INFN

Topics in gravity waves

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GW RECENT INTEREST

- Designing inflaton potential for PTA and PBH

2408.12587 with Gabriele Autieri

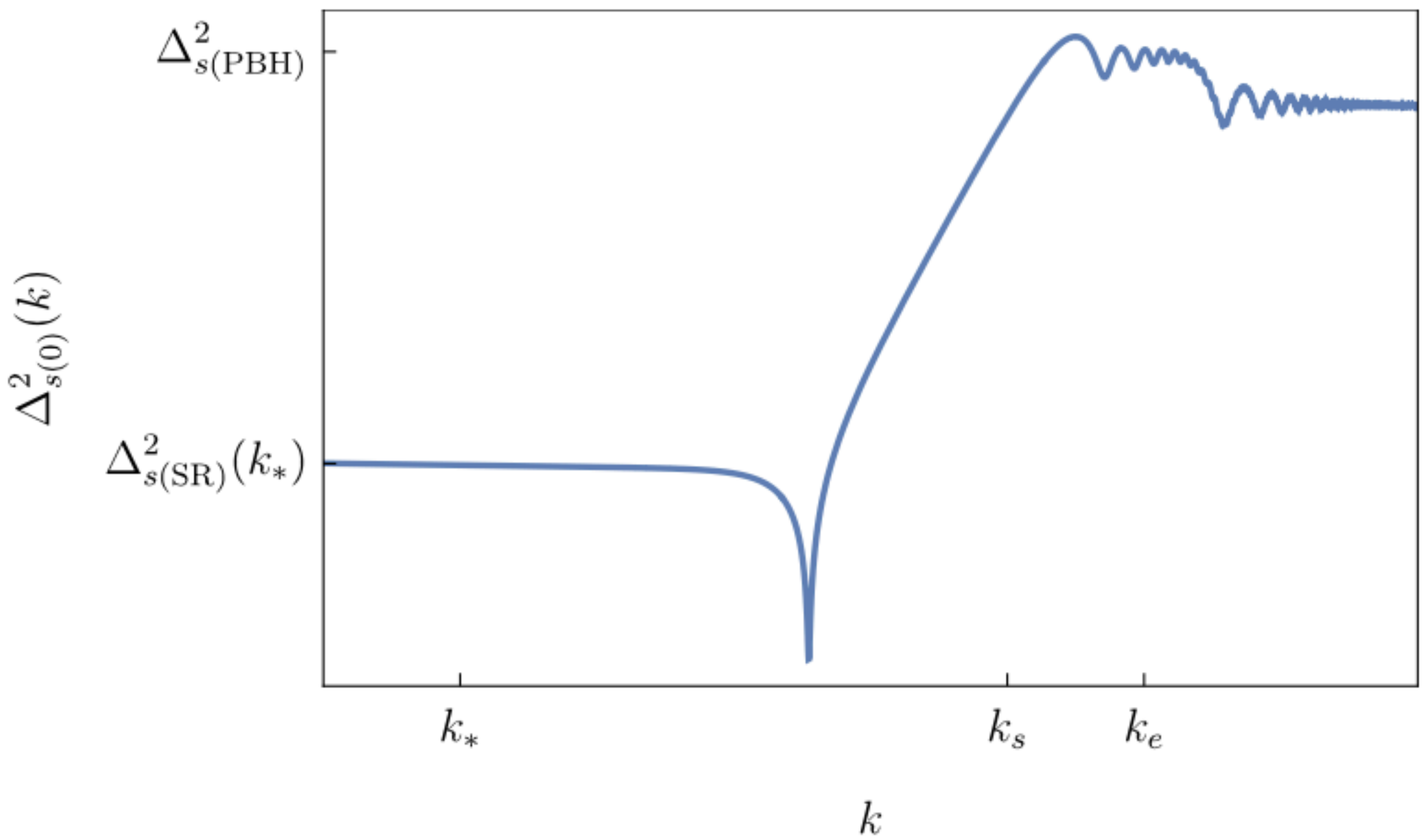
- DM production from scalar and tensor perturbations

2408.15987 with Raghuveer Garani and Andrea Tesi

Inflaton reconstruction:

[MR, Autieri 2408.12587]

A nice way to produce primordial black holes and gravity waves is to consider an enhanced primordial power spectrum of curvature perturbations, $O(10^{-2})$, at scales not directly tested



USR PS:
$\epsilon = 0\,, \eta = -3$

Most of the discussion in the "ultra slow roll regime".
What are the most general scenarios that allow to reproduce say NANOGrav signal?

In single field inflation one can easily reconstruct a potential that reproduces the desired features starting from an input power spectrum.

$$\epsilon(N) \equiv -\frac{\dot{H}}{H^2} \equiv \frac{1}{2M_p^2}\left(\frac{d\phi}{dN}\right)^2 = \frac{1}{2\mathcal{P}(k)M_p^2}\left(\frac{H_I}{2\pi}\right)^2\Big|_{k/a=H_I}$$

The exact potential is given by,

$$V(N) = V(N_0)\exp\left[-2\int_{N_0}^{N} dN'\,\frac{\epsilon(3-\eta)}{3-\epsilon}\right] \qquad \eta \approx -\frac{1}{2}\frac{d\log\epsilon}{dN}$$

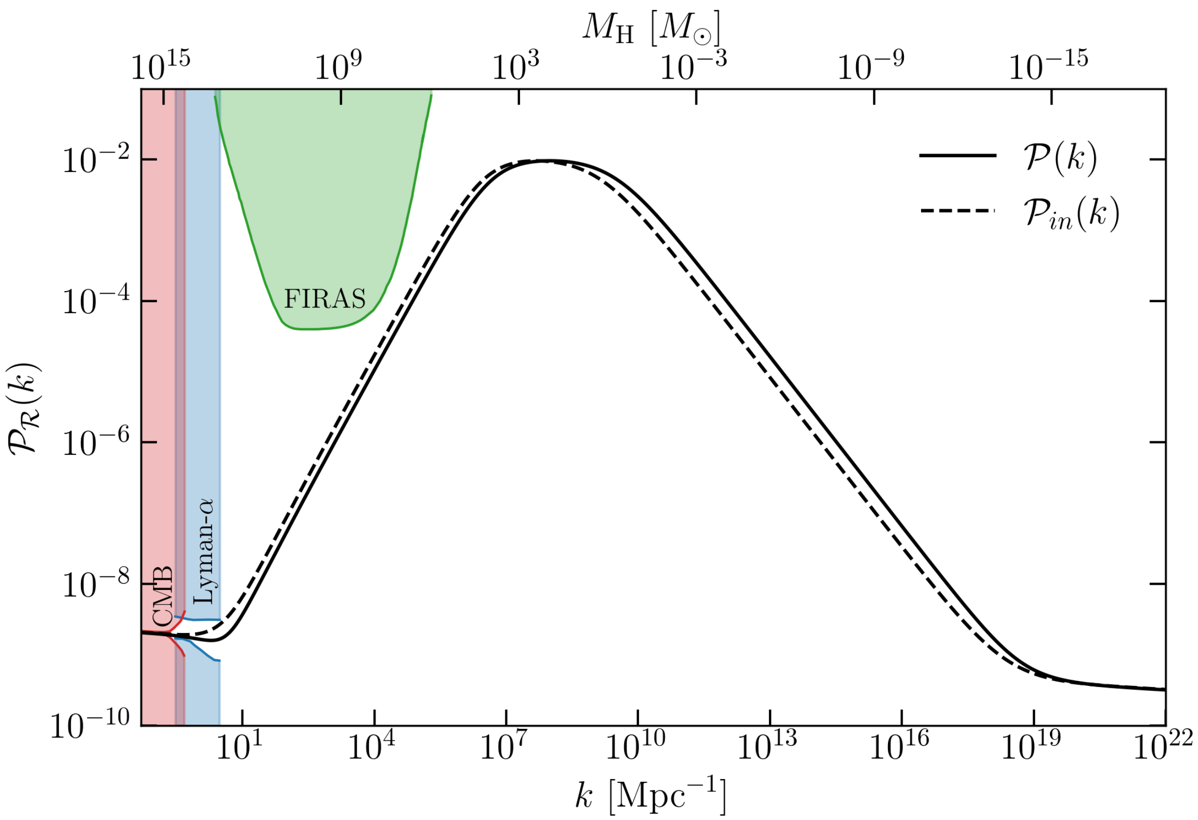
$$\phi(N) = \phi_0 + M_p\int_{N_0}^{N} dN'\sqrt{2\epsilon}$$

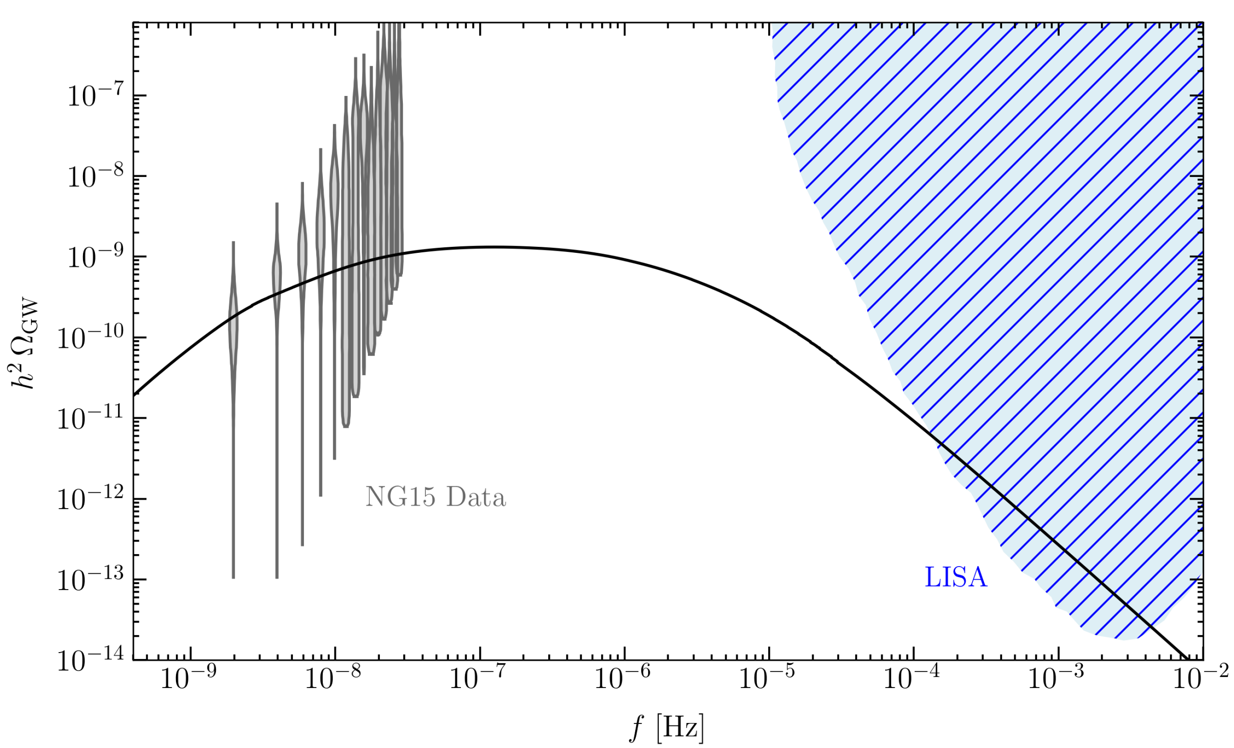
As example we consider a PS:

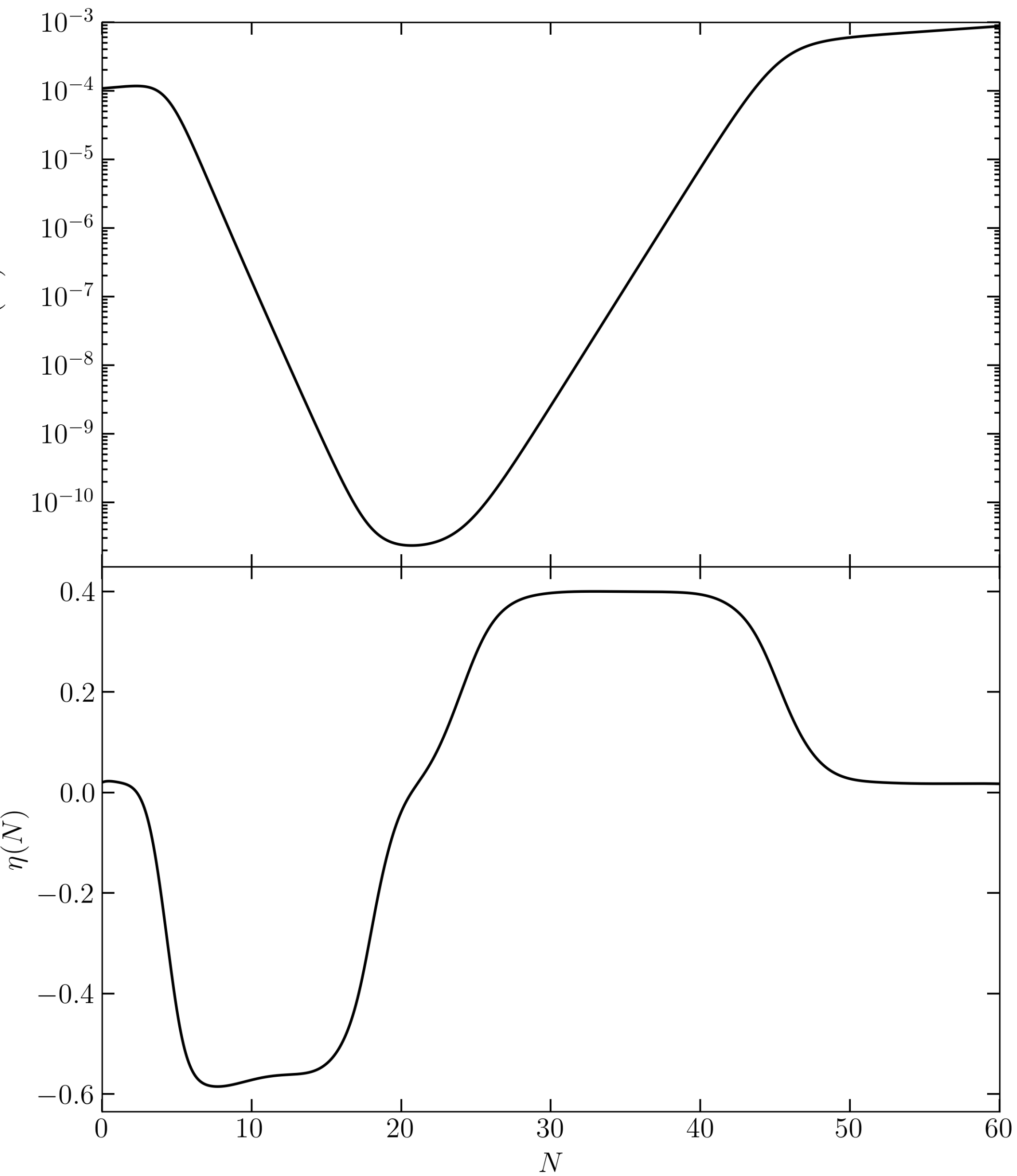
$$\Delta\mathcal{P}(k_* e^N) = \frac{A}{2}\left[\tanh\frac{N-N_1}{w_1} + \tanh\frac{N_2-N}{w_2}\right] \qquad \eta \sim \frac{1}{w}$$

In the context of PTAs we find that the signal can be borderline compatible with slow roll:

$$N_1 = 18\,,\, w_1 = 1.8\,,$$
$$N_2 = 24\,,\, w_2 = 2.5$$
$$A = 1.08 \times 10^{-2}$$

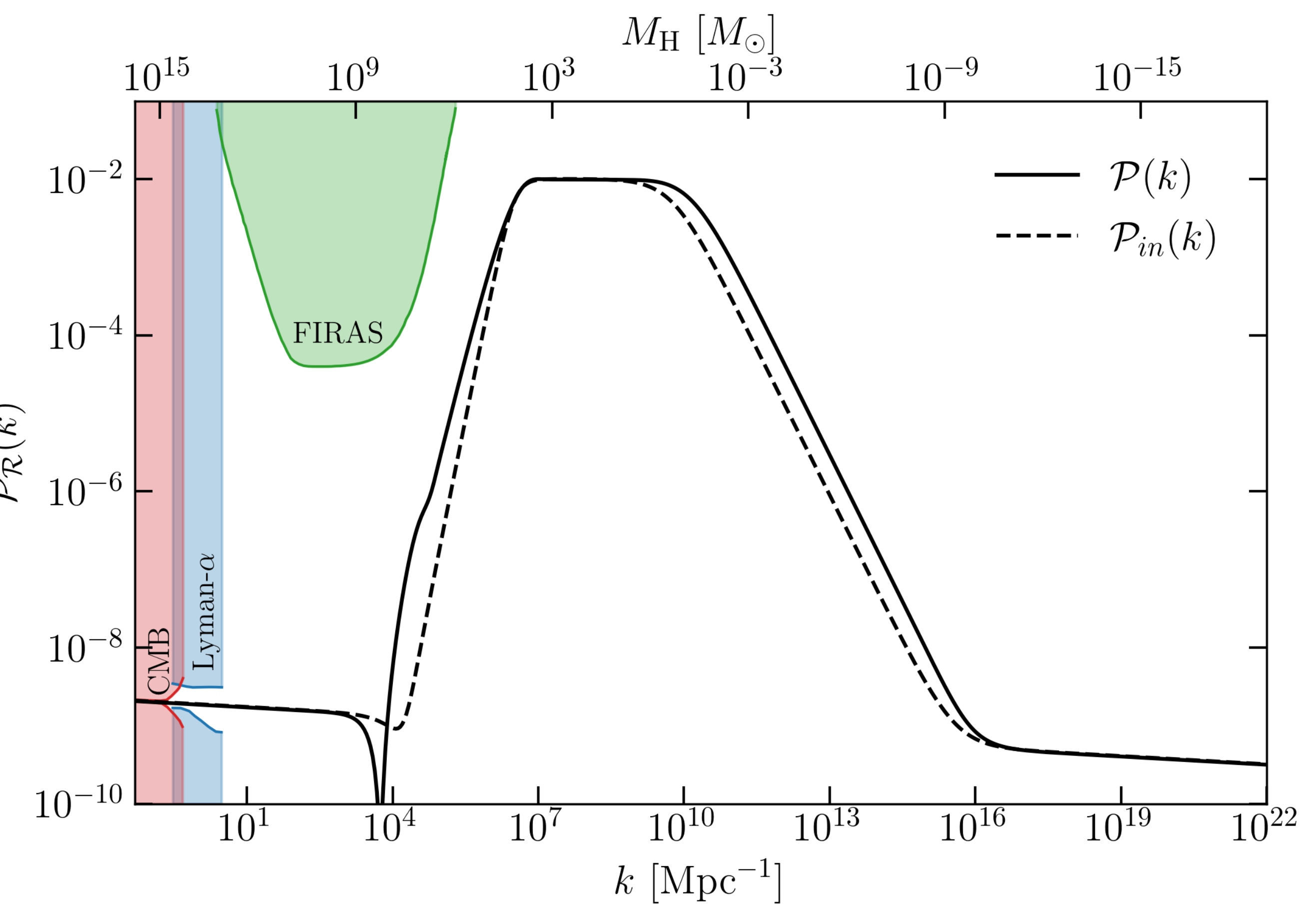


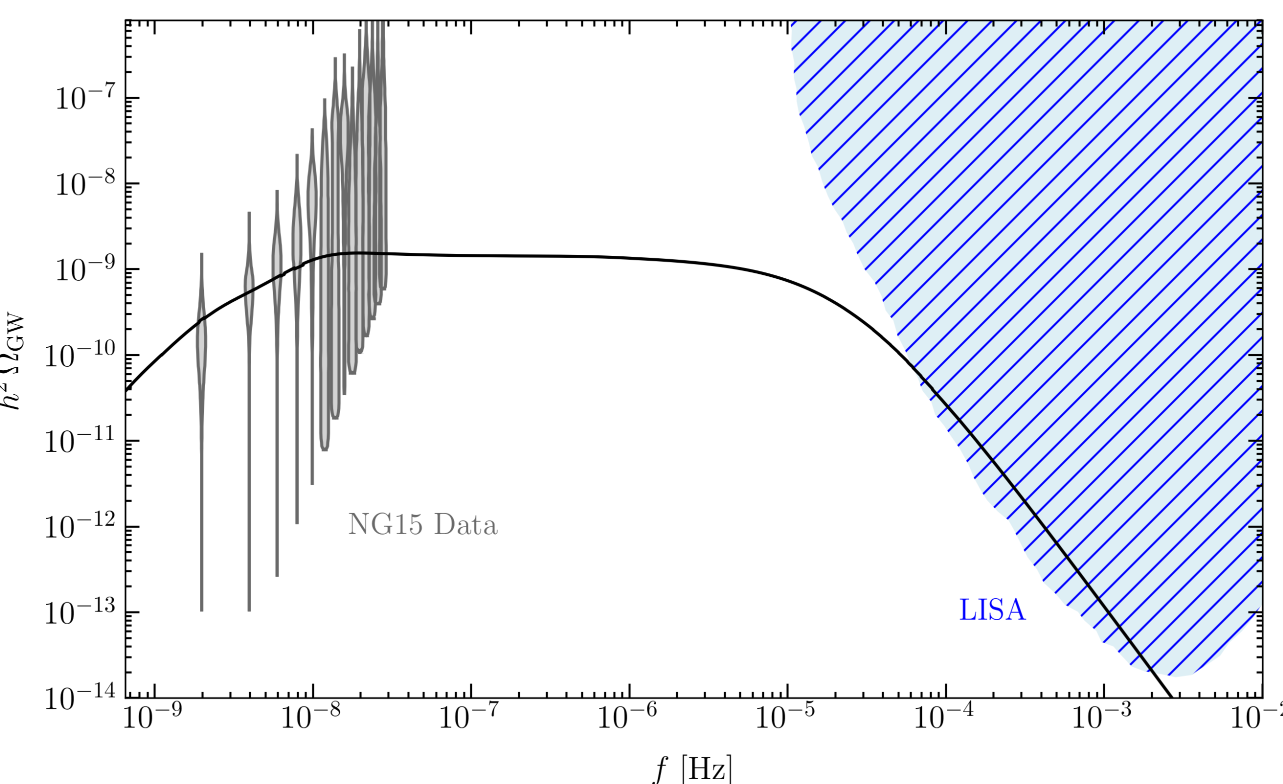


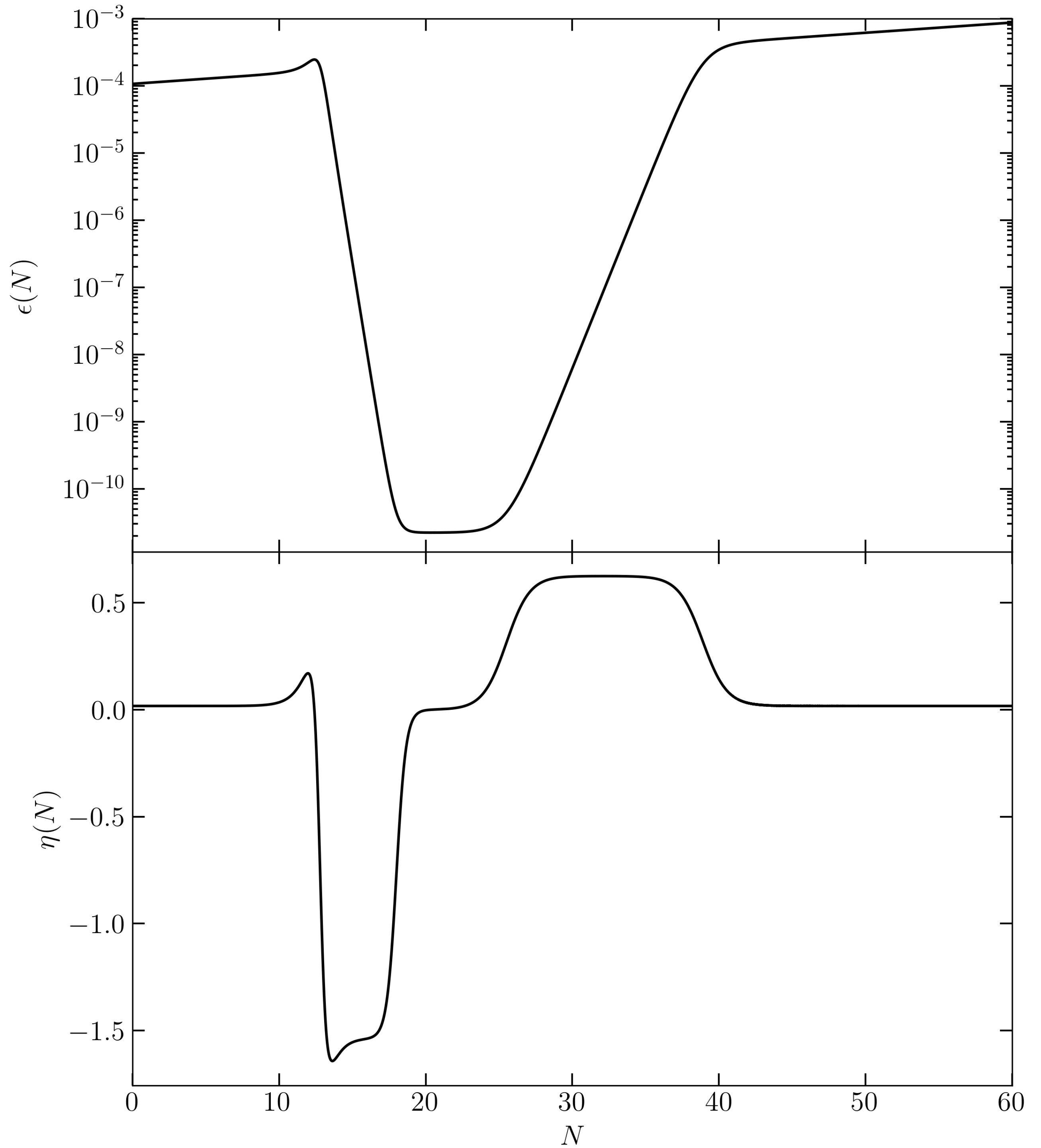


Fast roll NANOGrav:

$$N_1 = 18\,, w_1 = 0.65\,,$$
$$N_2 = 25.5\,, w_2 = 1.6$$
$$A = 1.06 \times 10^{-2}$$







Stochastic DM:

[Garani, MR, Tesi 2408.15987
+ work in progress]

Massless fermions and gauge fields are not produced in an FRW background due to Weyl invariance of the action,

$$ds^2 = a(\tau)^2(d\tau^2 - d\vec{x}^2) \longrightarrow \Box\chi = 0$$

It was noticed by Maleknejad and Kopp that massless fermions would be produced in a GW background because the metric is not flat up to a Weyl rescaling.

This phenomenon is completely general: scalar and tensor perturbations induce particle production of any spin.

The abundance can be computed from the Bogoliubov transformation induced by the stochastic background:

$$\langle|\beta_{\vec{k}}|^2\rangle = \frac{1}{2}\int d\tau \int d\tau' \int d(\log q) \int dx$$
$$\times\, e^{-i(k+\omega)(\tau-\tau')}\Delta_\Psi(q,\tau,\tau')\mathcal{K}[k\,,q\,,x]\,.$$

$$\langle \Psi_{\vec{q}}(\tau)\Psi^*_{\vec{q}'}(\tau')\rangle = (2\pi)^3\delta^3(\vec{q}-\vec{q}')\frac{2\pi^2}{q^3}\Delta_\Psi(q,\tau,\tau'),$$

For curvature perturbations produced by inflation we can be even more explicit:

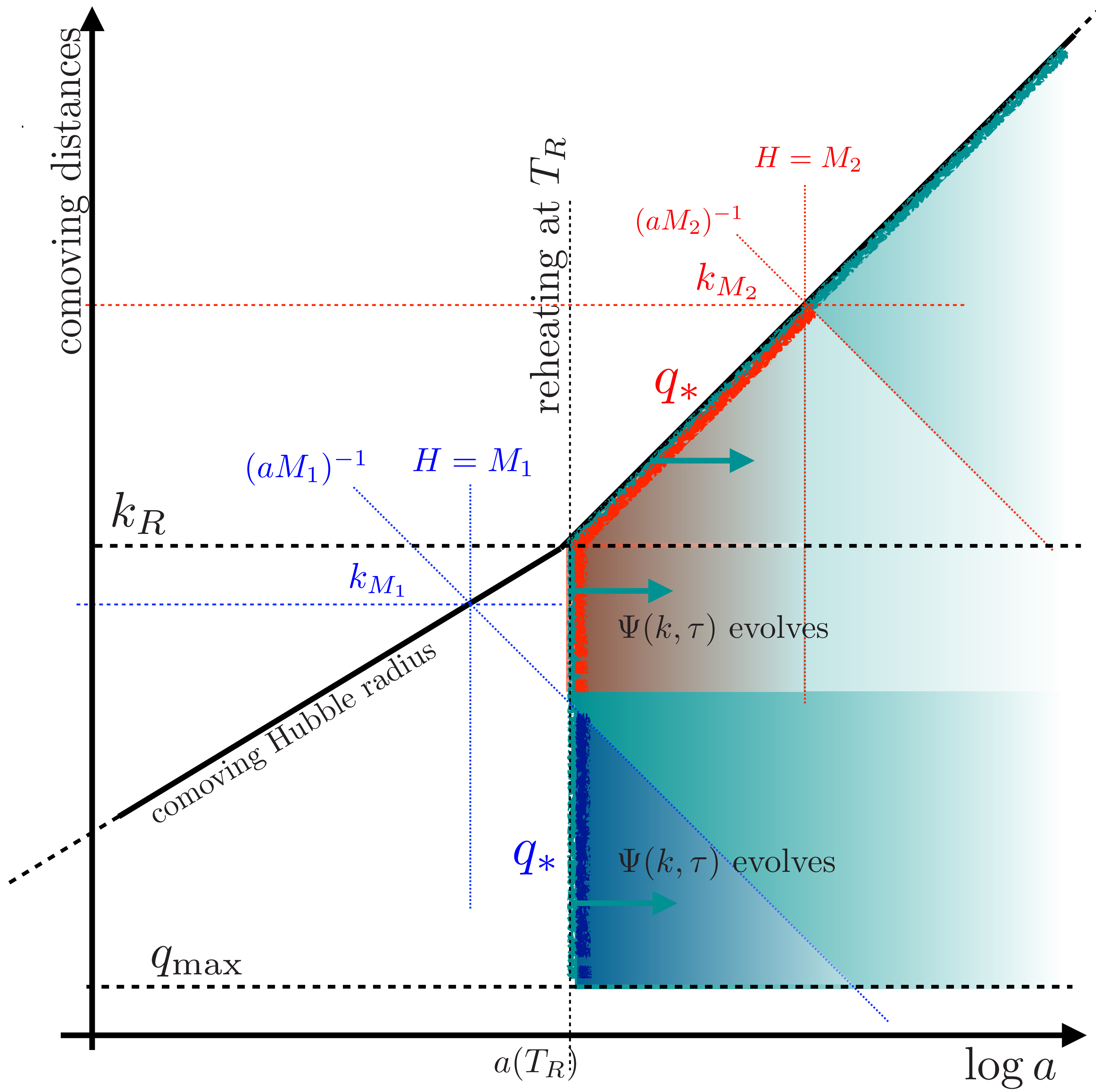
$$\frac{d(na^3)}{d\log k} = \frac{k^3}{4\pi^2}\int d(\log q)\,dx\,\Delta_\zeta(q)|\mathcal{I}(q,k+\omega)|^2\mathcal{K}[k\,,q\,,x]\,.$$

power spectrum | **evolution** | **kinematics**

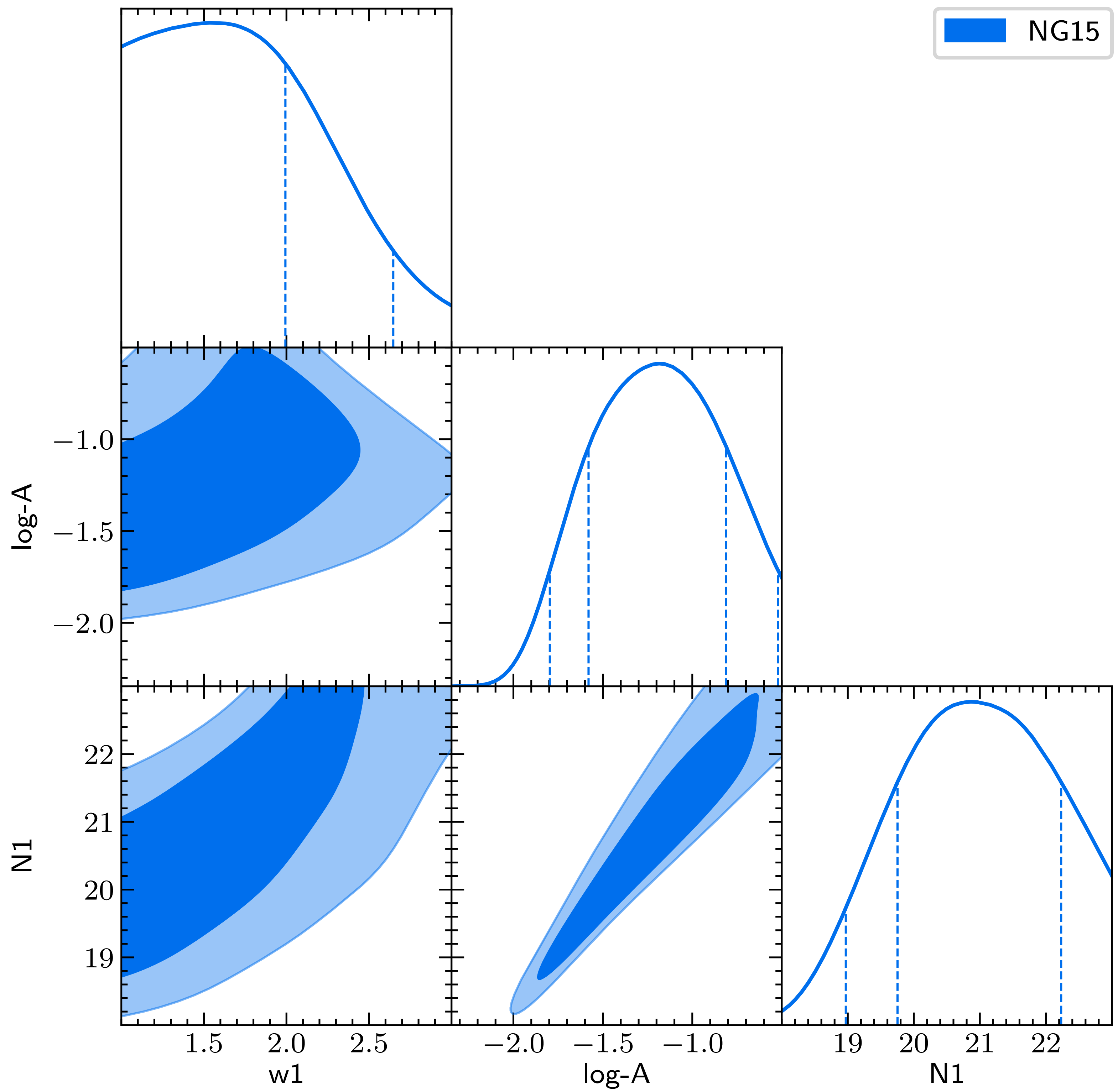
$$\Omega_{\rm DM}|_{\rm stochastic} \approx \frac{A}{4\pi^2}\frac{M\,q_*^3}{3M_p^2H_0^2}\Delta_\zeta(q_*) \qquad A\sim 0.01$$

DM abundance reproduced for:

$$q_* \sim 10^{-7}{\rm eV}\left(\frac{10^6\,{\rm GeV}}{M}\right)^{\frac{1}{3}}\left(\frac{0.01}{\Delta_\zeta(q_*)}\right)^{\frac{1}{3}}\left(\frac{0.01}{A}\right)^{\frac{1}{3}}$$



comoving distances
reheating at T_R
$H = M_2$
$(aM_2)^{-1}$
k_{M_2}
q_*
$(aM_1)^{-1}$
$H = M_1$
k_R
k_{M_1}
$\Psi(k,\tau)$ evolves
comoving Hubble radius
q_*
$\Psi(k,\tau)$ evolves
$q_{\rm max}$
$a(T_R)$
$\log a$



Posterior distributions of parameters obtained with PTArcade.
Confirmed tension with abundance of solar mass black holes.