 0, \quad u = z\mathcal{R}, \; z = \frac{a\dot{\phi}}{H} \tag{5}$$

- PDF for linear compaction C_l as a marginal distribution (Gow et al. 2022)

$$P[C_l] = \int \mathrm{d}\zeta_G \, \frac{3}{4|J_1|} P\left\{-\frac{1}{|J_1|}\frac{3}{4}C_l, \zeta_G\right\}, \quad J_1 = \frac{\partial \zeta}{\partial \zeta_G} \tag{6}$$

$$M_{\mathrm{PBH}} \sim M_H(\mathcal{C} - C_c)^{\gamma} \tag{7}$$

- horizon mass M_H can be related to N_{togo}
- SIGW inevitable

Method

- numerically solving inflaton EOM and MS equation
- PDF for linear compaction C_l as a marginal distribution (Gow et al. 2022)
- horizon mass M_H can be related to N_{togo}

$$M_H \propto e^{2N_{\text{togo}}} M_\odot \tag{5}$$

- SIGW inevitable

$$\Omega_{GW} h^2 \sim 10^{-6} P_R^2 \tag{6}$$

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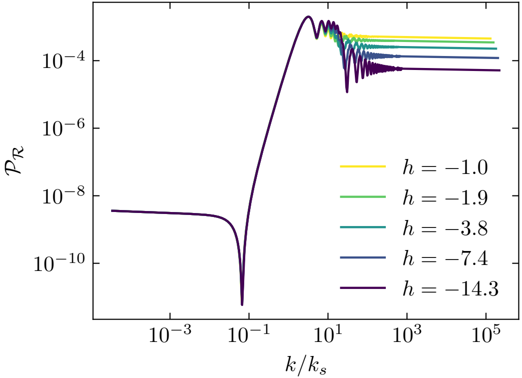
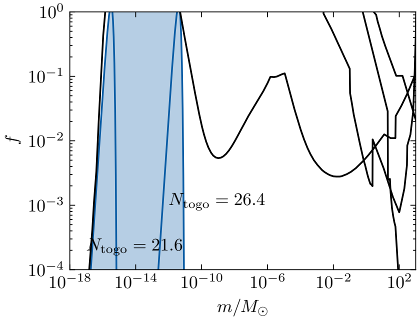
Results

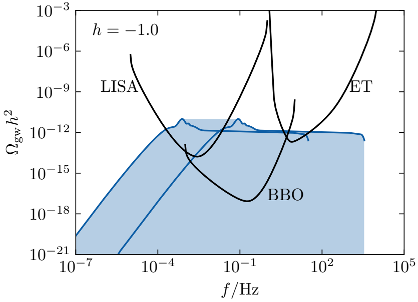
- power spectra



Results

- power spectra
- PBH DM fraction and GW signals with $f_{\text{PBH}} = 1$ and $h = -1$





Results

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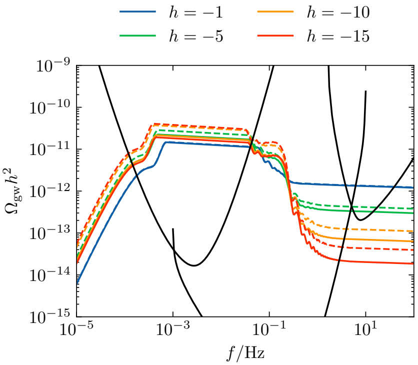
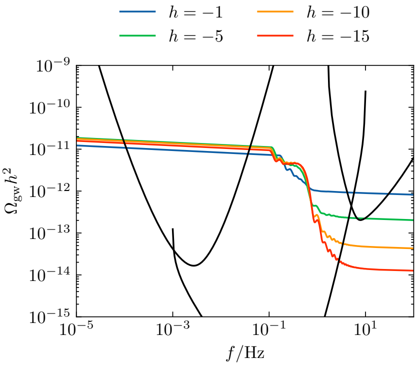
- PBH DM fraction and GW signals with $f_{\text{PBH}} = 1$ and $h = -1$
- envelope of possible signals with $f_{\text{PBH}} = 1$ and $f_{\text{PBH}} = 10^{-3}$
  - DM isocurvature constraint (e.g. Young and Brynes 2015)





Results

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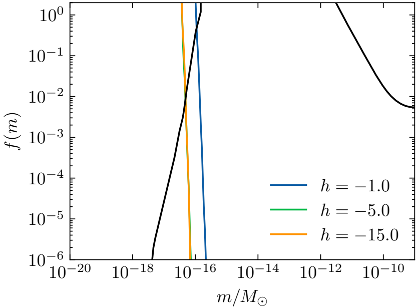
- envelope of possible signals with $f_{\mathrm{PBH}} = 1$ and $f_{\mathrm{PBH}} = 10^{-3}$
- projection of non-detection at LISA



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Discussion and Conclusions

- considered perfect USR with transitions
- complex relation between compaction and curvature perturbation accounted for
- detect SIGW with LISA
- non-detection means low PBH DM
- GW anistropies ($l \gtrsim 15$) might help (Bartolo et al. 2015)

Questions

Thank you!
Questions?

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