Probing pNG with PTA

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(Andrea Mitridate's last slide)

OUTLOOK

- strong evidence for a GWB in the nHz band
- SMBH or cosmological signal? still unclear
- anisotropies and CW searches will help discriminating
- precise estimates of detection probabilities are needed
- PTAs can be used to set tight constraints on NP models

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Dawn of GW Early Universe Cosmology !

$$\Phi \,, \; h_{ij}$$

$$\Phi(k,t) = T(kt)\, R_k$$

$$\Box h_{ij} = 0 + \underbrace{S_{ij}}_{\sim \{\partial_i \Phi\, \partial_j \Phi\}} \quad \text{(FLRW)}$$

$$S_{ij} = \epsilon^{\lambda}_{ij}\, S_\lambda(k,t)$$

$$h_{ij} = \epsilon^{\lambda}_{ij}\, h_\lambda(k,t)$$

$$h_{ij} = \int dt'\, G(k,t-t')\, S_k(t')$$

$$S_k = \int d\vec{q}\; Q^{\lambda}\, f(\vec{q}, \vec{k}-\vec{q}, t) \times R_{\vec{q}}\, R_{\vec{k}-\vec{q}}$$

$$\Omega_{GW} \propto \langle h_{ij}(\vec{k},t)\, h_{ij}(\vec{k}',t) \rangle = \int dt_1\, dt_2\, G_1 G_2 \int d\vec{q}_1\, d\vec{q}_2\; Q_1 Q_2\, f_1 f_2\, \underbrace{\langle R_{\vec{q}_1} R_{\vec{k}-\vec{q}_1} R_{\vec{q}_2} R_{\vec{k}'-\vec{q}_2} \rangle}$$

(D) $$= \sum_{ij} \langle R^2 \rangle_i \langle R^2 \rangle$$

(G) $$+ \underbrace{T(\vec{k}_1, \vec{k}_2, \dots \vec{k}_4)}_{\text{PNG}}\, \delta^{(3)}\left(\sum \vec{k}_i\right)$$

local pNG:

$$\mathcal{R} = \underset{\substack{\downarrow \\ \text{G.F}}}{\zeta} + \underbrace{f_{NL}\left(\zeta^2 - \sigma_\zeta^2\right)}_{\ll \zeta} + \cancel{g_{NL}\,\mathcal{O}(\zeta^3)} \rightarrow P_{\mathcal{R}} = P_G + f_{NL}^2 \int d^3q\, P_{G,\vec{q}}\, P^{(G)}_{\hat{k}-\vec{q}}$$

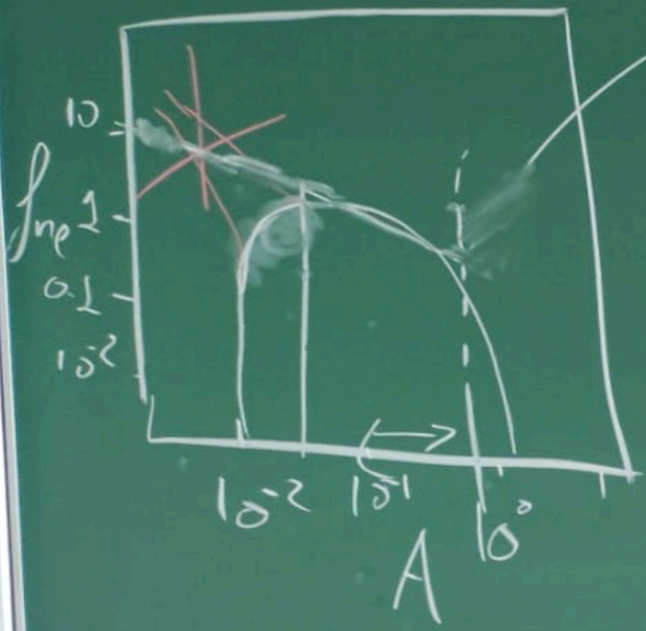
$$\langle \mathcal{R}^4 \rangle \sim \left\langle \left[\zeta + f_{NL}\left(\zeta^2 - \sigma_\zeta^2\right)\right]^4 \right\rangle = \langle \zeta^4 \rangle + f_{NL}^2 \underbrace{\langle \zeta^6 \rangle}_{\underbrace{\sum_{i=1}^{3} \langle \zeta^6 \rangle_i}_{\sim P_G P_G P_G}} + f_{NL}^4 \underbrace{\langle \zeta^8 \rangle}_{\underbrace{\sum_{i=1}^{3} \langle \zeta^8 \rangle_i}_{\sim P_G P_G P_G P_G}}$$

$$\langle \zeta_k^2 \rangle = P_G = \frac{A}{\sqrt{2\pi}\,\sigma} e^{-\ln^2(k/k_*)/2\sigma_*^2}$$

$$\boxed{\Omega_{GW}(k,t)} = \Omega_{GW}^{(G)}(k,t) + f_{NL}^2\, \Omega_{GW}^{(2)}(k,t) + f_{NL}^4\, \Omega_{GW}^{(4)}(k,t)$$

$$= A^2 \omega_0(x) + f_{NL}^2 A^3 \omega_2(x) + f_{NL}^4 A^4 \omega_4(x) \qquad x = f/f_*$$

$$= \boxed{A^2\left(\omega_0(x) + B_{NL}\,\omega_2(x) + B_{NL}^2\,\omega_4(x)\right)} \qquad \boxed{B_{NL} \equiv f_{NL}^2 A}$$

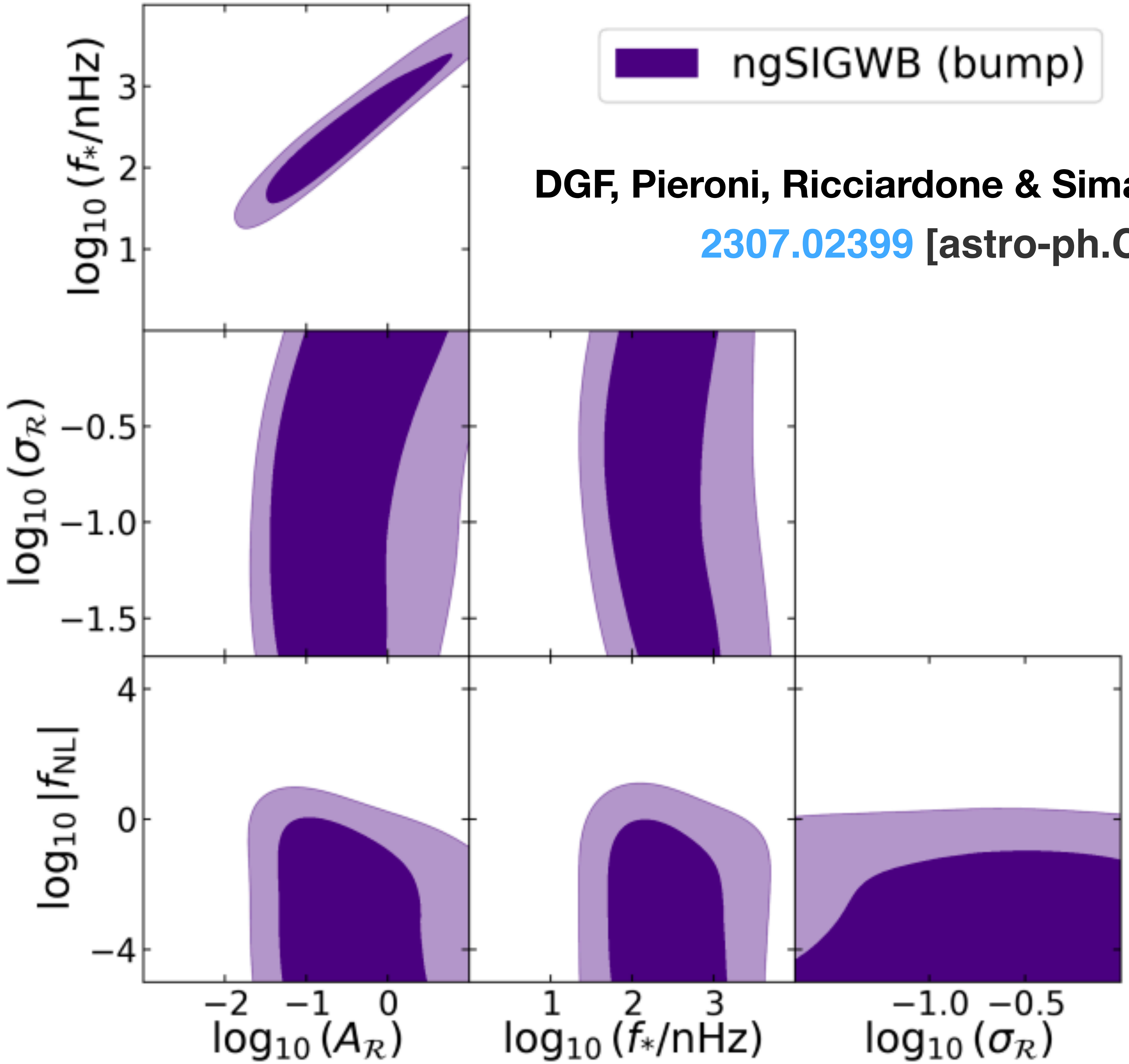


$B_{ne} = A f_{ne}^2 \gg 1 \Rightarrow \Omega_{GW} \propto A^2 B_{ne}^2 = A^4 f_{ne}^4 \rightarrow f_{ne} \propto 1/A$

Perturbativity: $(f_{ne} \lambda^4)^2 < \lambda^2 \Rightarrow f_{ne}^2 A^2 < A \Rightarrow$ $\boxed{B_{ne} = f_{ne}^2 A < 1}$

@95% CL: $\boxed{f_{ne} \leq 2.34}$ $\qquad f_{ne} \leq 1/A_{min}$

Results



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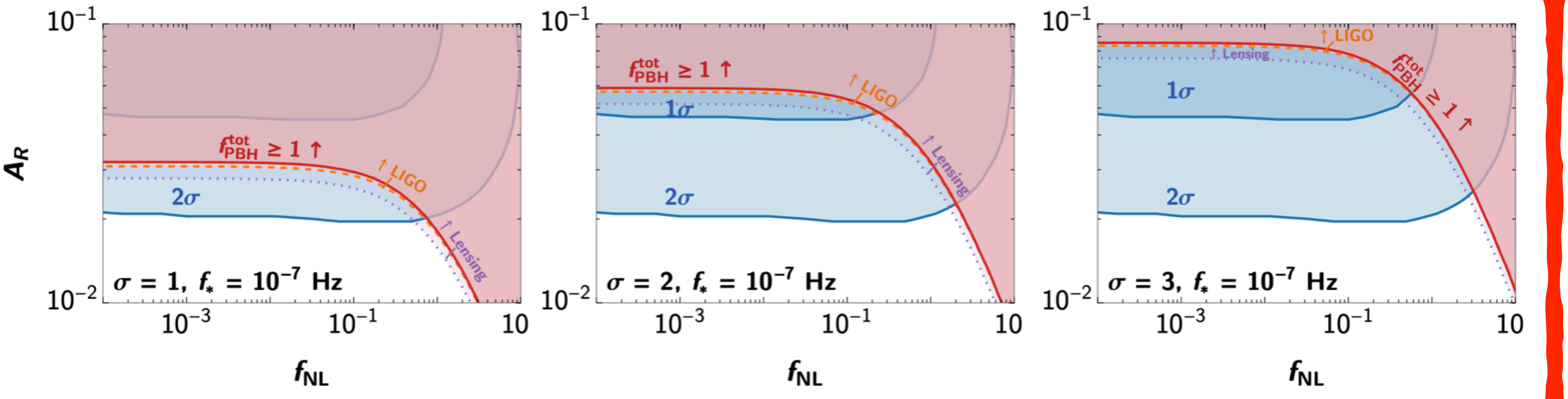

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Bonus

If you want to learn how to "latticesize" your problems …

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CosmoLattice

2nd CL School 2023: Sept 25-29

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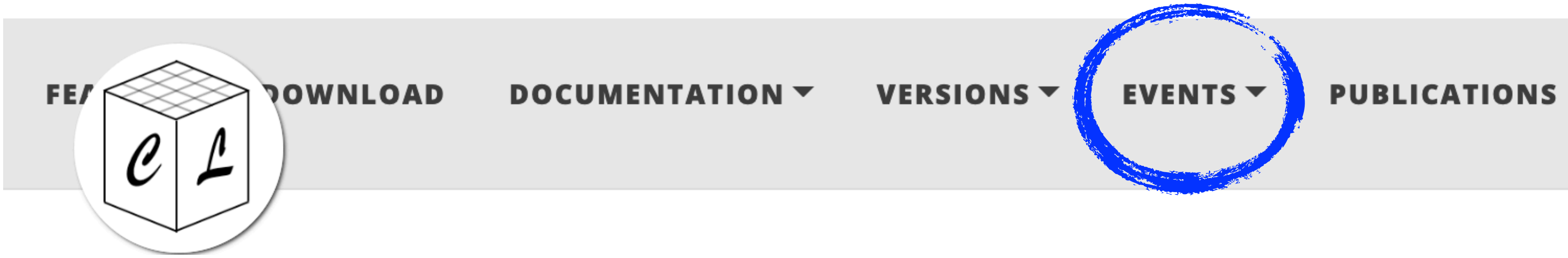

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Thanks for your attention !

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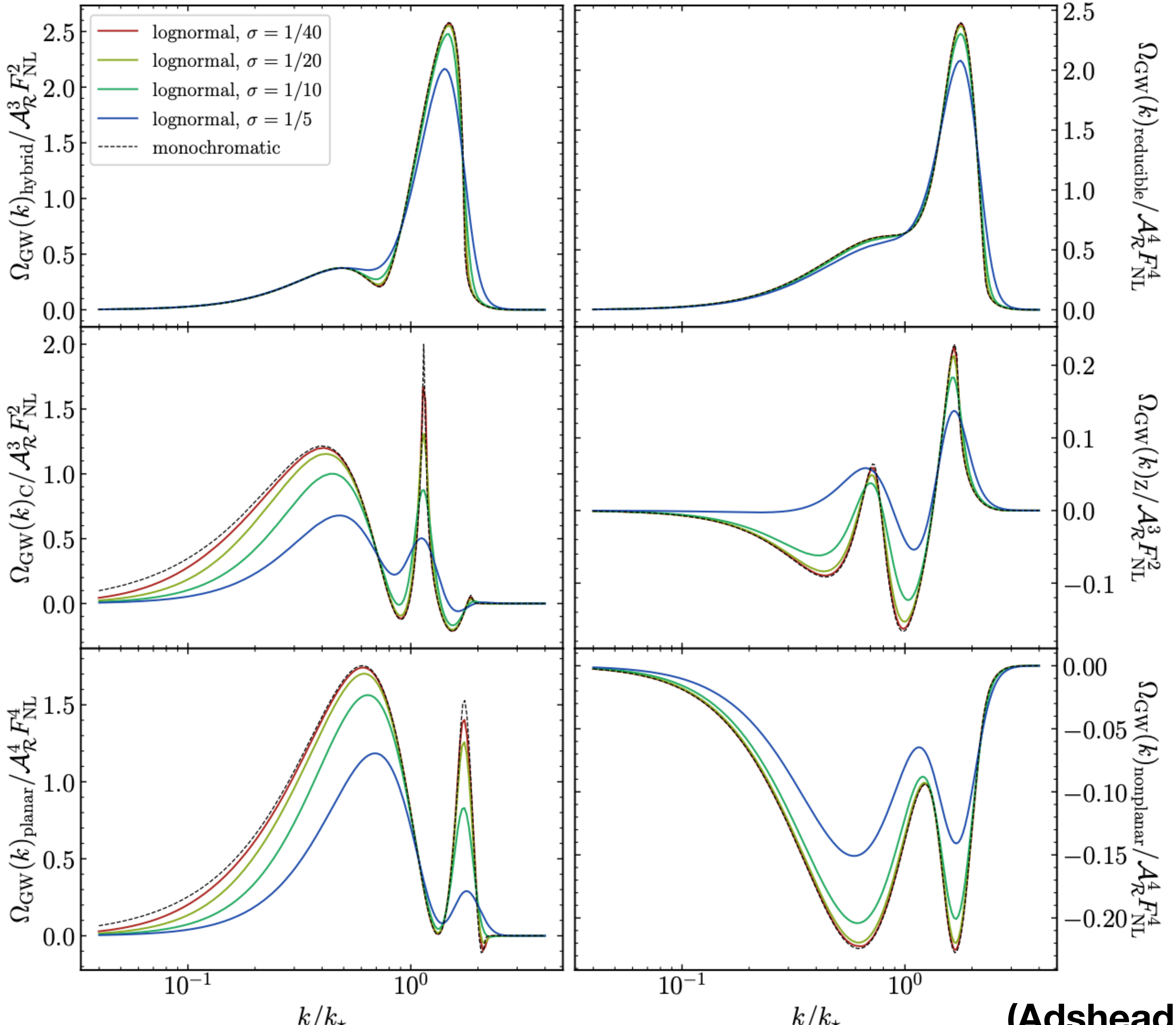

(Adshead et al 2021)

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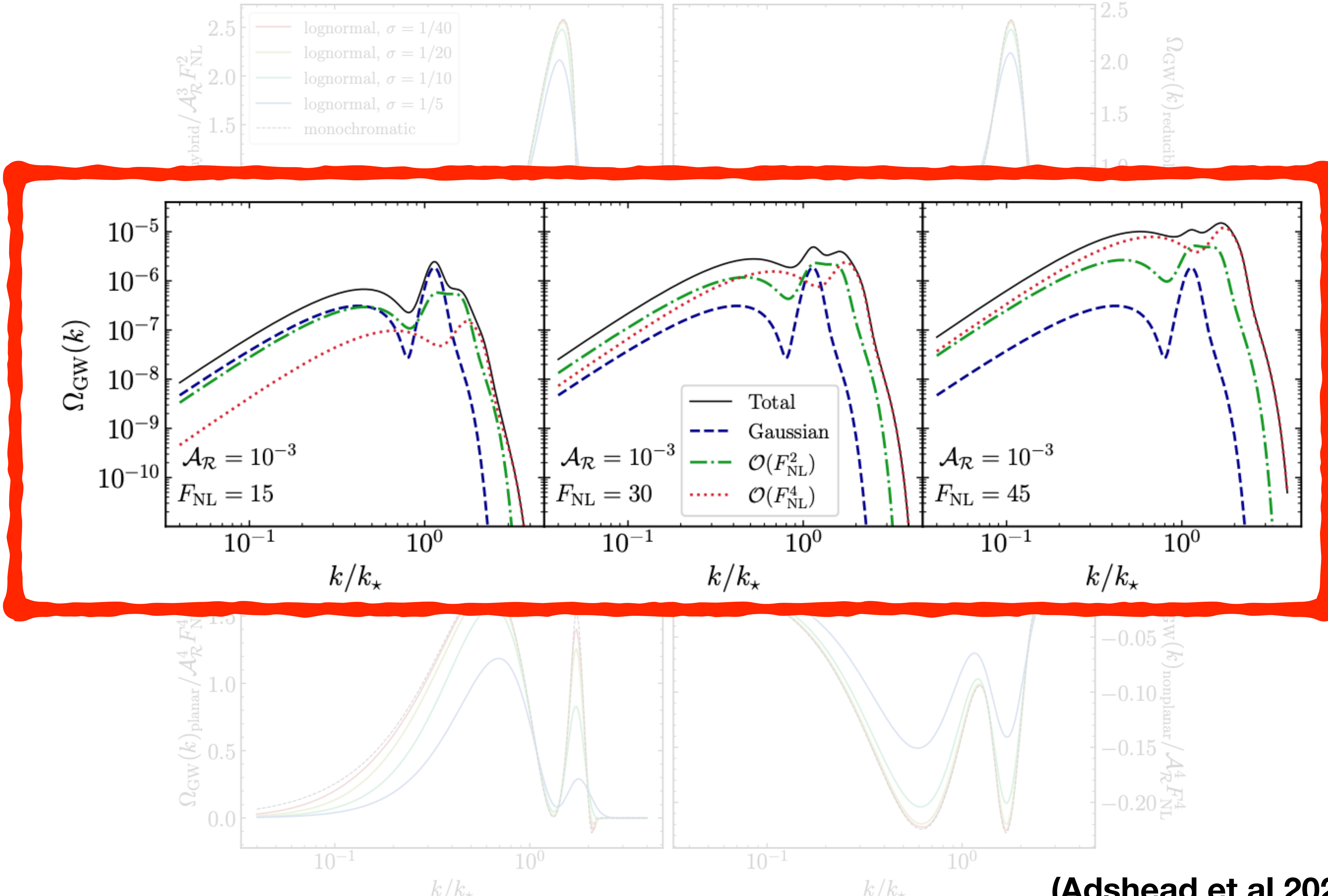

(Adshead et al 2021)