

UNIVERSITÀ DEGLI STUDI DI PADOVA

INFN PADOVA
Istituto Nazionale di Fisica Nucleare
Sezione di Padova

PBH Dark Matter and GWs from Axion Inflation

Nadir Ijaz



M. Barbon, G. Franciolini, M. Peloso

arXiv: 2510.17207, JCAP 06 (2026) 013
arXiv: 2604.27496, JCAP 09 (2026) 058

Axion Inflation

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- In this talk we study some effects of coupling an axion(-like) inflaton to gauge fields.

Axion Inflation + Gauge Fields

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Turner, Widrow '88
Garretson, Field, Carroll '92
Anber, Sorbo '06, '10

$$S = \int d^4x\sqrt{-g}\left[\frac{M_p^2}{2}R - \frac{1}{2}\left(\partial\phi\right)^2 - V\left(\phi\right) - \frac{1}{4}F^2 - \frac{1}{8\sqrt{-g}}\frac{\phi}{f}\epsilon^{\mu\nu\alpha\beta}F_{\mu\nu}F_{\alpha\beta}\right]$$

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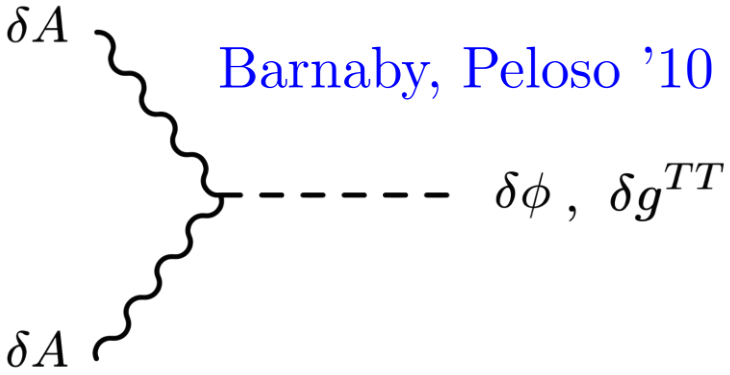
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Barnaby, Peloso '10

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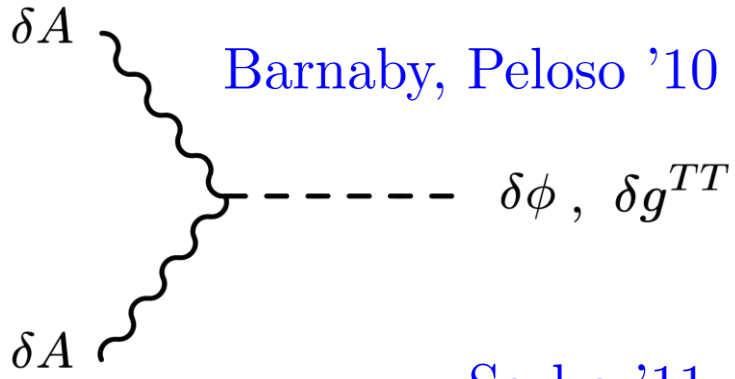
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Sorbo '11

- GWs are chiaral, $\delta g_L^{TT} \gg \delta g_R^{TT}$.

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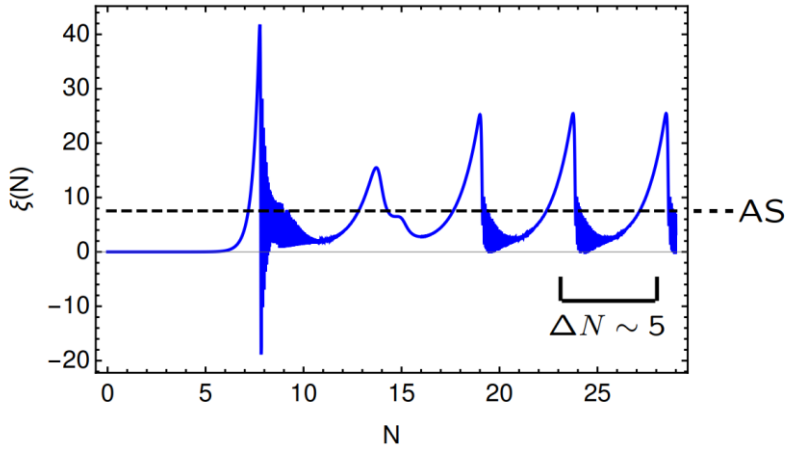
- Inflation can occur even on steep potentials (large V').

$$V' \simeq -2.4\times 10^{-4}\,\frac{H^4}{f}\,\frac{e^{2\pi\xi}}{\xi^4}\,, \qquad \xi \equiv \frac{\dot{\varphi}}{2Hf}\,,$$

Homogenous Backreaction

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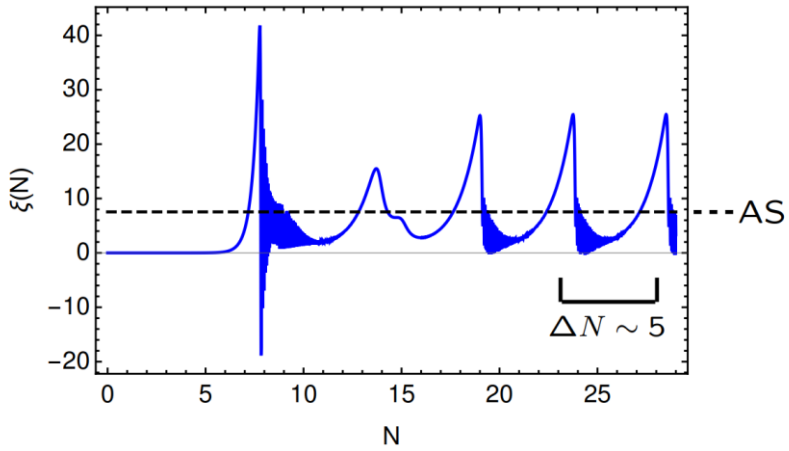
- Oscillatory behaviour from simplified numerical solutions of the system (set of gauge modes + homogeneous inflaton)



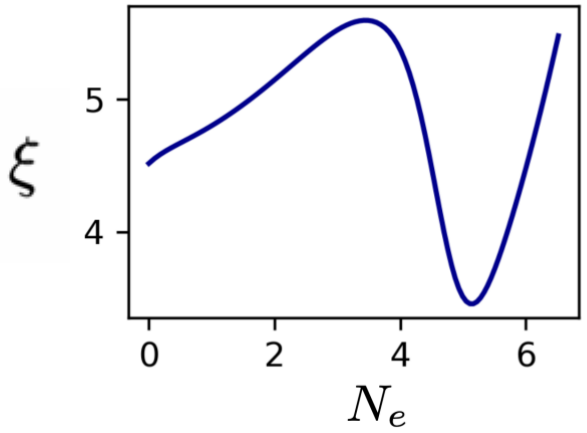
Cheng, Lee, Ng '15
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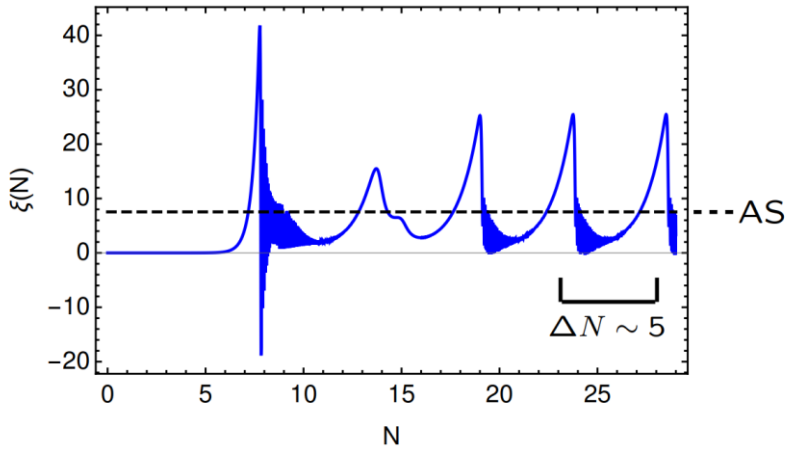
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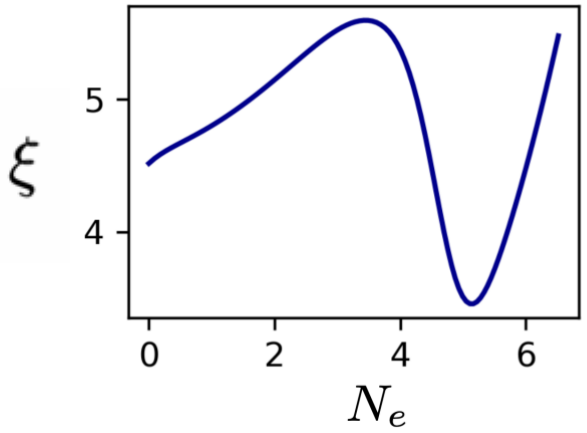
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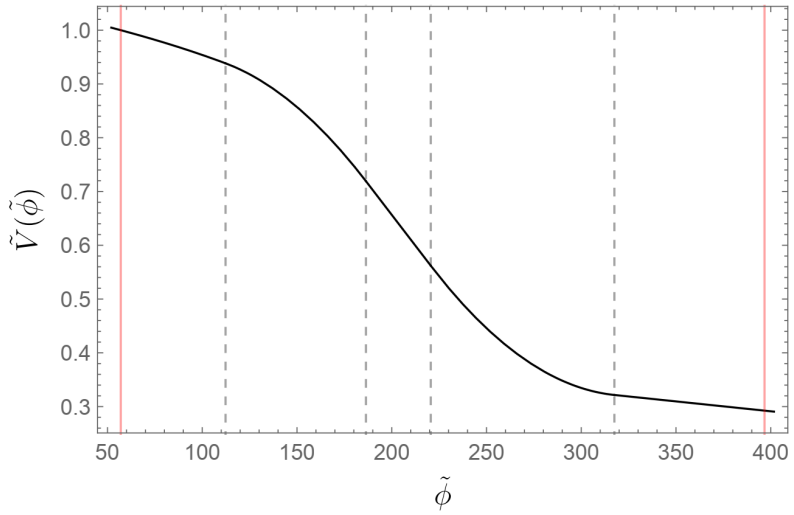
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Domcke, Guidetti, Welling, Westphal '20
Peloso, Sorbo '22

- Interpreted as delayed effect between the moment the gauge quanta are produced and the moment they backreact on $\varphi(t)$.

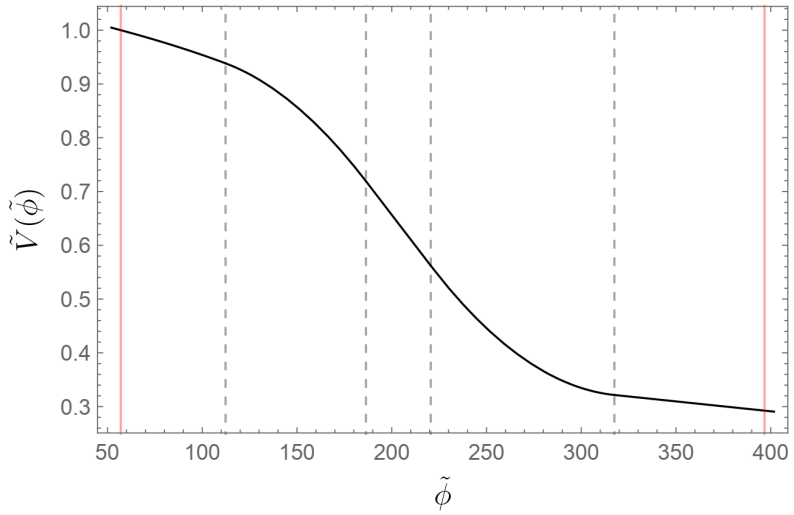
Gravitational Wave Signatures

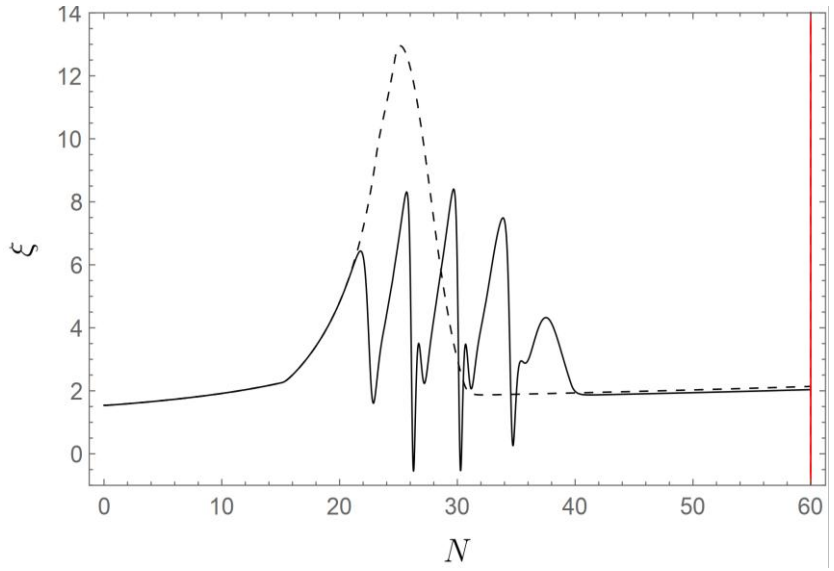
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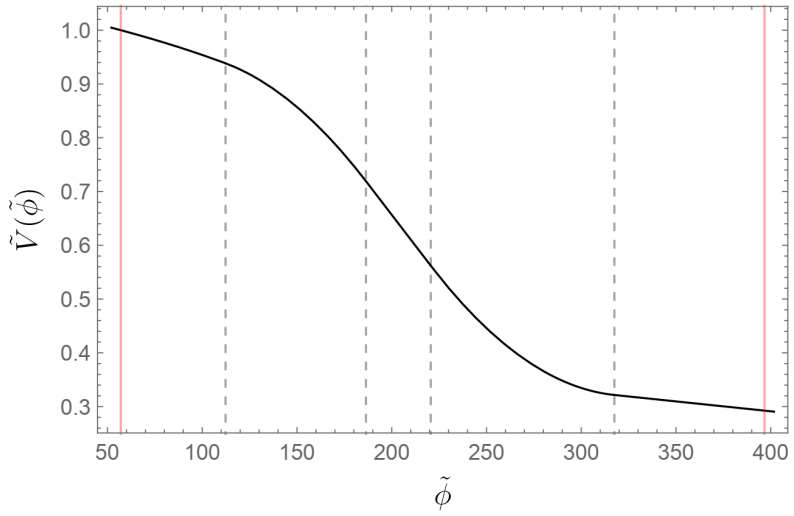


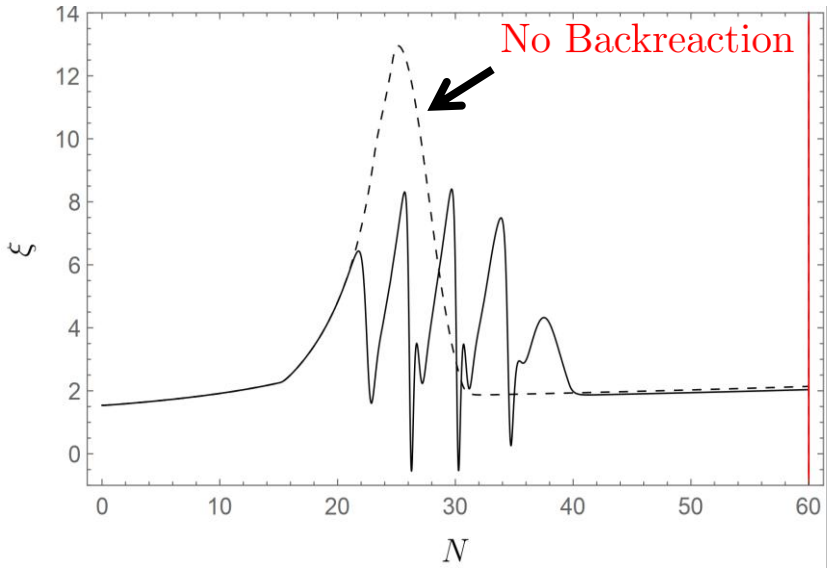


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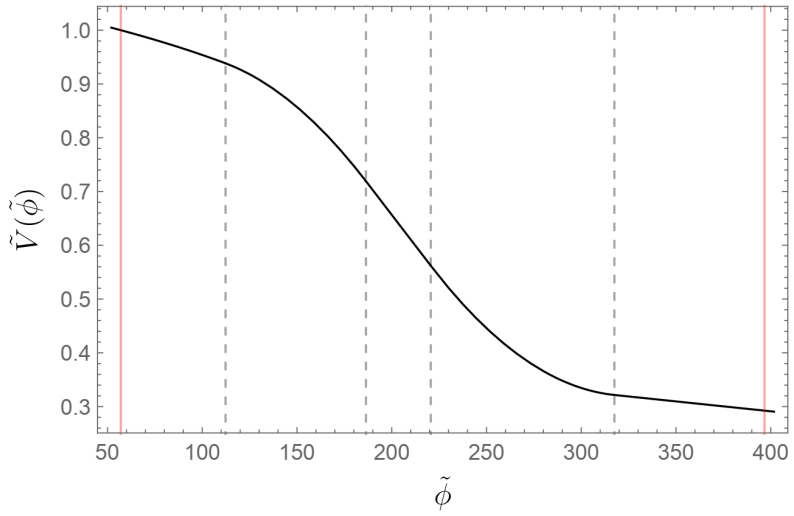
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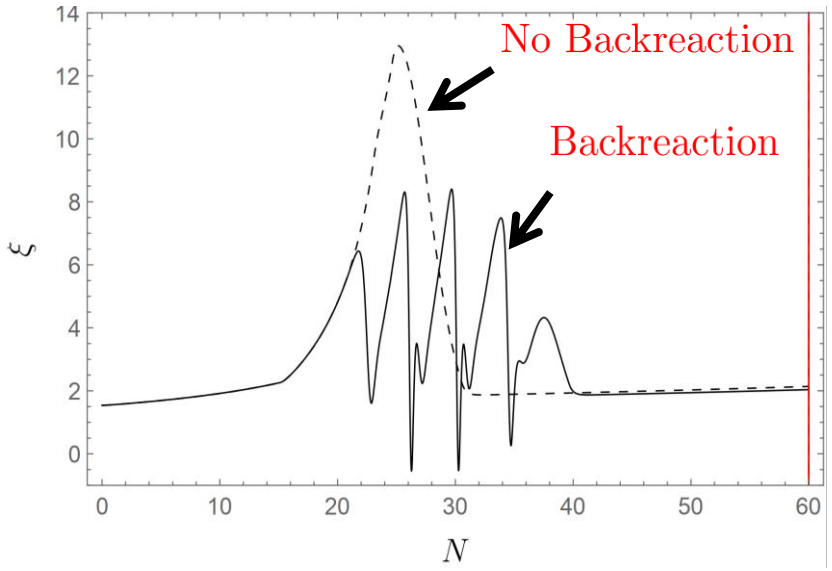




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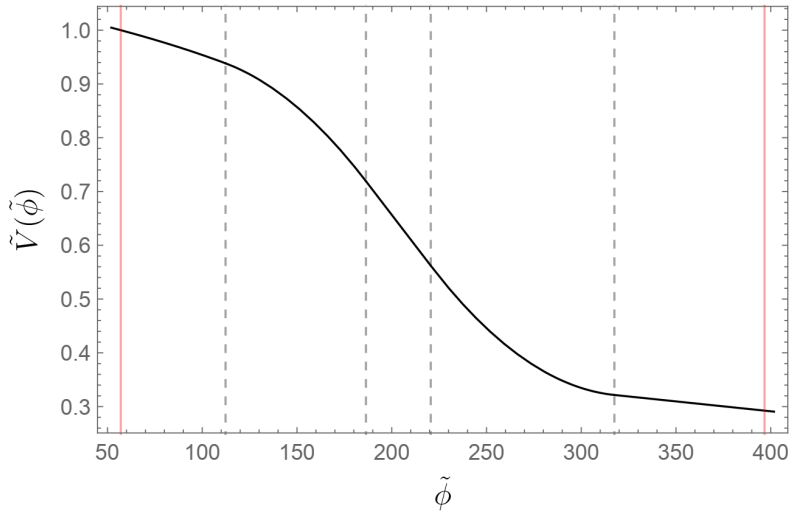
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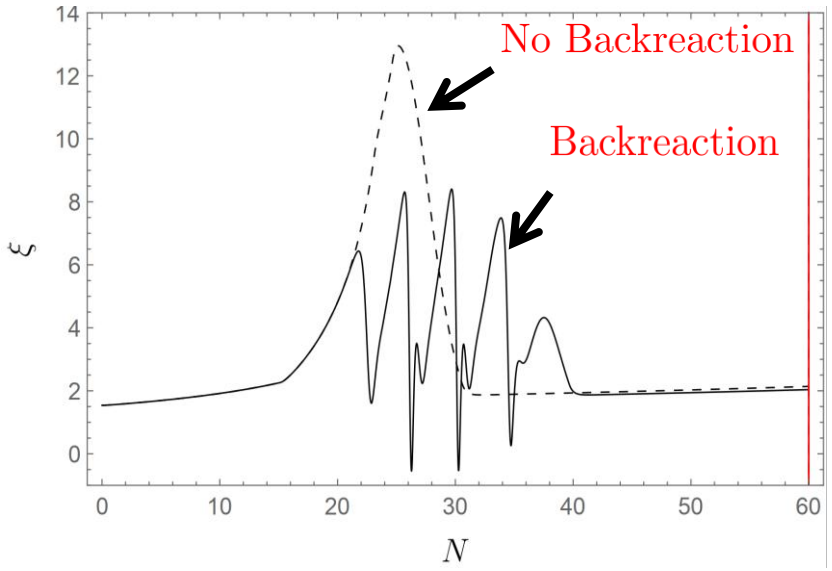


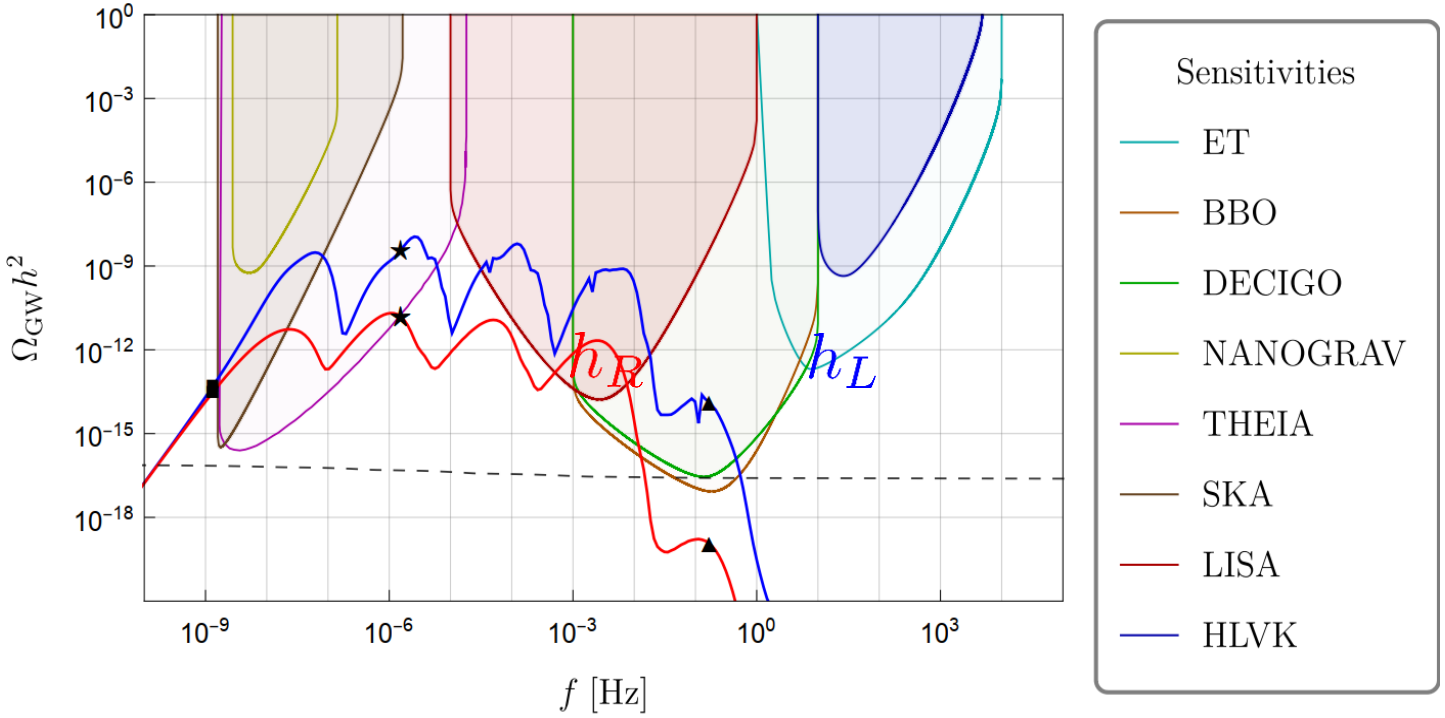


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Inhomogenous Backreaction

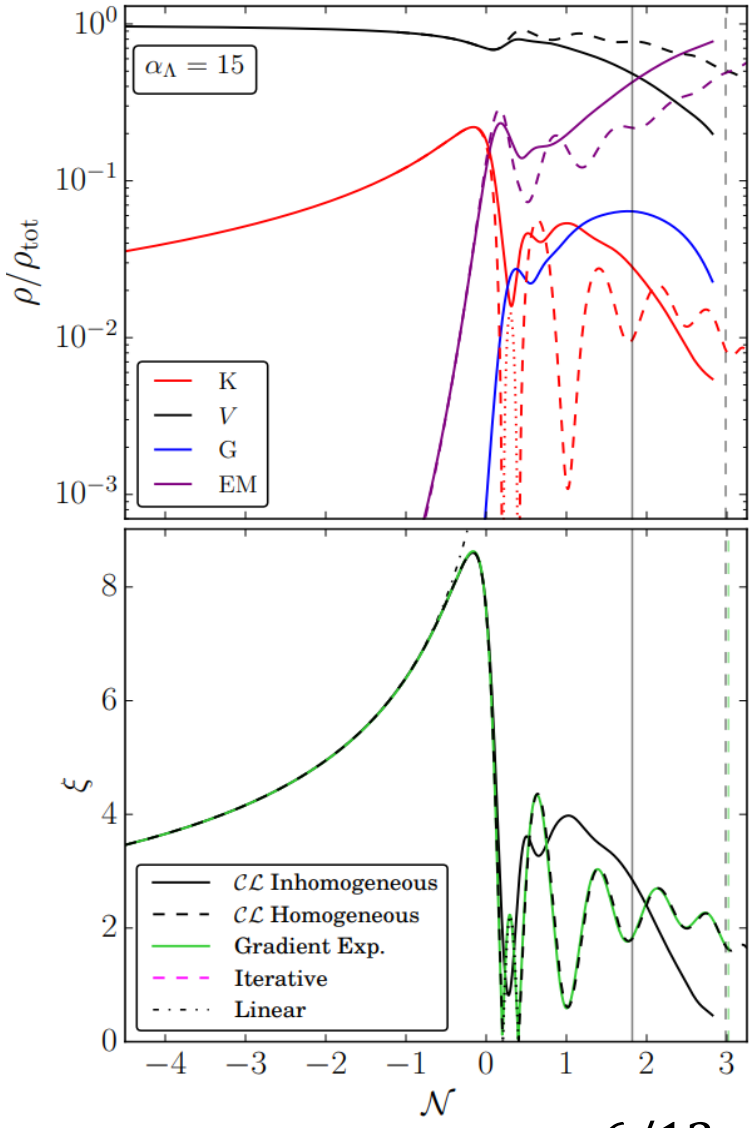
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- Spatial gradients in the axion field alters the spectrum of the fluctuations.

Inhomogenous Backreaction

Figueroa, Lizarraga, Urio Urrestilla '23

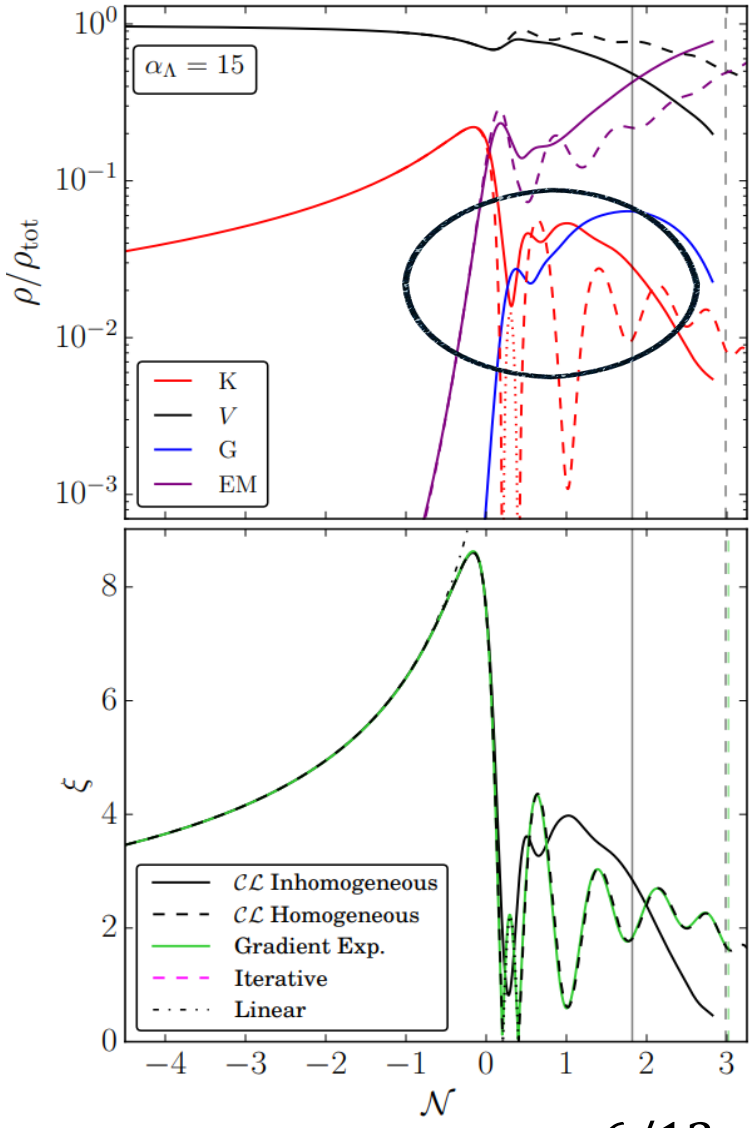
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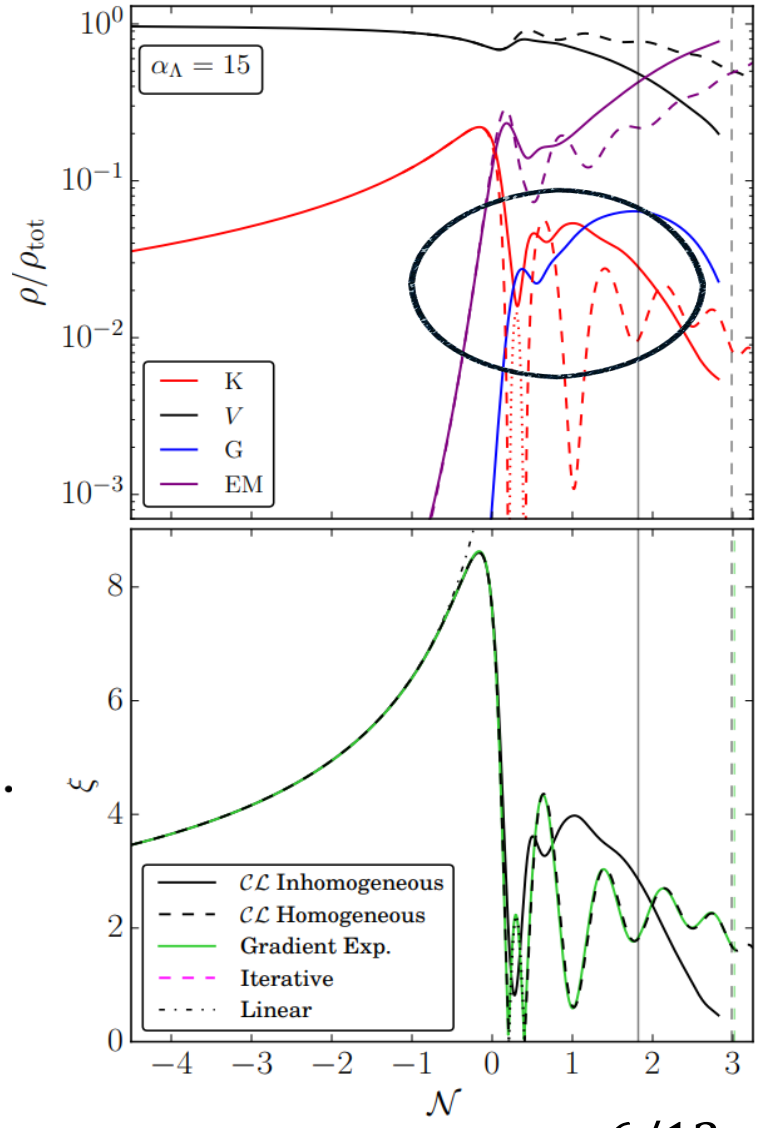
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- Computationally expensive, cover only last 7 efolds.



Validity of the homogeneous backreaction

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Barbon, NI, Peloso '25

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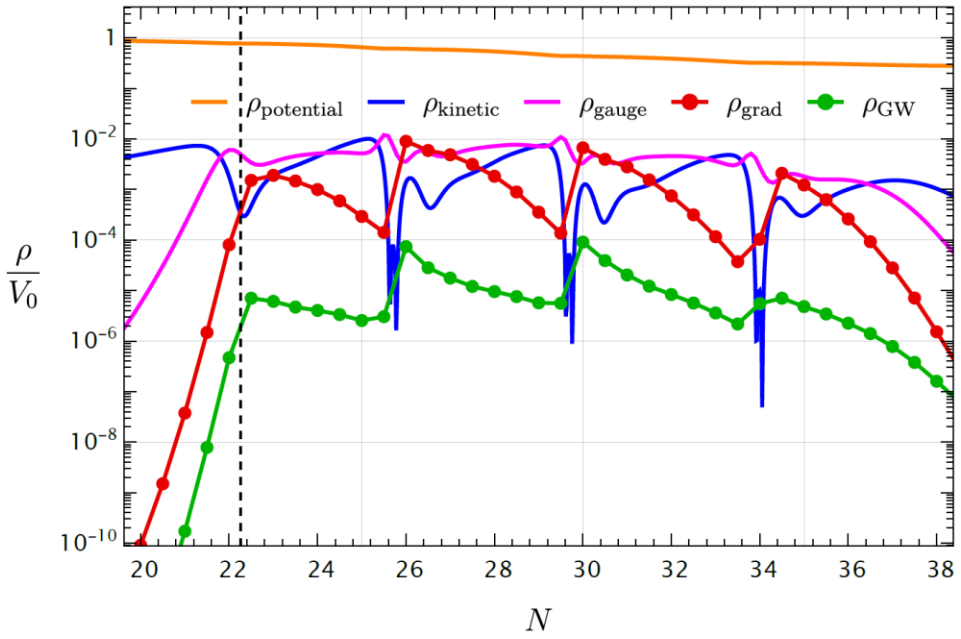
- Source of GW and scalar perturbations: gauge fields obtained numerically within homogeneous backreaction. All this is self-consistent if $\frac{\rho_{\rm grad}}{\rho_{\rm kin}}$ is small (comparing with lattice, it should be at the percent level, or less).

Results

Results

Barbon, NI, Peloso '25

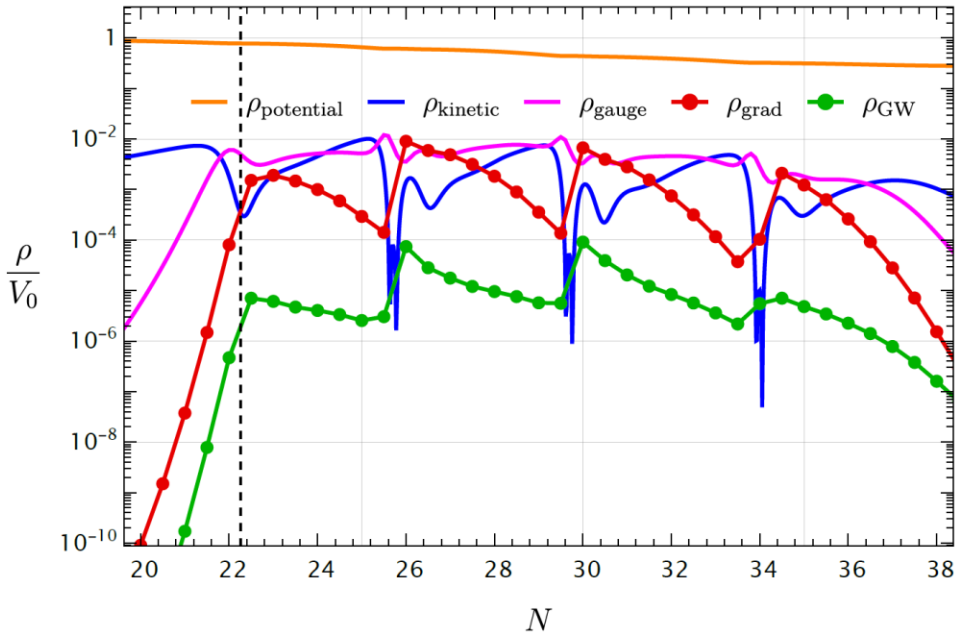
Original parameters	Max $\frac{\rho_{\rm grad}}{\rho_{\rm kin}} = 17.68$

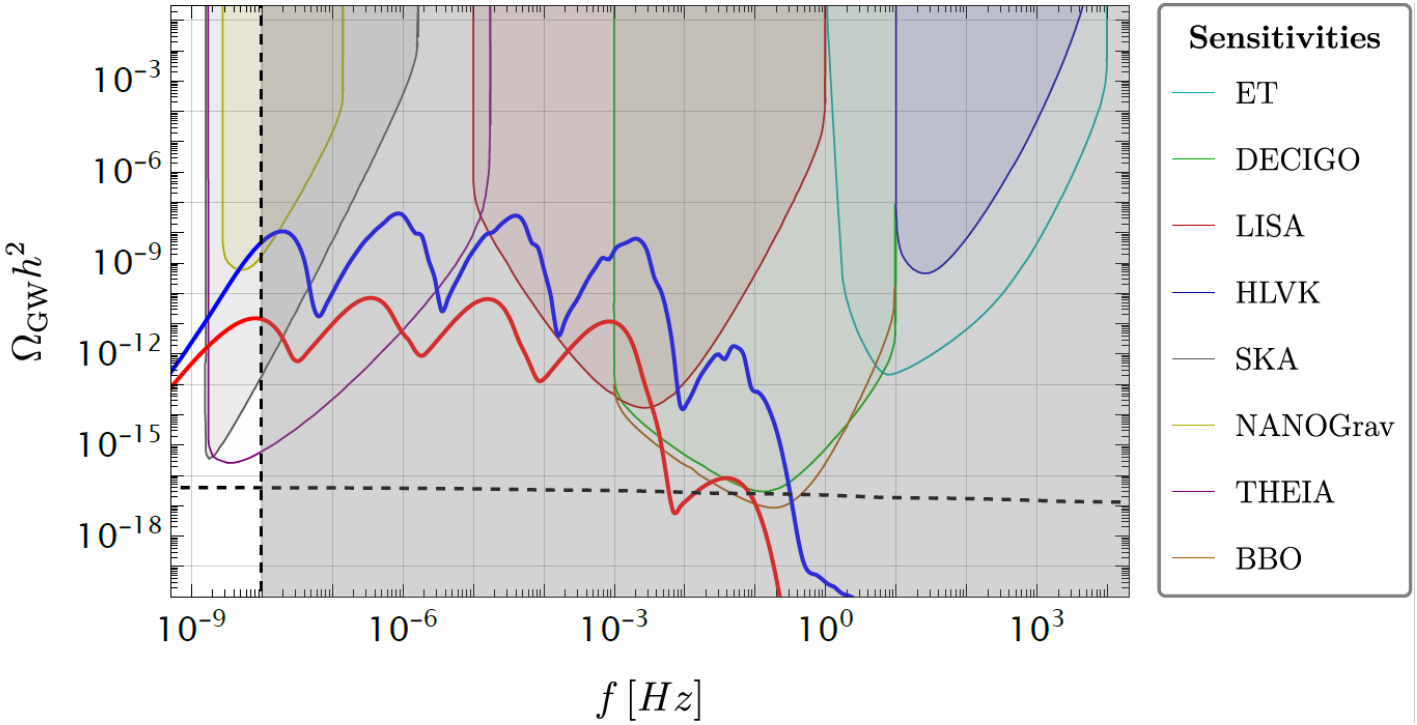


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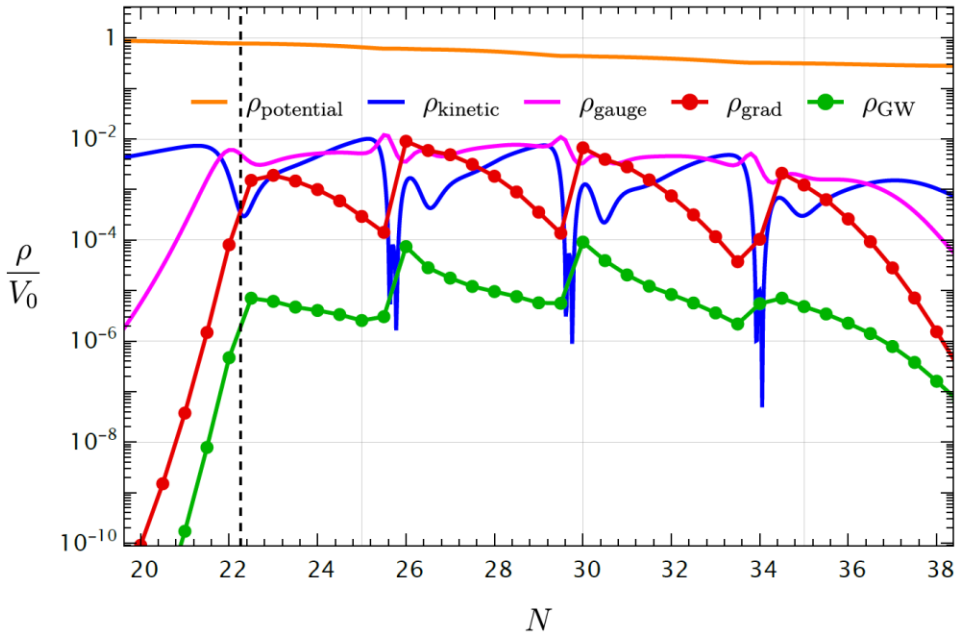


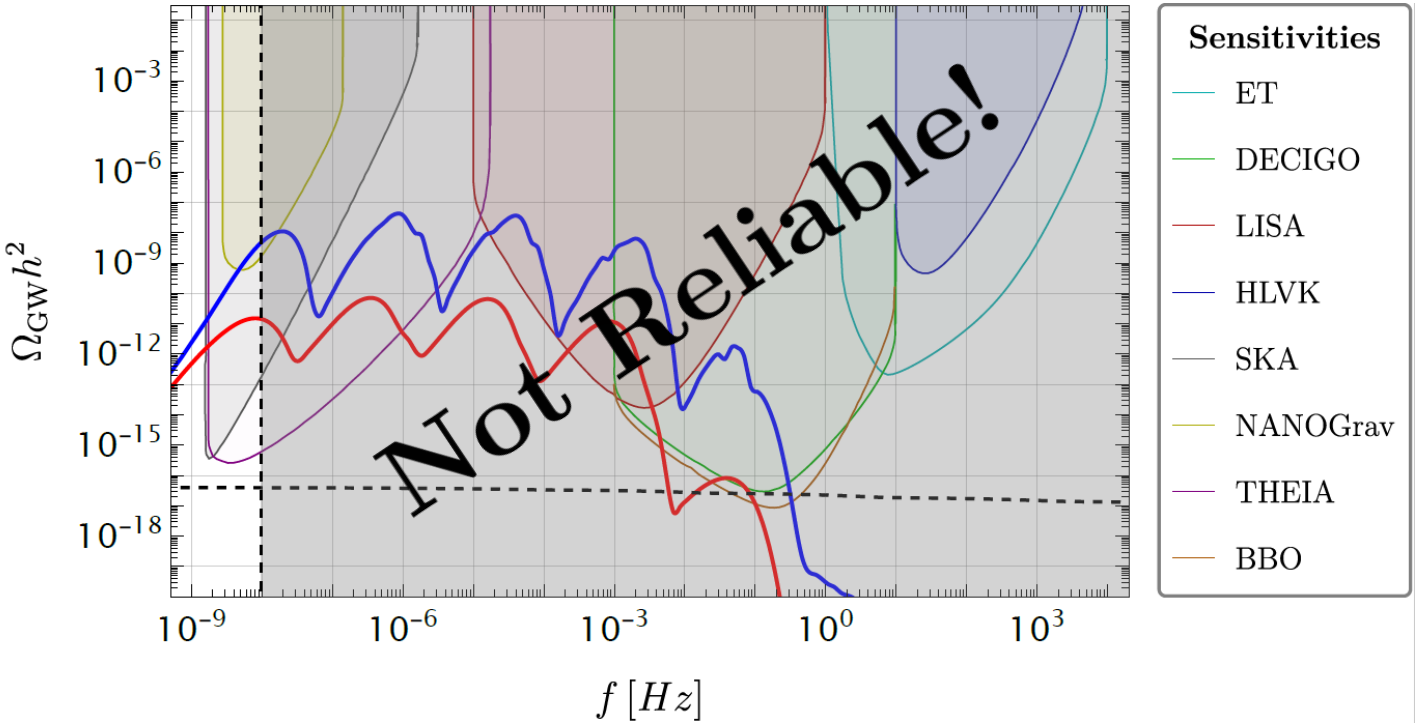


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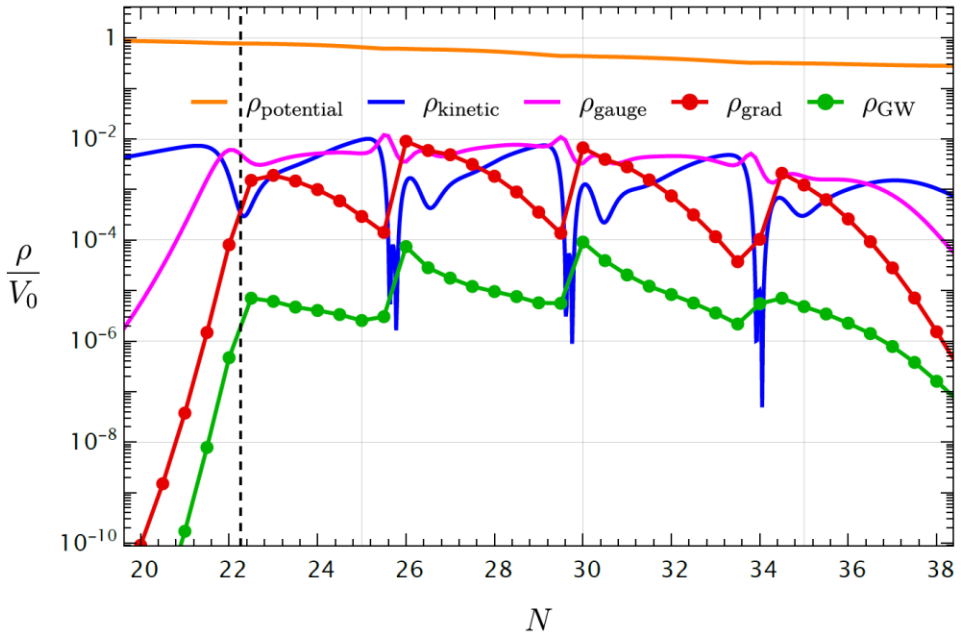


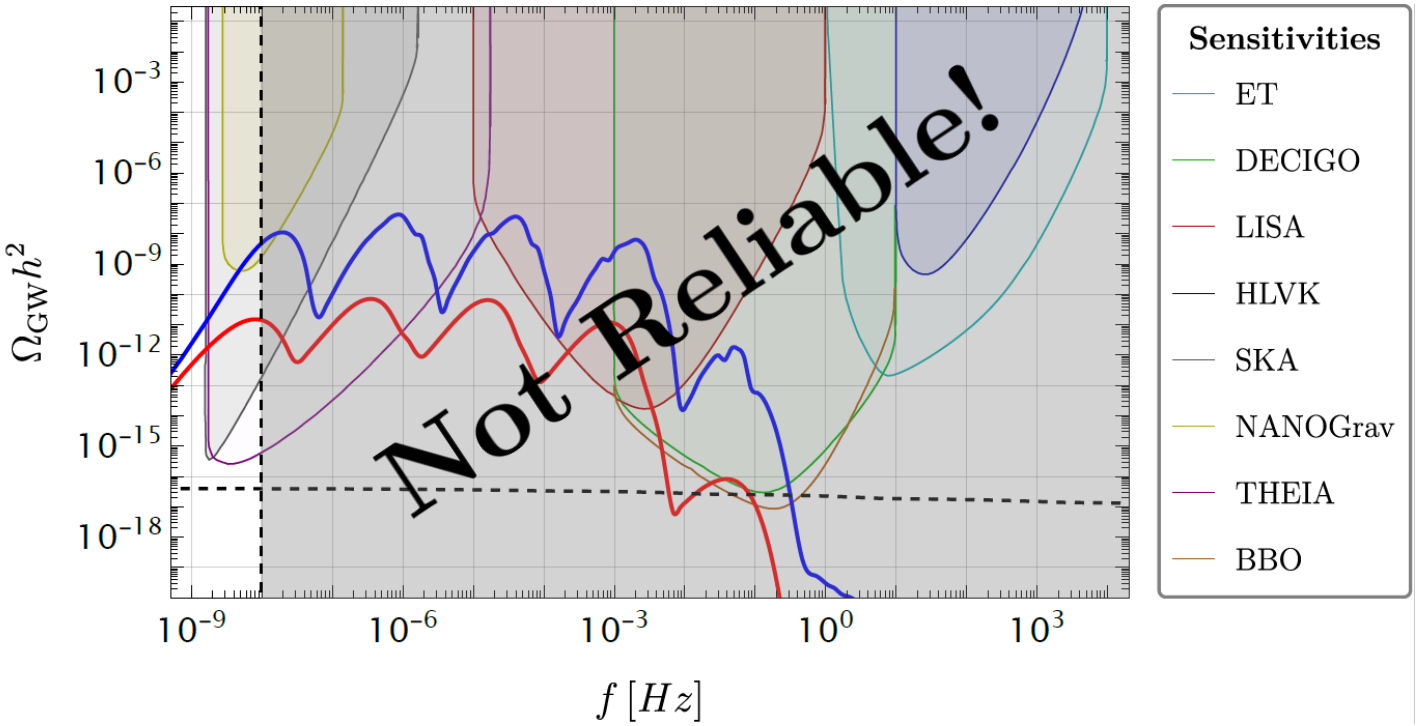


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Is there a parameter range with interesting phenomenology where backreaction stays weak enough for the homogeneous approximation to remain valid?

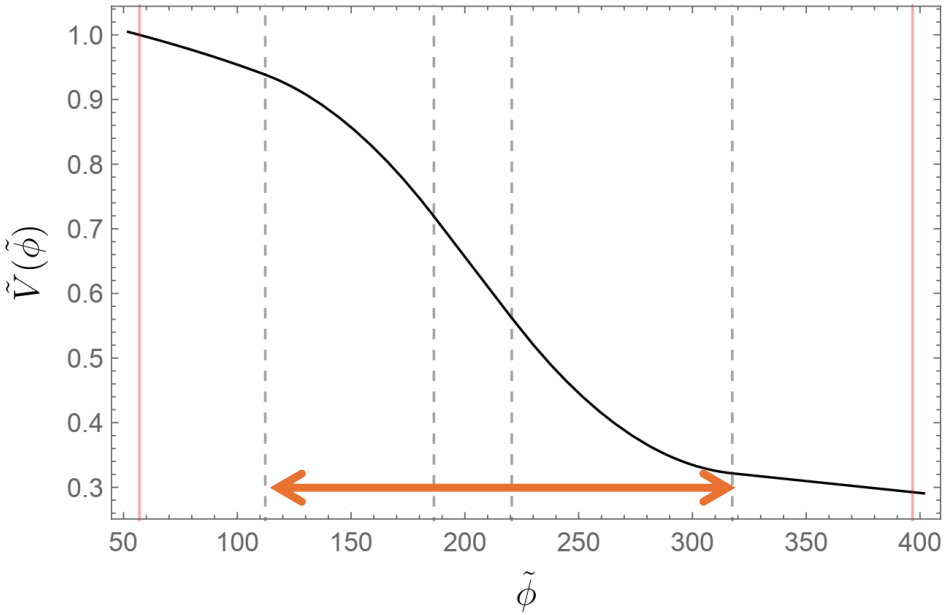
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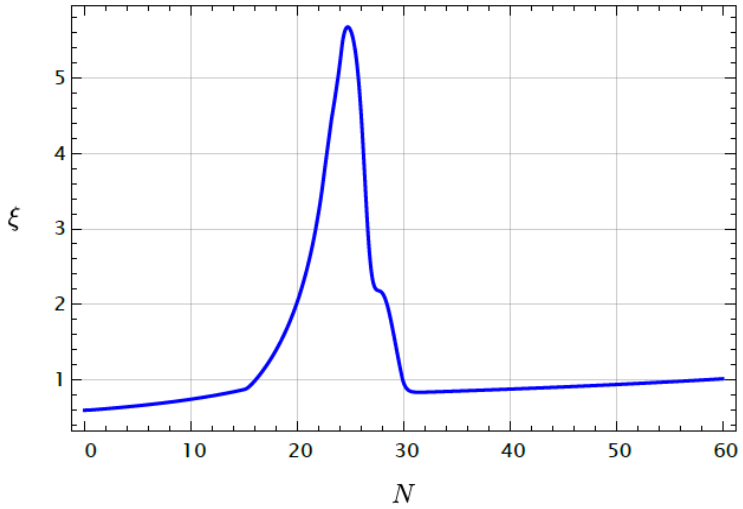
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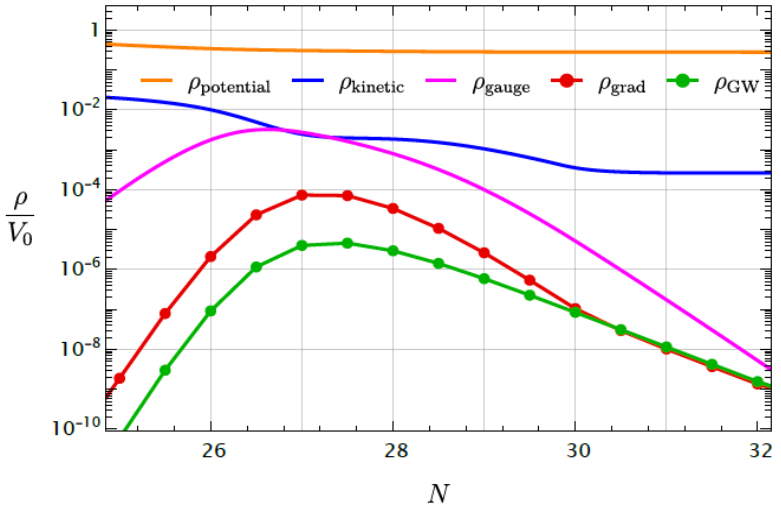


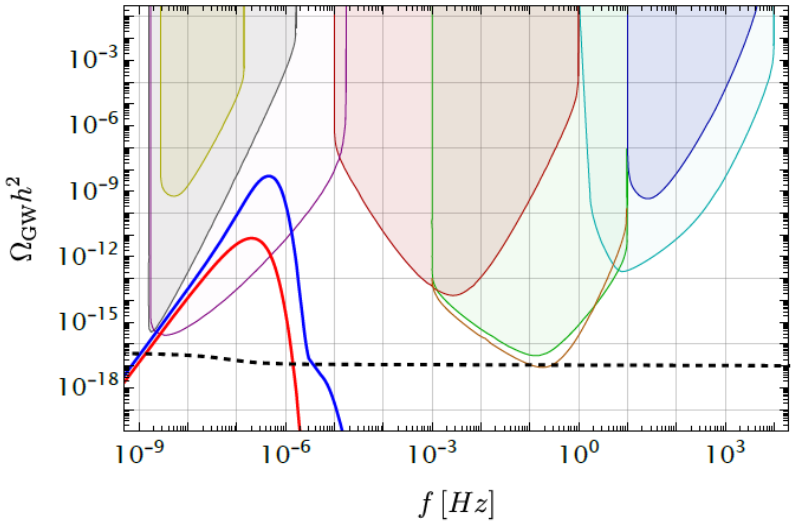
Results

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Increased axion decay constant w.r.t to original

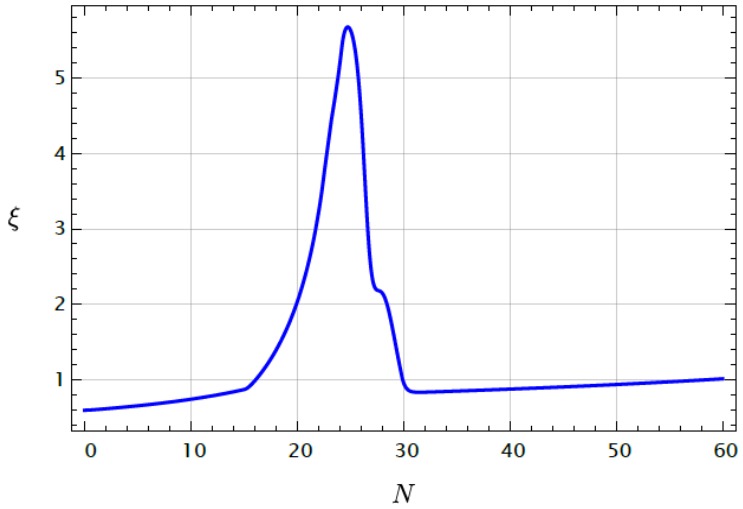


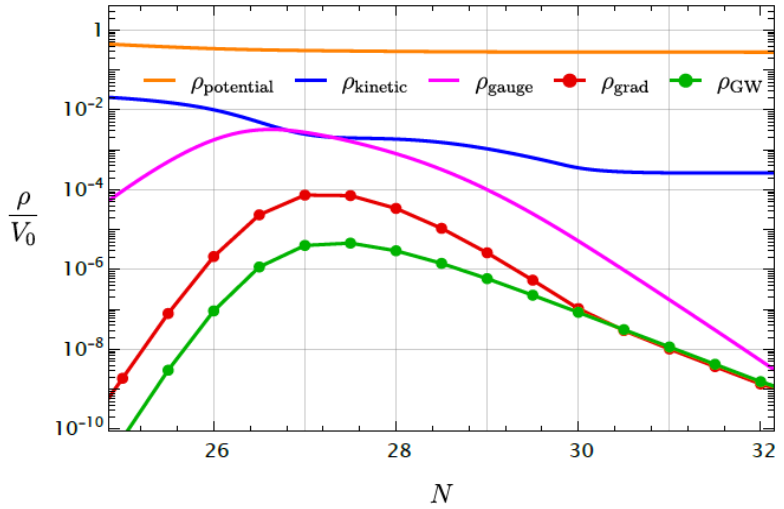


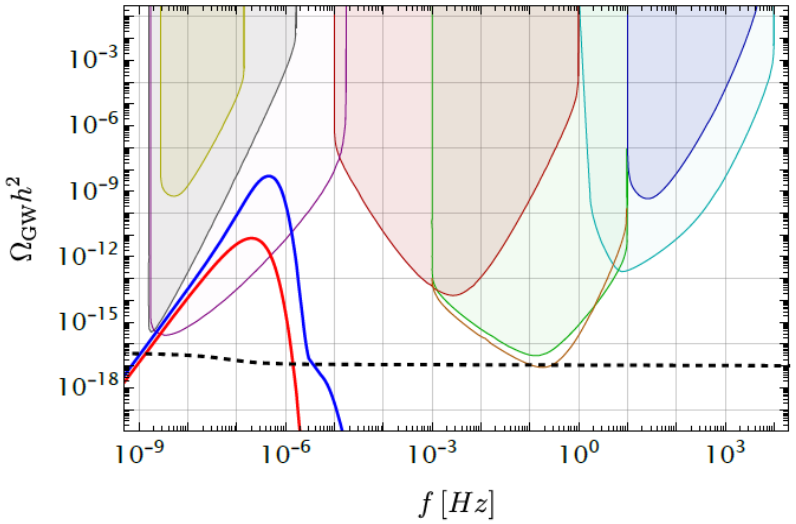


Results

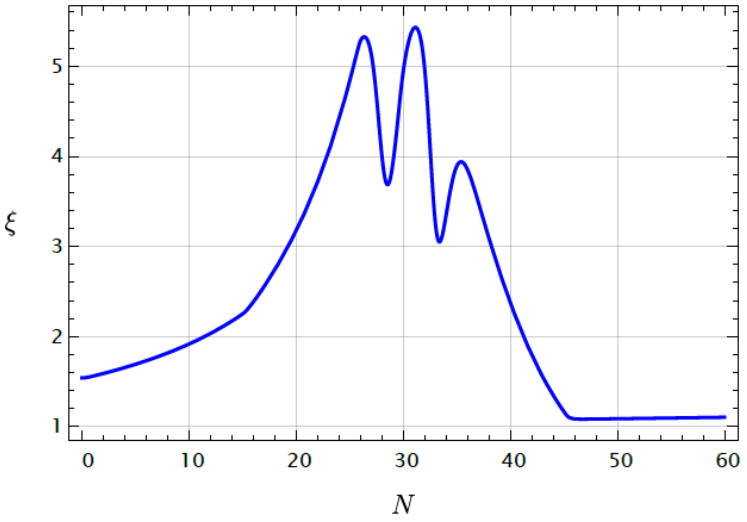
Increased axion decay constant w.r.t to original

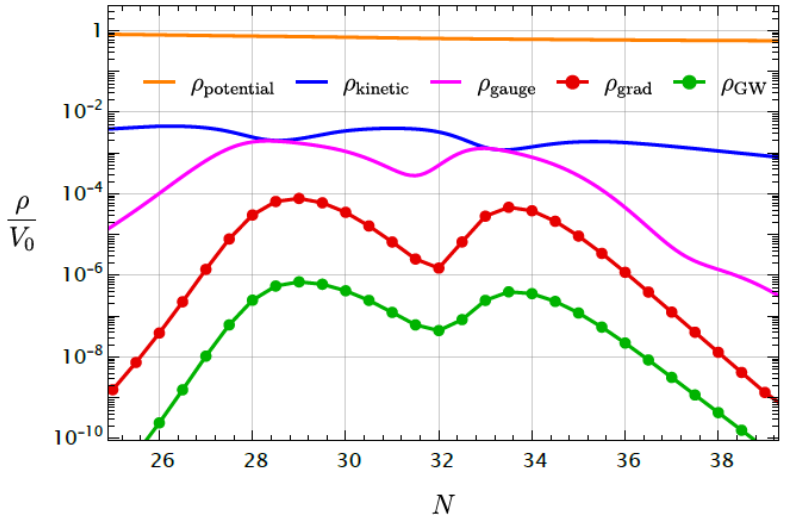


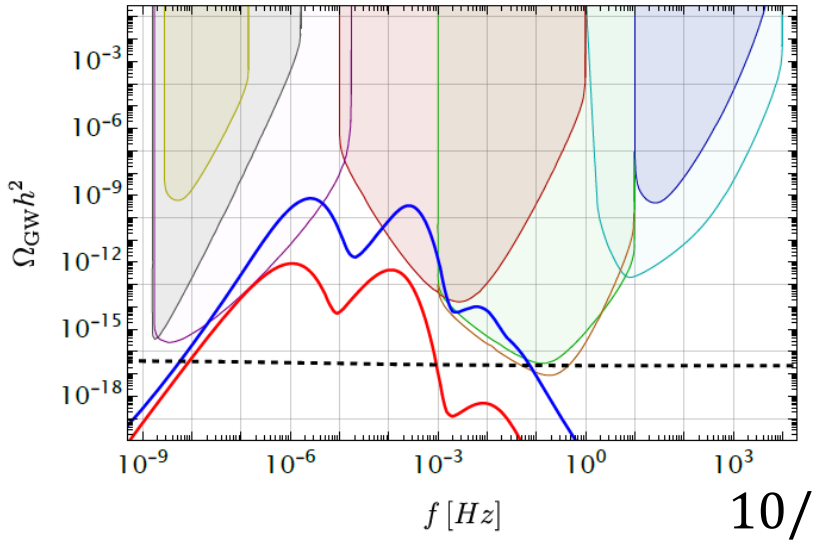




Decreased slope of the potential w.r.t to original





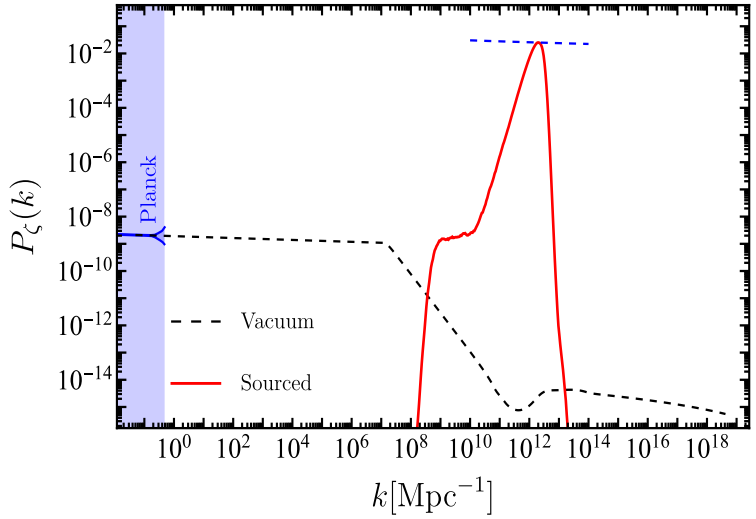


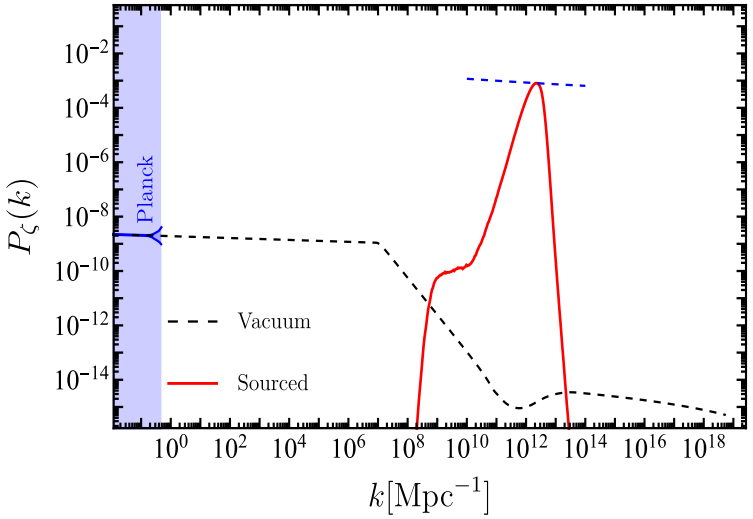
Scalar perturbation

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Scalar perturbation

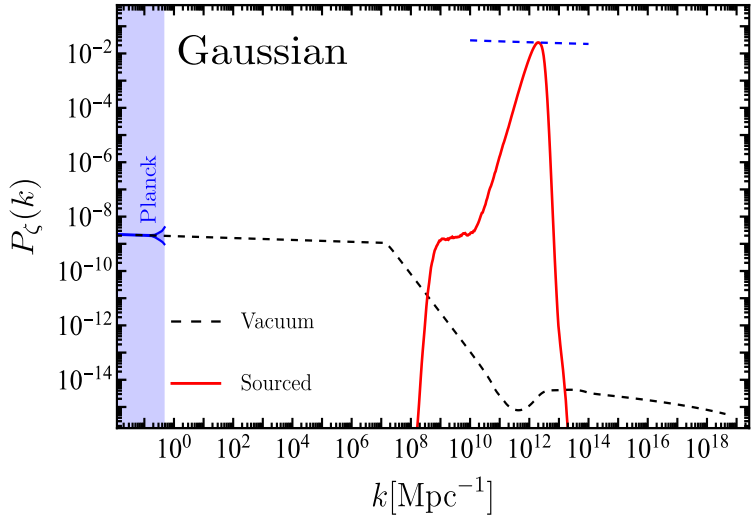
Franciolini, NI, Peloso '26

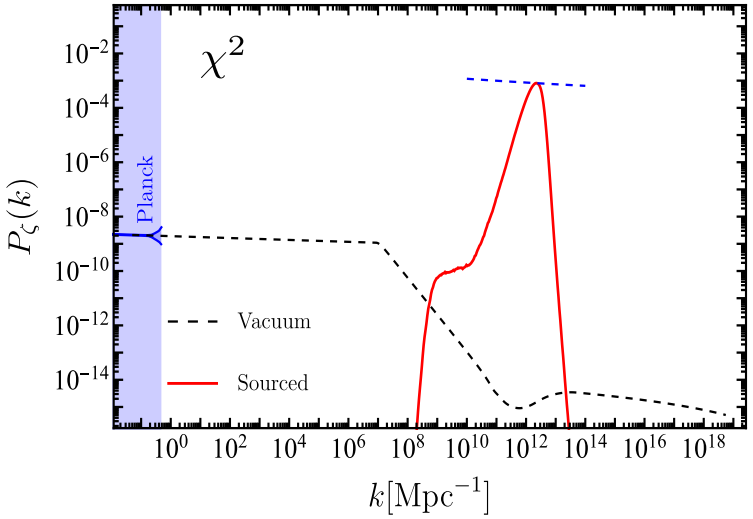




Scalar perturbation

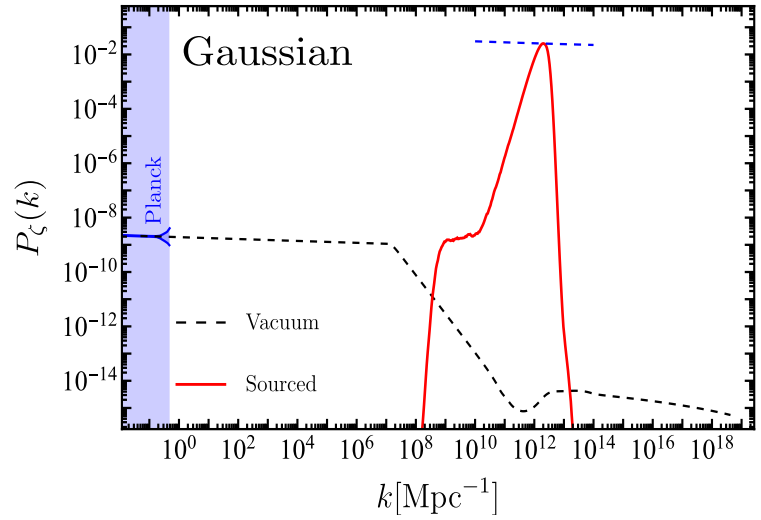
Franciolini, NI, Peloso '26

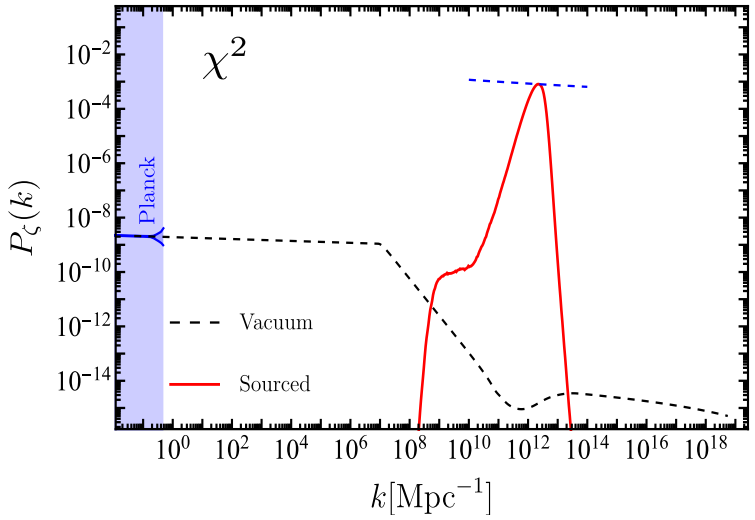


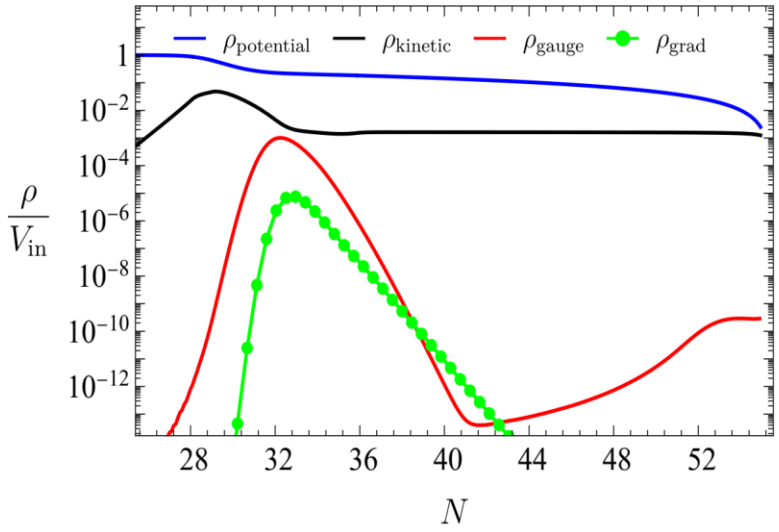


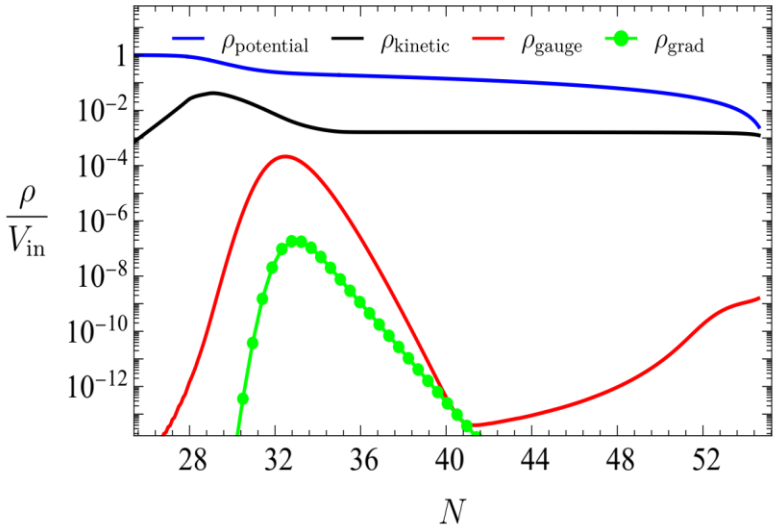
Scalar perturbation

Franciolini, NI, Peloso '26







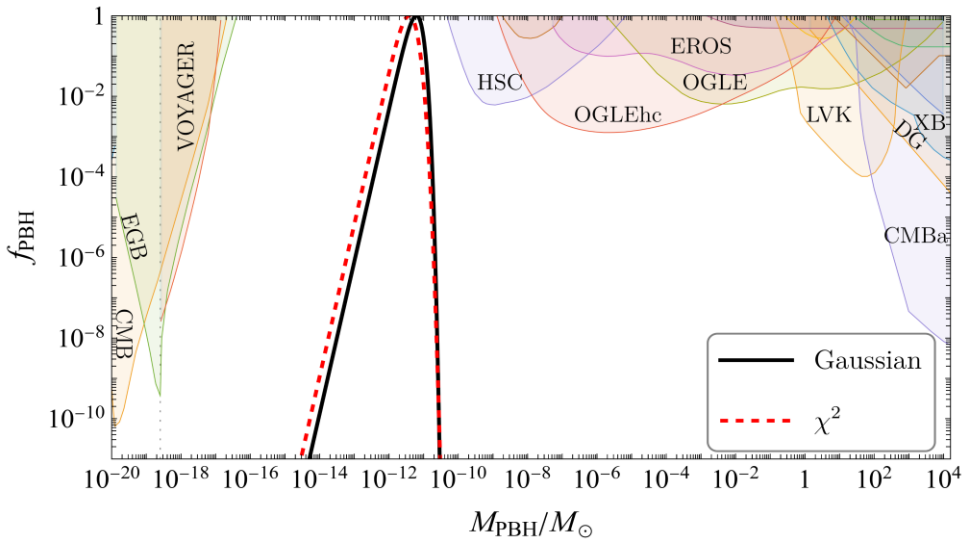


PBHs and SIGW

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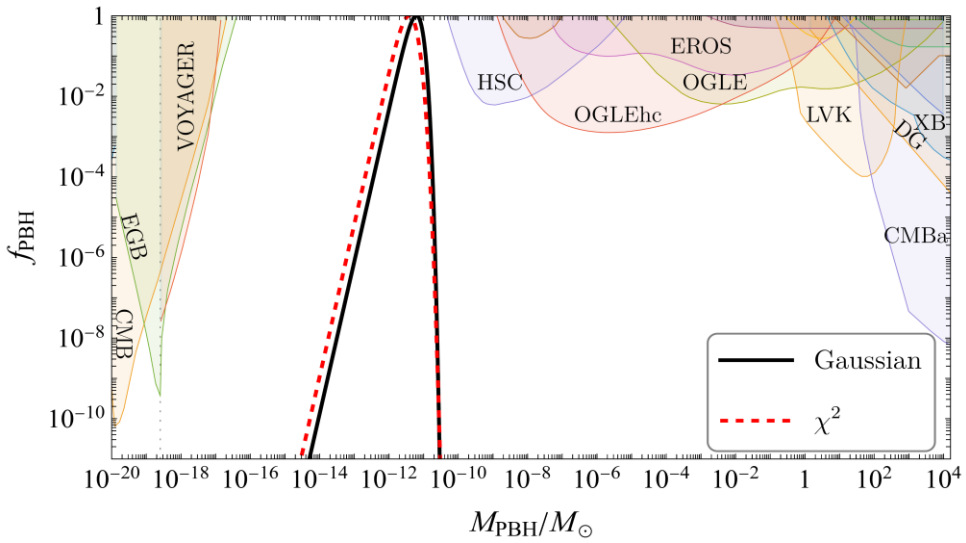
PBHs and SIGW

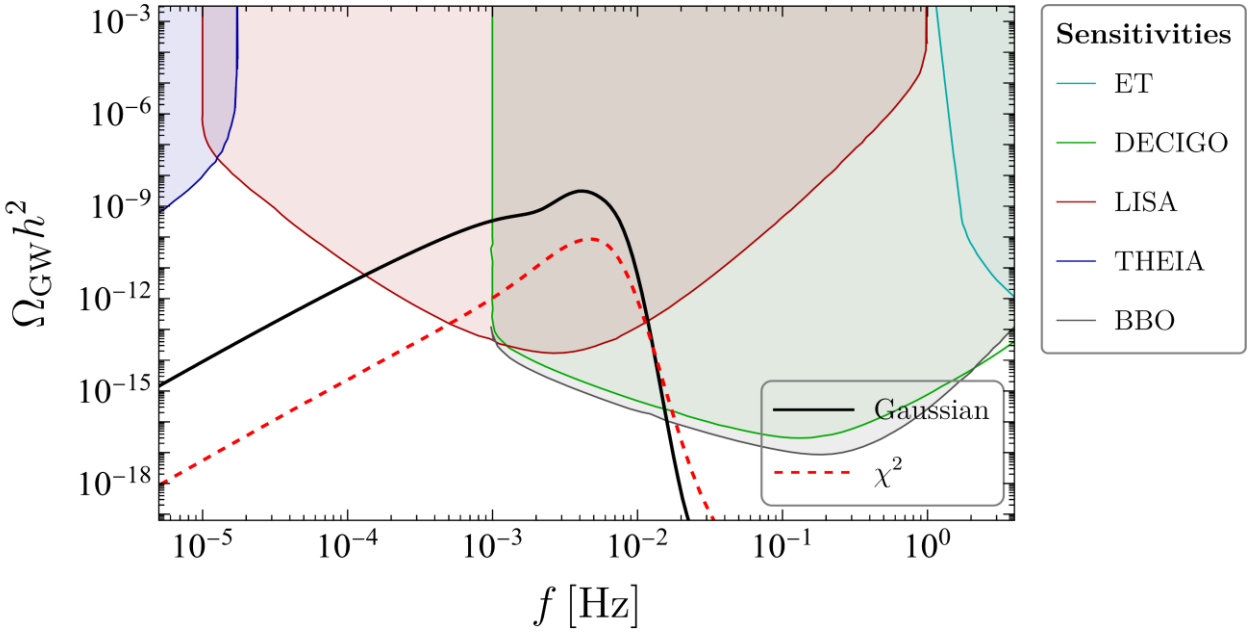
Franciolini, NI, Peloso '26



PBHs and SIGW

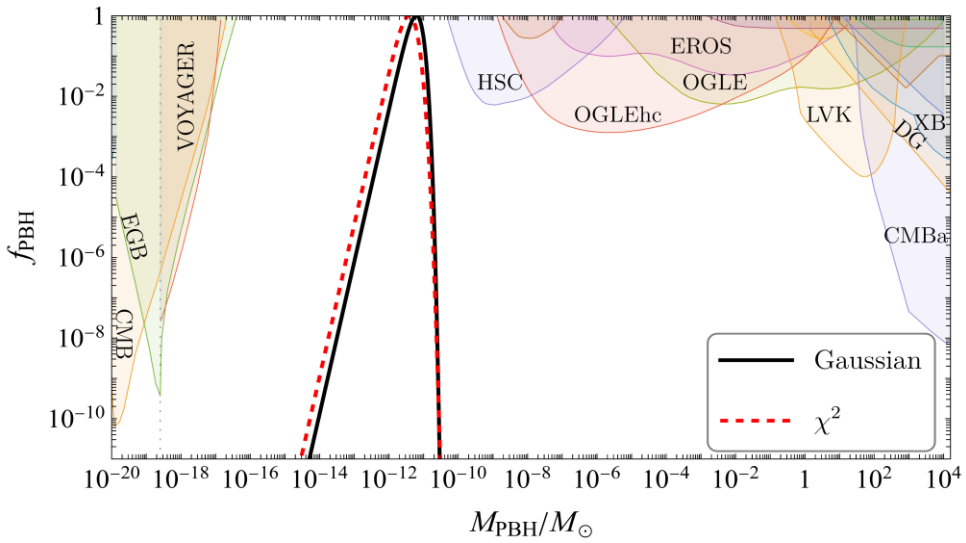
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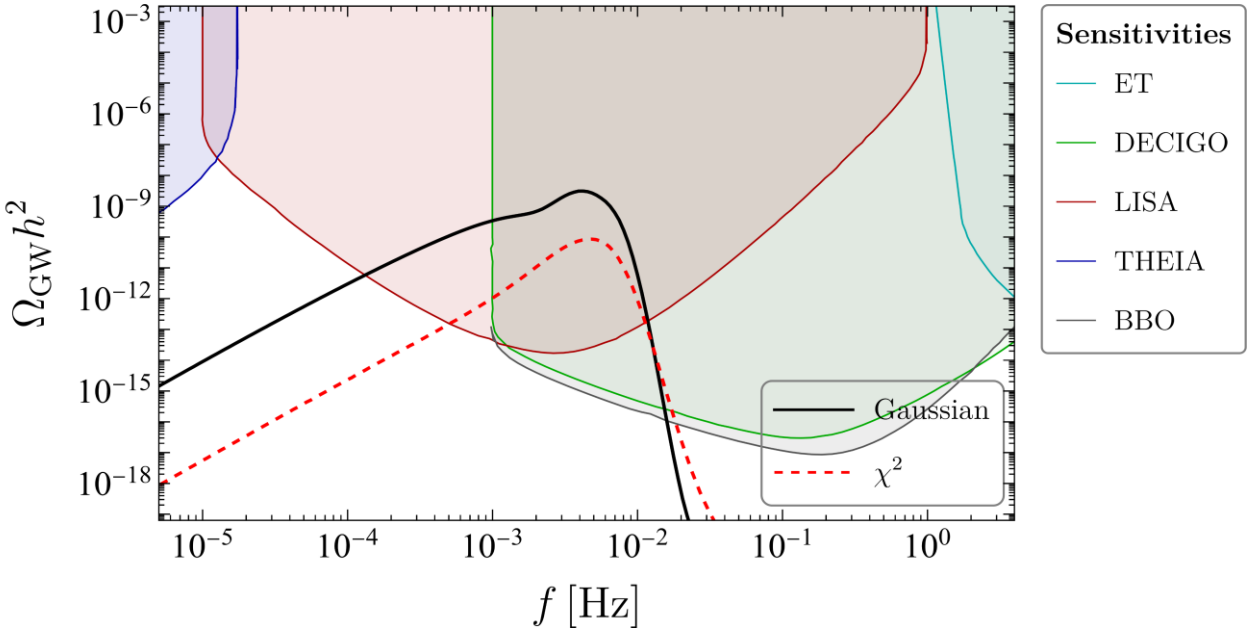


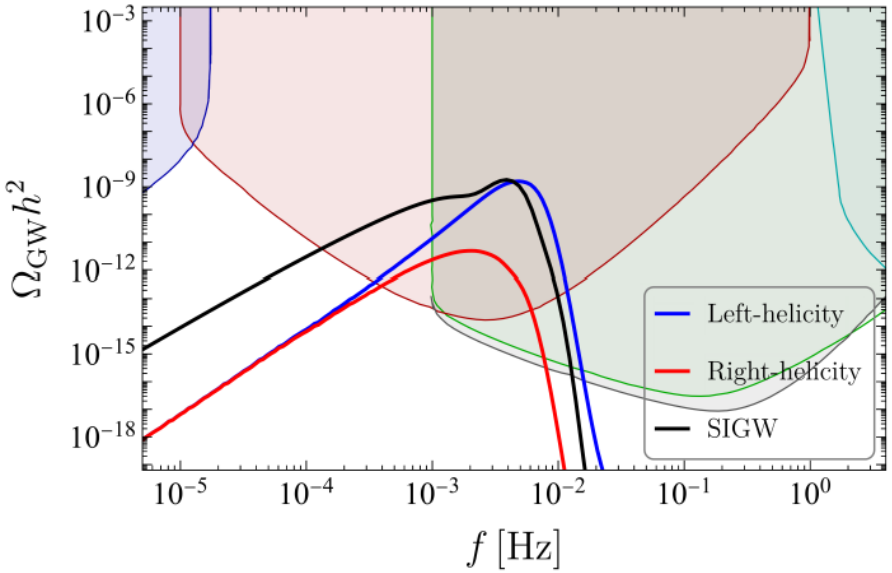


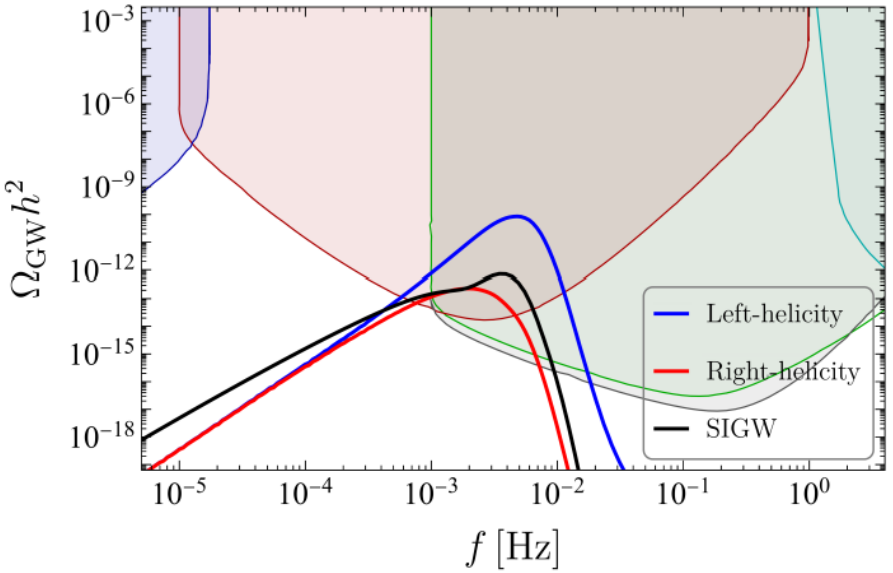
PBHs and SIGW

Franciolini, NI, Peloso '26









Summary

- Axion–gauge coupling leads to exponential gauge-field amplification during inflation.
- Strong backreaction can invalidate homogeneity; consistency requires $\rho_{\rm grad} \ll \rho_{\rm kin}$.
- Repeated gauge-field amplification produces a multi-peaked, chiral primordial GW signal.
- Enhanced scalar perturbations can produce asteroid-mass PBHs accounting for all dark matter.
- For fixed PBH abundance, χ^2 statistics require less scalar power than Gaussian statistics.
- The associated scalar-induced GWs lie in the LISA band and probe the scalar statistics.

Thank You !