Sharp turns in axion monodromy: primordial black holes and gravitational waves

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arXiv: 2205.06065 (SB, Ivonne Zavala)

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Motivation

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  - Features via deviation from slow-roll $\rightarrow$ require to implement fine-tuned inflection points/bumps in potential(1702.03901, 1911.00057). Interesting consequences: PBH, GW
- **Why multifield?**
  - Effective single field behaviour at large scales (near CMB pivot) can still satisfy Planck constraints.
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- **Goal and why?**
  - **Is it possible to construct a multifield model in supergravity with minimal fine-tuning?**
  - **Features with sharp turns in field space, but small field-space curvature. Consequences for the power spectra? PBH, induced GW?**

Multifield inflation: The model

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- Can be consistent with swampland conjecture.(1901.08603)
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$$K/M_{\rm Pl}^2 = -\alpha\log[(\Phi+\bar{\Phi})/M_{\rm Pl} - \beta S\bar{S}/M_{\rm Pl}]$$
$$W = S(M\Phi + i\lambda e^{-b\Phi})$$

with $\rho \equiv \mathrm{Re}(\Phi)$ and $\theta \equiv \mathrm{Im}(\Phi)$ leading to

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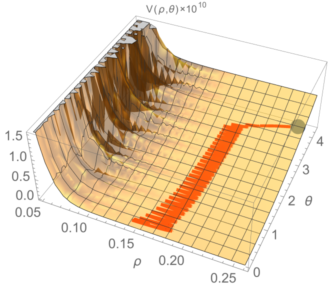
- The potential is not just the sum of two potentials, but they are coupled: allows gentle cliffs and plateaus when the saxion is slightly away from its minimum.
- Turning rate: $\omega \equiv \frac{\Omega}{H} \equiv -N_a(D_tT^a)/H = \frac{V_N}{H\dot{\varphi}}$, where $T^a = \frac{\dot{\phi}^a}{\dot{\varphi}}$.

Multifield inflation: The model

- Multiple sharp turns in (ρ, θ) space, without requiring large field space curvature.
- Repeated inflection points due to oscillations in the potential $\rightarrow$ slow-roll violation $\eta > 1 \rightarrow$ large turns $\omega > 1$ and sharp turns $\nu \gg 1$.



$$
\begin{aligned}
\epsilon &\equiv -\frac{\dot{H}}{H^2} = \frac{\dot{\varphi}^2}{2M_{Pl}^2 H^2} \\
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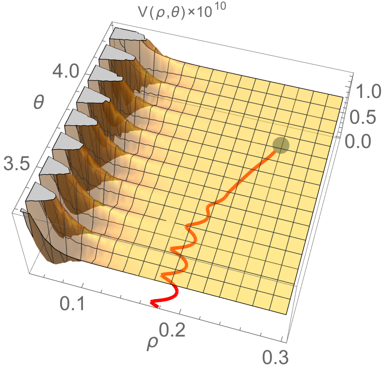

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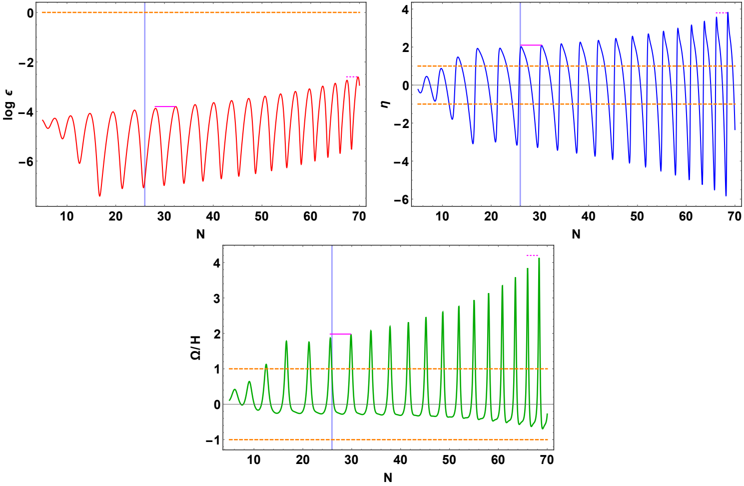
Slow Roll Parameters

For $\lambda/M = 80,\ b = 50$:



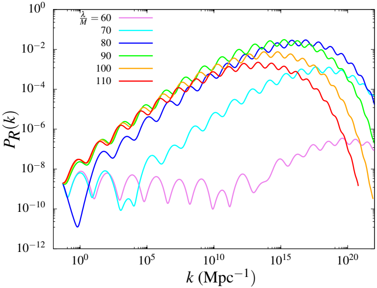
Oscillations with decreasing period.

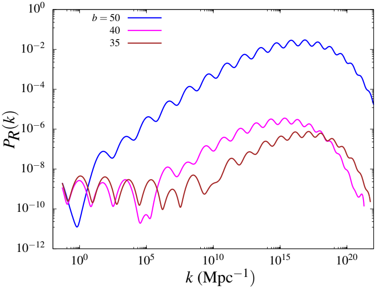
Power spectra

$$\ddot{Q}_T + 3H\dot{Q}_T + \left(\frac{k^2}{a^2} + m_T^2\right) Q_T = (2\omega H Q_N)^{\cdot} - \left(\frac{\dot{H}}{H} + \frac{V_T}{\dot{\varphi}}\right) 2\,\omega H Q_N\,,$$

$$\ddot{Q}_N + 3H\dot{Q}_N + \left(\frac{k^2}{a^2} + m_N^2\right) Q_N = -2\,\omega\dot{\varphi}\dot{\mathcal{R}}$$

$\mathcal{R} = \frac{H}{\dot{\varphi}} Q_T$.



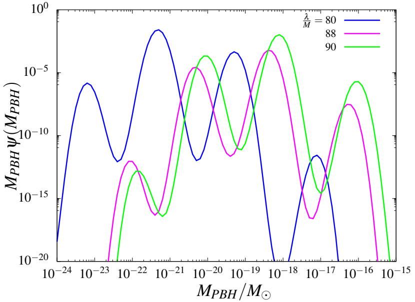


For these examples, $N_{\rm inf} \sim 55 - 65$, $r \sim 0.010 - 0.024$, $V_{\rm inf}^{1/4} \sim 0.003 - 0.03 M_{\rm Pl}$. For CMB normalization, $\beta = 1$, $M \sim 10^{-8} - 10^{-6} M_{\rm Pl}$.

Light PBHs in abundance

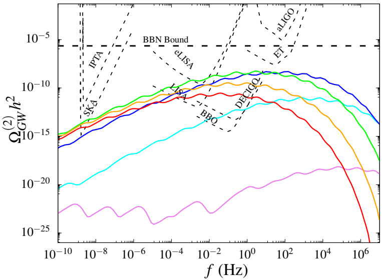
$$\psi(M_{\rm PBH}) = \frac{\gamma}{T_{\rm eq}}\left(\frac{g_s(T_1)}{g_s(T_{\rm eq})}\right)^{\frac{1}{3}}\left(\frac{\Omega_m h^2}{\Omega_c h^2}\right)\left(\frac{90 M_{\rm Pl}^2}{\pi^2 g_*(T_1)}\right)^{\frac{1}{4}}(4\pi\gamma M_{\rm Pl}^2)^{\frac{1}{2}}\frac{\beta_{\rm PBH}(M_{\rm PBH})}{M_{\rm PBH}^{\frac{3}{2}}}.$$

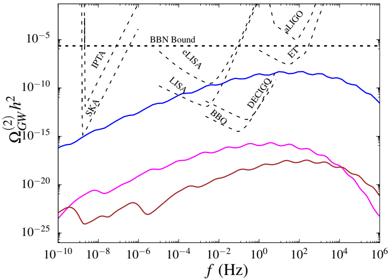
- $M_{\rm PBH} \sim k^{-2}$ in RD.
- $f_{\rm PBH} \sim 10^{-3} - 10^{-2}$.
- BBN constraint : $f_{\rm PBH} \lesssim 10^{-4}$; CMB and $\gamma-$ray observations constrain $f_{\rm PBH} < 10^{-10}$ for $10^{-20} M_\odot \lesssim M_{\rm PBH} \lesssim 10^{-17} M_\odot$ (monochromatic $\psi(M_{\rm PBH})$).
- Some target $M_{\rm PBH}$ are produced more than the others.



Induced GW

- $P_h(k,\tau) \propto \int du \int dv \mathcal{I}_R D P_{\mathcal{R}}(ku) P_{\mathcal{R}}(kv)$.
- $\Omega^{(2)}_{\rm GW}(k,\tau) \sim k^2 \tau^2 P_h(k,\tau)$.





- Wide and large GW spectra, can be probed by multiple future surveys together.
- Spectral shape is characteristic, can be analysed with GW surveys.

Summary and Outlook

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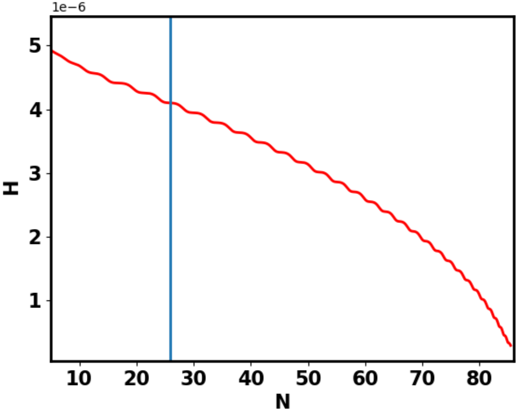

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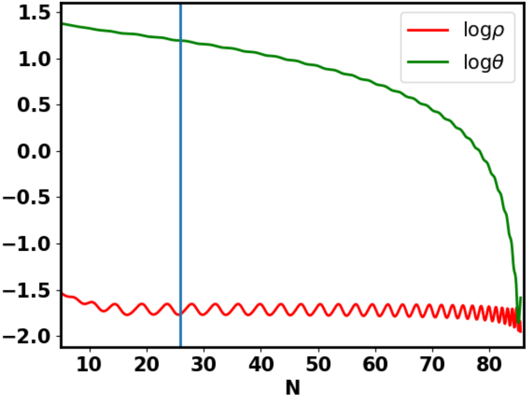

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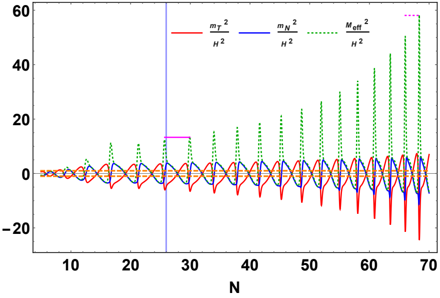

$$\frac{m_T^2}{H^2} \equiv -\frac{3}{2}\eta - \frac{1}{4}\eta^2 - \frac{1}{2}\epsilon\eta - \frac{1}{2}\frac{\dot{\eta}}{H}$$

$$\frac{m_N^2}{H^2} = \frac{V_{NN}}{H^2} + M_{\rm Pl}^2\,\epsilon\,\mathbb{R} - \omega^2$$

$$M_{eff}^2 \equiv m_N^2 + 4H^2\omega^2 = V_{NN} + M_{\rm Pl}^2\,\epsilon\,\mathbb{R}H^2 + 3H^2\omega^2.$$

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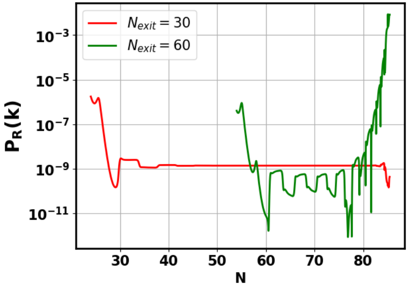

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Extra

M	λ/M	b	$\rho_{\rm ini}$	$\theta_{\rm ini}$	$N_{\rm inf}$	r	$V_{\rm inf}^{1/4}$
2.52×10^{-6}	60	50	0.250	4.20	64.77	0.010	0.0029
2.73×10^{-6}	70	50	0.250	4.20	62.32	0.016	0.0030
2.15×10^{-6}	80	50	0.245	4.20	59.48	0.018	0.0027
6.41×10^{-7}	90	50	0.250	4.20	57.49	0.020	0.0015
1.10×10^{-7}	100	50	0.250	4.20	56.07	0.022	0.0006
1.25×10^{-8}	110	50	0.250	4.20	55.06	0.024	0.0002
1.60×10^{-6}	80	40	0.250	4.50	63.63	0.011	0.0026
1.60×10^{-6}	80	35	0.400	5.50	56.99	0.012	0.0026