# CONSTRAINTS ON SCALAR PERTURBATIONS FROM PTA

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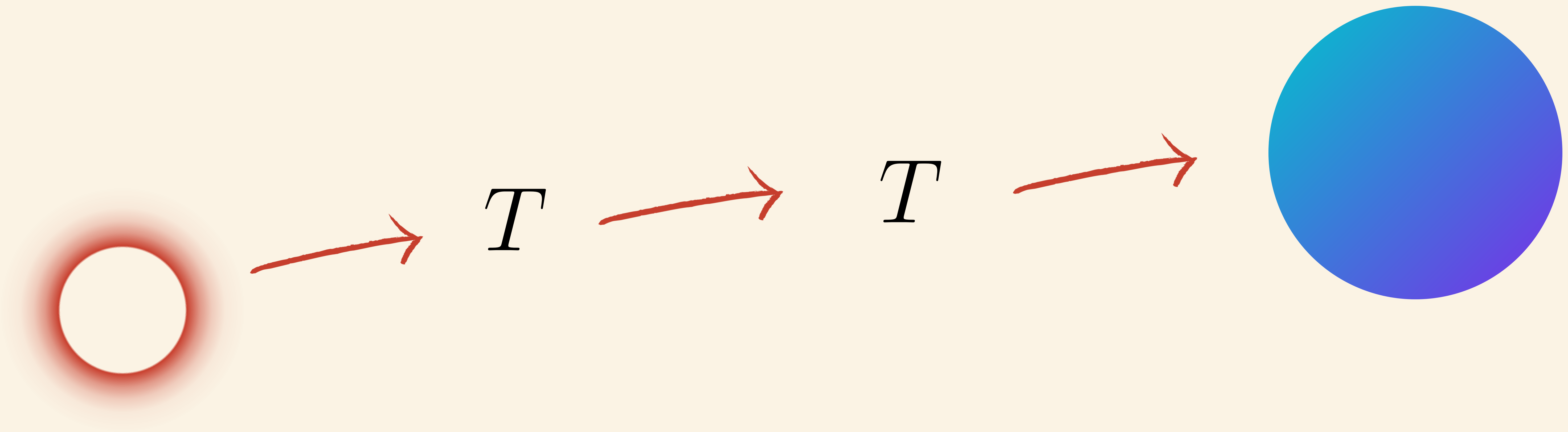
# MOTIVATION

# POTENTIAL SIGNAL OF GRAVITATIONAL WAVES IN PTA

- Pulsars send light pulses with stable period




- PTA observe multiple pulsars with a well know period

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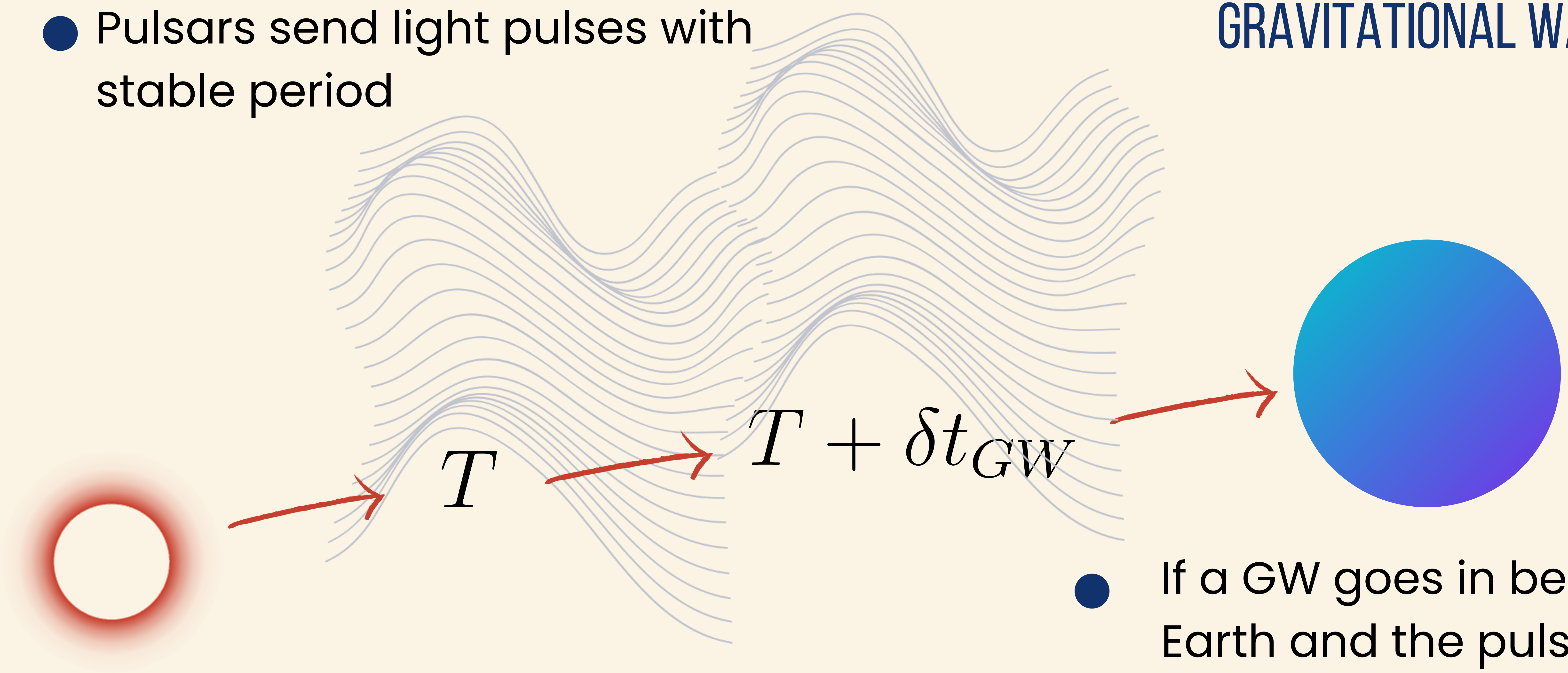


- If a GW goes in between the Earth and the pulsar, the time of arrival of the next pulse is delayed

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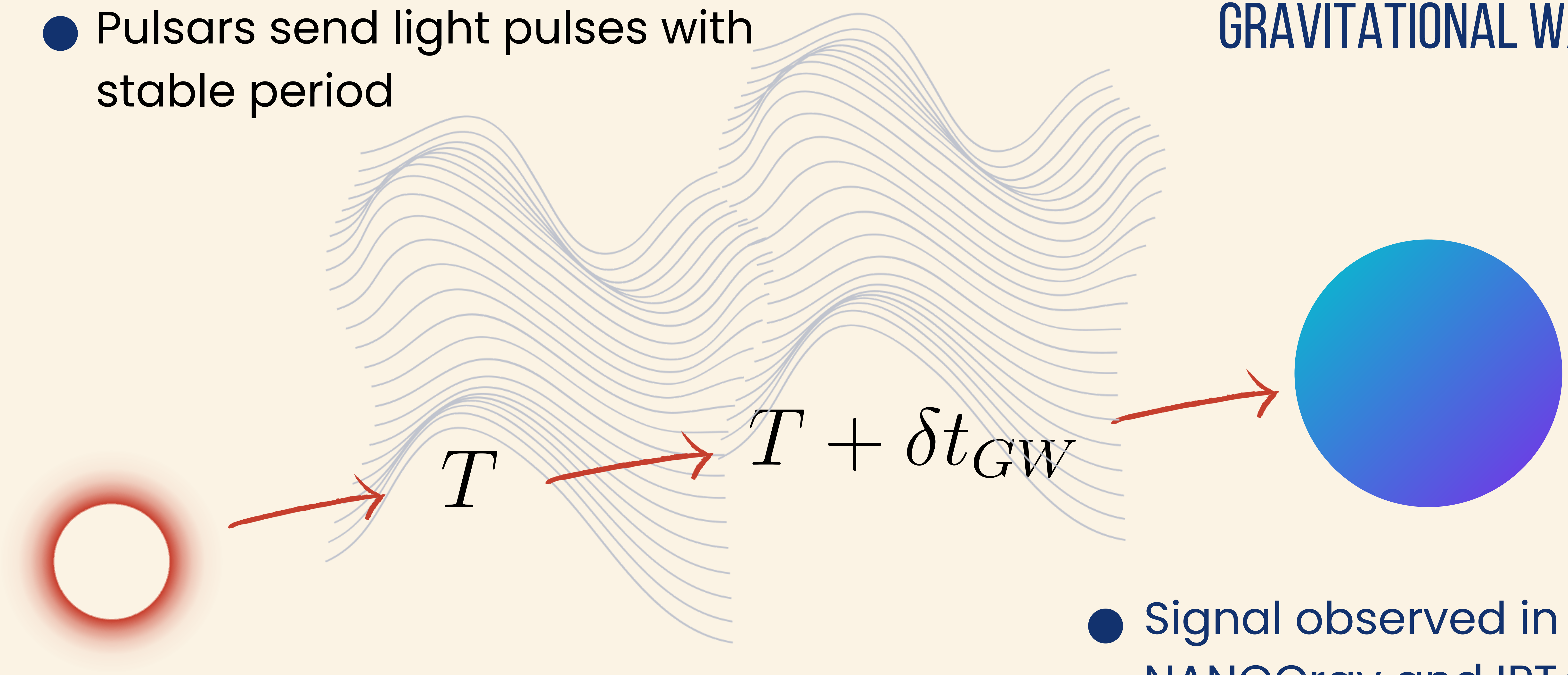


- Signal observed in NANOGrav and IPTA

# WHAT IS THE ORIGIN OF THOSE GW?

- Coallescence of super massive black holes → not the hypothesis we are going to consider here

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$P_\zeta \approx \mathcal{O}(10^{-9})$ at scales $k \approx \mathcal{O}(1\mathrm{Mpc}^{-1})$

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Almost no constraints at small scales !

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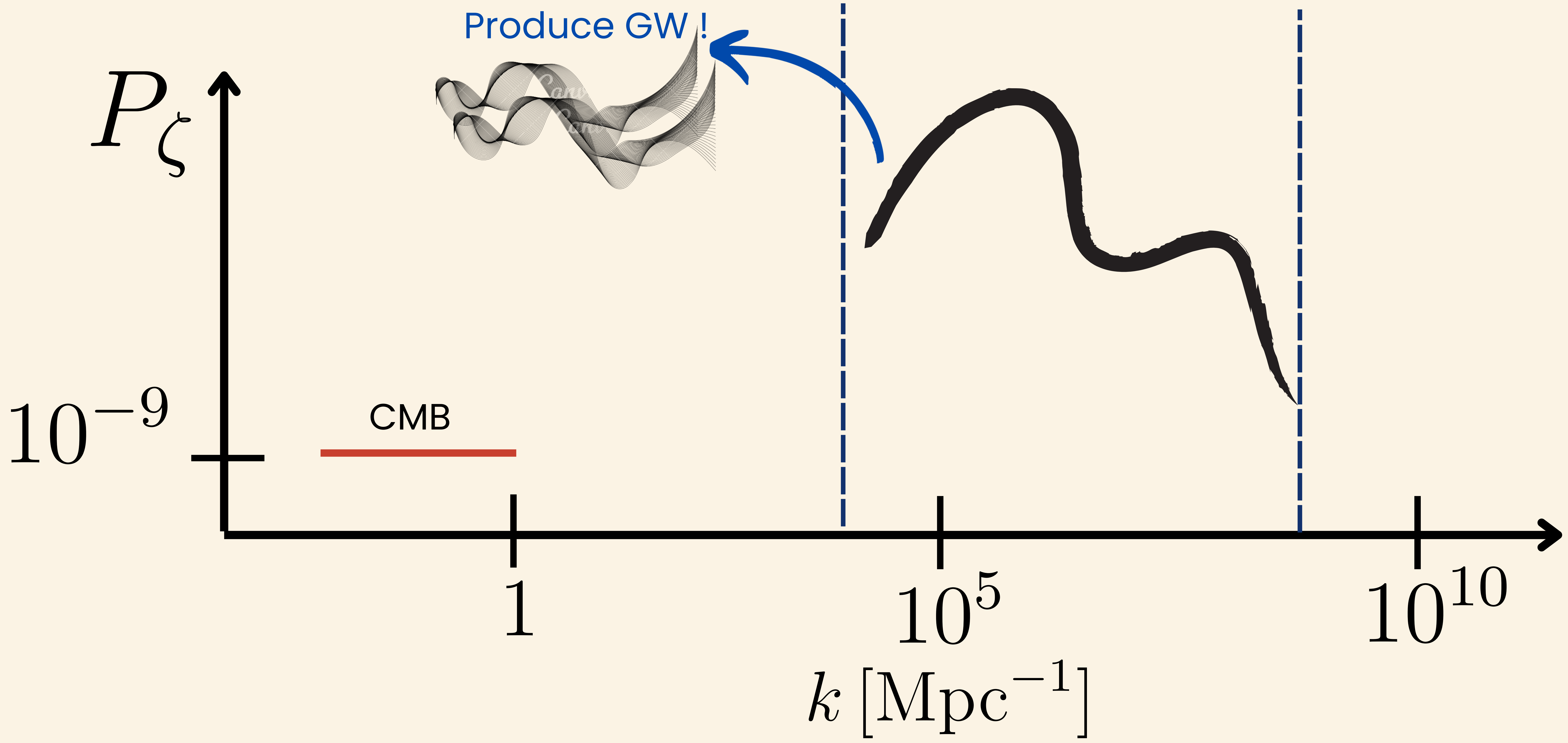

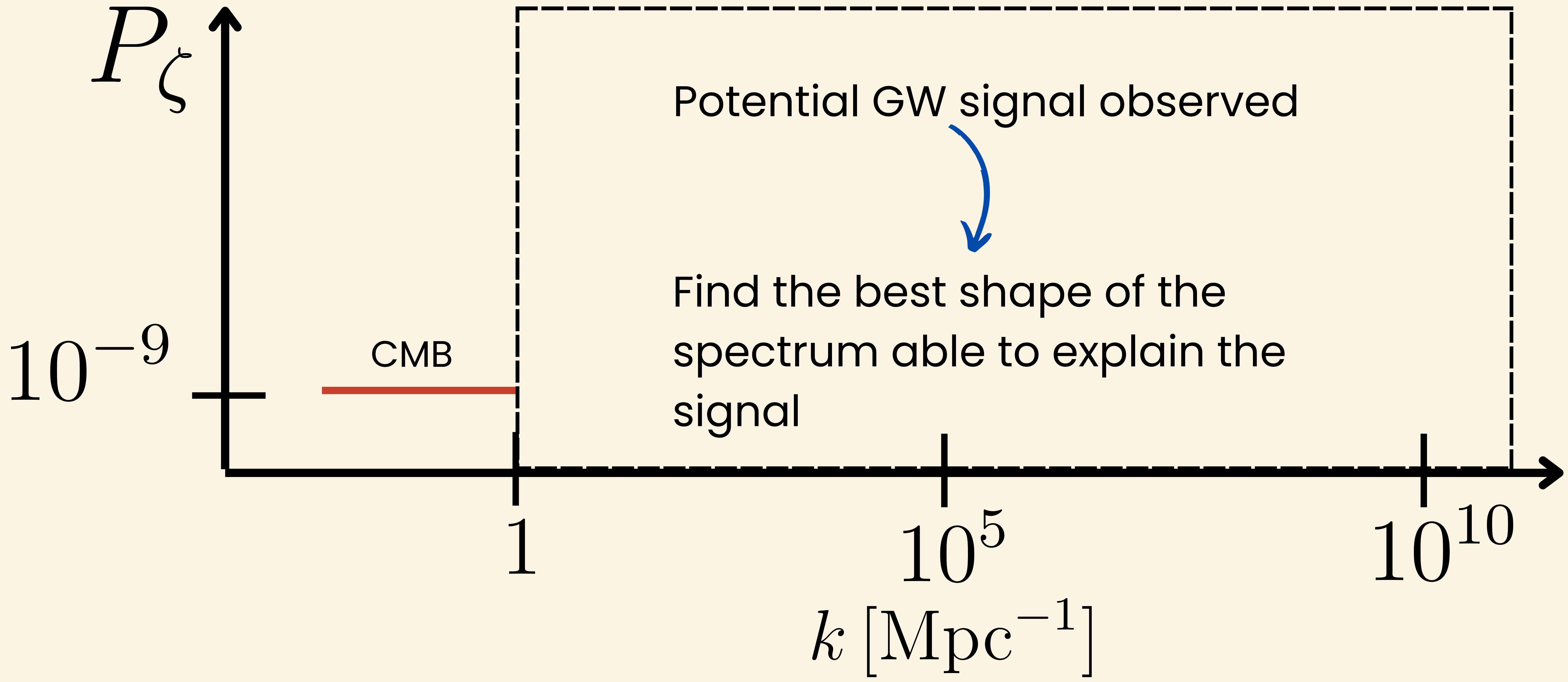
$P_\zeta$
$10^{-9}$
CMB
Potential GW signal observed
Find the best shape of the spectrum able to explain the signal
1
$10^5$
$10^{10}$
$k\,[\mathrm{Mpc}^{-1}]$

# SCALAR INDUCED GRAVTATIONAL WAVES (SIGW)

- Metric perturbations are decomposed into scalar and tensor perturbations

$$ds^2 = a^2(\eta)\left[-(1+2\Psi)d\eta^2 + ((1+2\Phi)\delta_{ij} + h_{ij})\,dx^i dx^j\right]$$

Negligible at linear order

# SIGW

- Metric perturbations are decomposed into scalar and tensor perturbations

$$ds^2 = a^2(\eta)\left[-(1+2\Psi)d\eta^2 + ((1+2\Phi)\delta_{ij} + h_{ij})\, dx^i dx^j\right]$$

Sourced by the scalar perturbations at second order

Negligible at linear order

- Gravitational wave spectrum as a function of the curvature power spectrum

$$\Omega_{GW}(k) = F(P_\zeta(k))$$

# HOW TO PROBE SMALL SCALE POWER SPECTRUM ?

- Use gravitational waves to probe small scale power spectrum

Hint of a signal in Pulsar observations !

- Parametrize the power spectrum with a log-normal shape

$$P_\zeta(k) = \frac{A_{\rm PS}}{\sqrt{2\pi}\Delta}{\rm Exp}\left(-\frac{\log^2(k/k_*)}{2\Delta^2}\right)$$

Best fit parameters to explain the signal

# HOW TO PROBE SMALL SCALE POWER SPECTRUM ?

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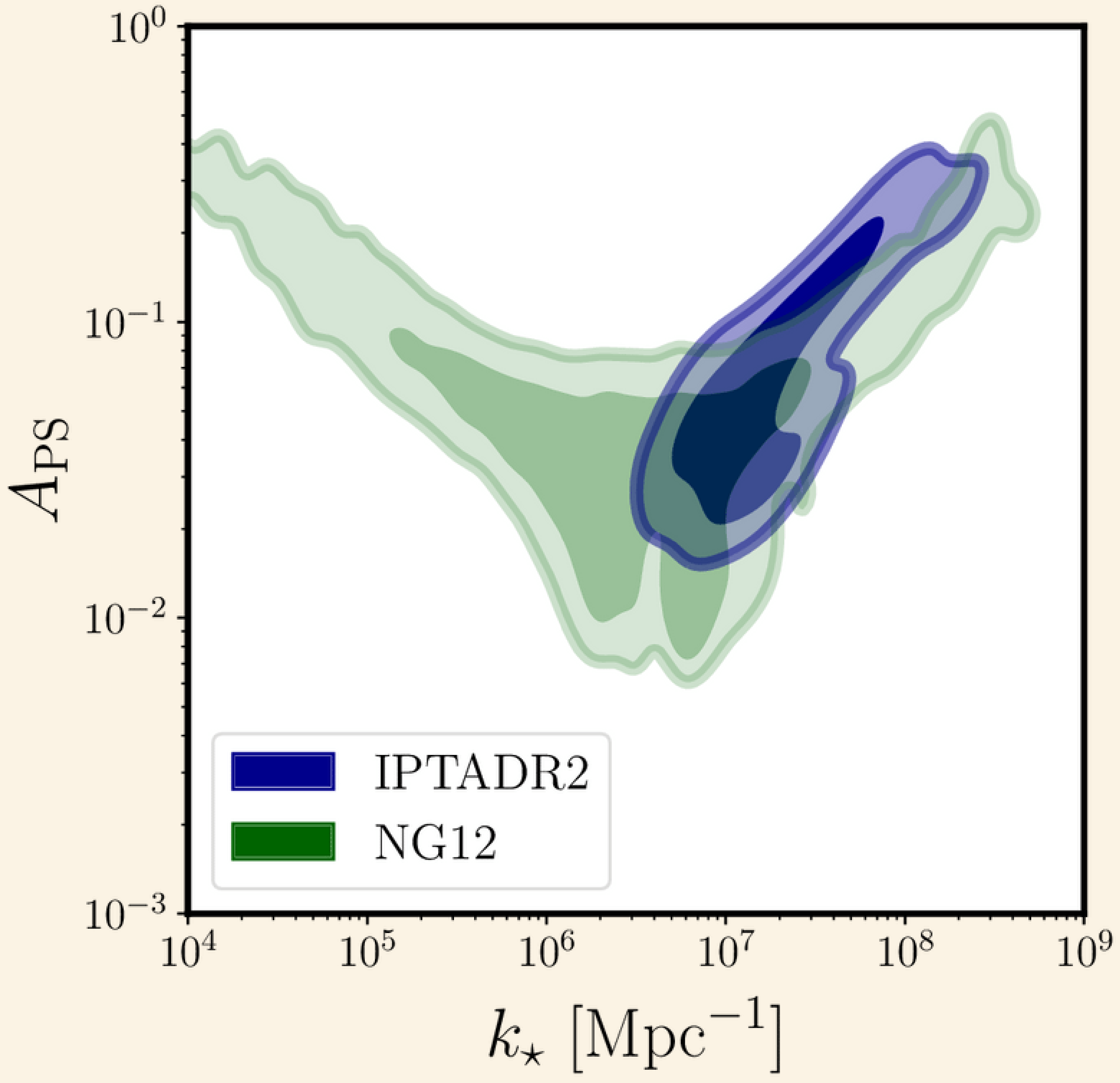
$$P_\zeta(k) = \frac{A_{\rm PS}}{\sqrt{2\pi}\Delta} \mathrm{Exp}\left(-\frac{\log^2(k/k_*)}{2\Delta^2}\right)$$

→ Perform bayesian search to determine the evidence regions



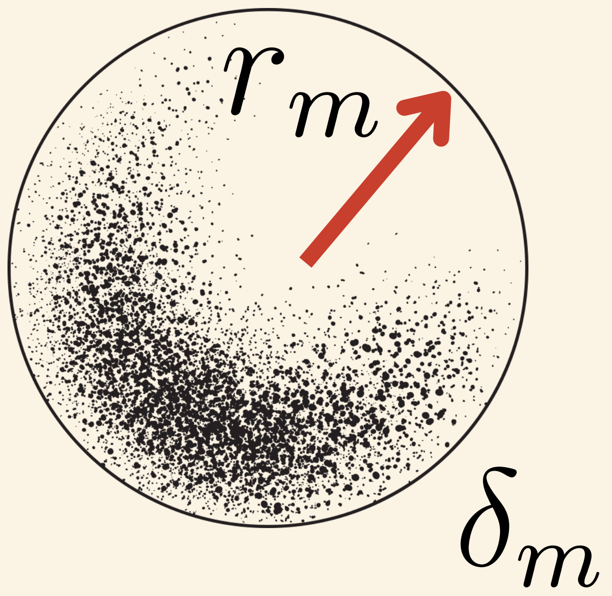
# PRIMORDIAL BLACK HOLES FROM CURVATURE PERTURBATIONS

# PBH FORMATION FROM LARGE CURVATURE FLUCTUATIONS

- Let's consider a perturbation $\delta_m$ with a given scale $r_m$

For big enough perturbation

$$M = \kappa M_H(r_m)\left(\delta_m - \frac{3}{8}\delta_m^2 - \delta_c\right)^\gamma$$

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→ Depends on the curvature power spectrum

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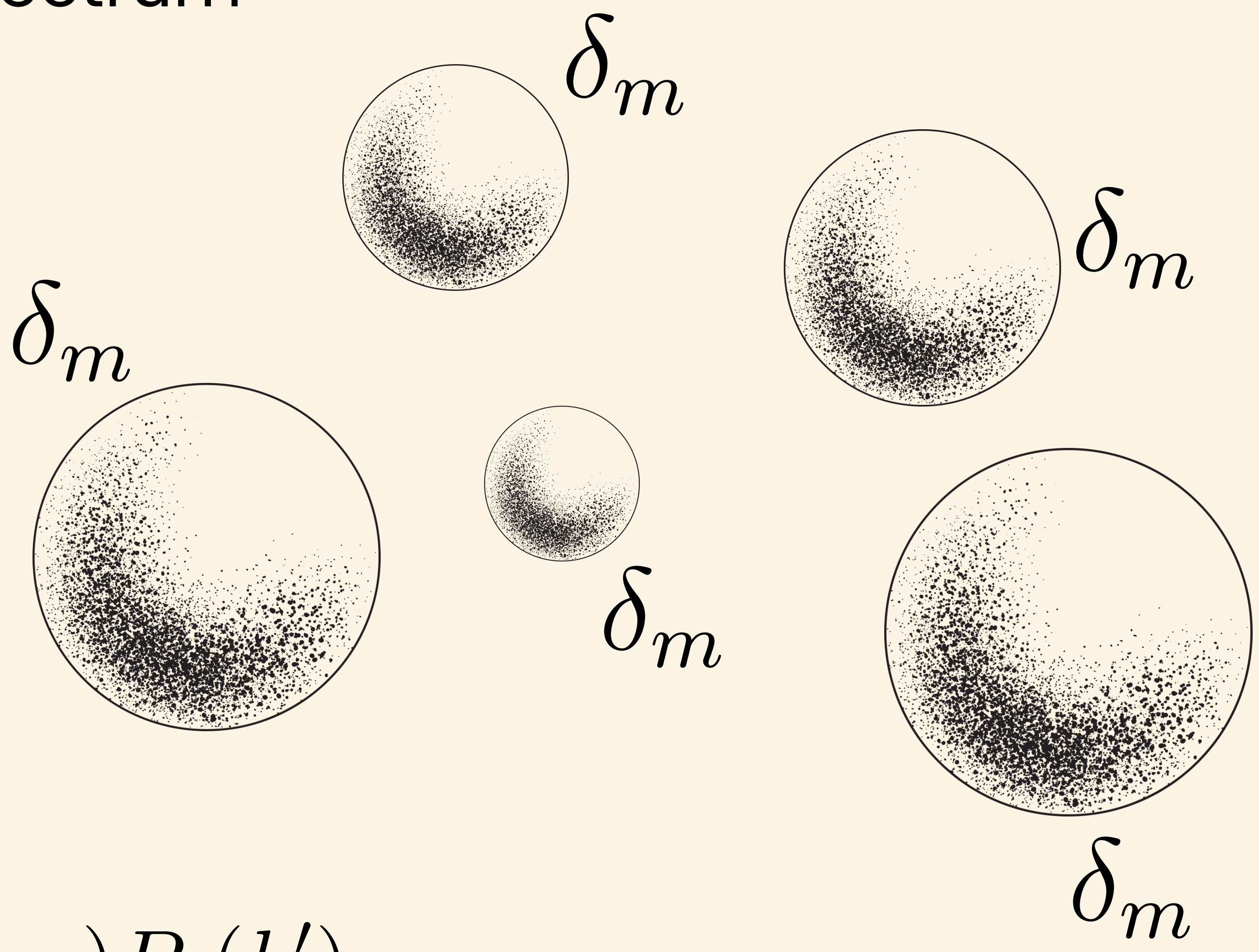
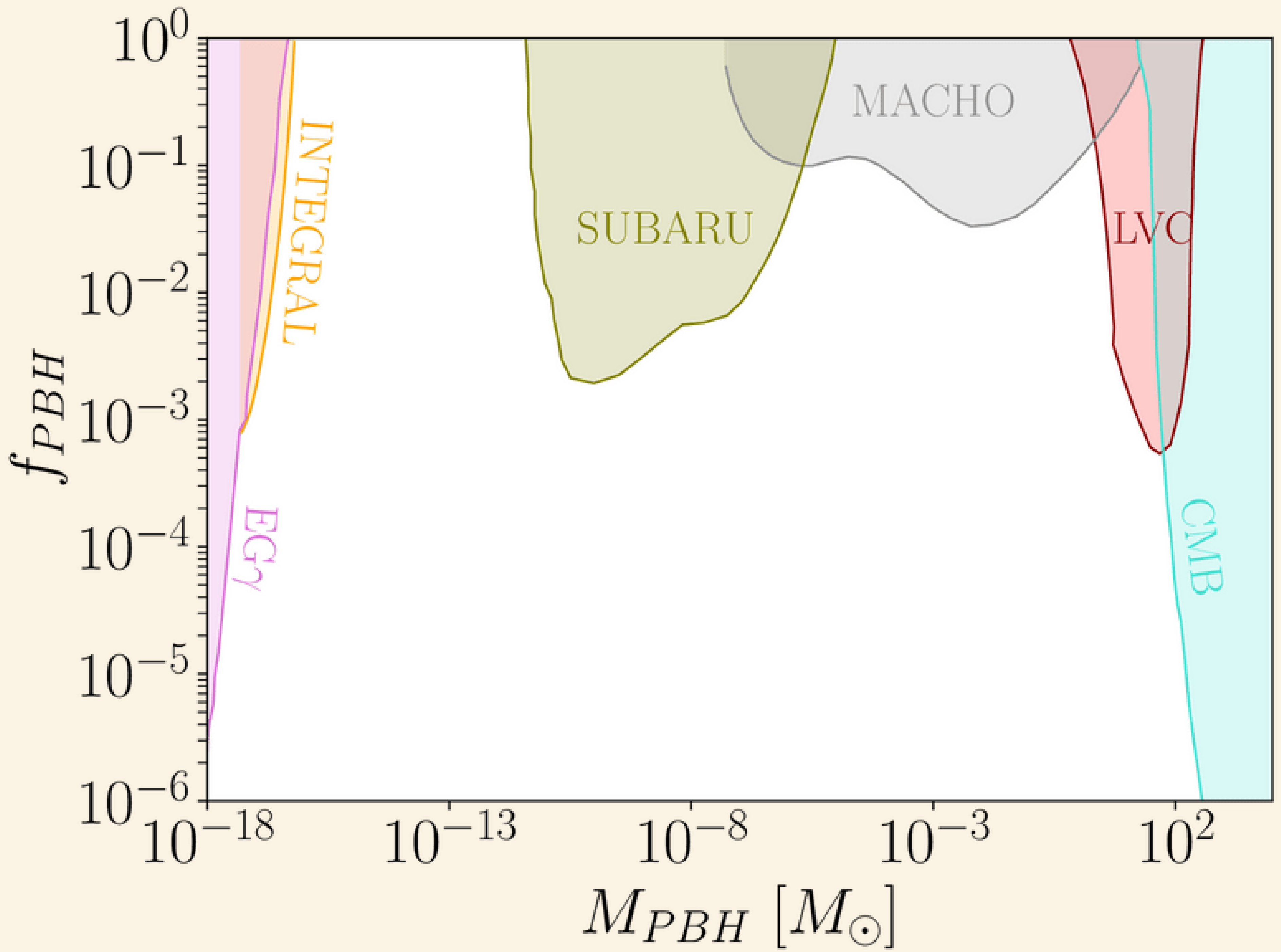



$$P_{r_m}(\delta_m) = \frac{1}{\sqrt{2\pi\sigma^2_{r_m}}} \exp\left(-\frac{\delta_m^2}{2\sigma^2_{r_m}}\right)$$

$$\sigma^2_{r_m} = \frac{16}{81}\int_0^\infty \frac{\mathrm{d}k'}{k'}(k' r_m)^4 T^2(k', r_m) W^2(k'; r_m) P_\zeta(k').$$

# PBH FORMATION FROM LARGE CURVATURE FLUCTUATIONS

- $$f_{\rm PBH} = F_f(P_\zeta)$$
  $$\langle M_{\rm PBH} \rangle = F_M(P_\zeta)$$
- Lots of constraints exist on PBH abundance!
- One could translate them into constraints on the amplitude $A_{PS}$



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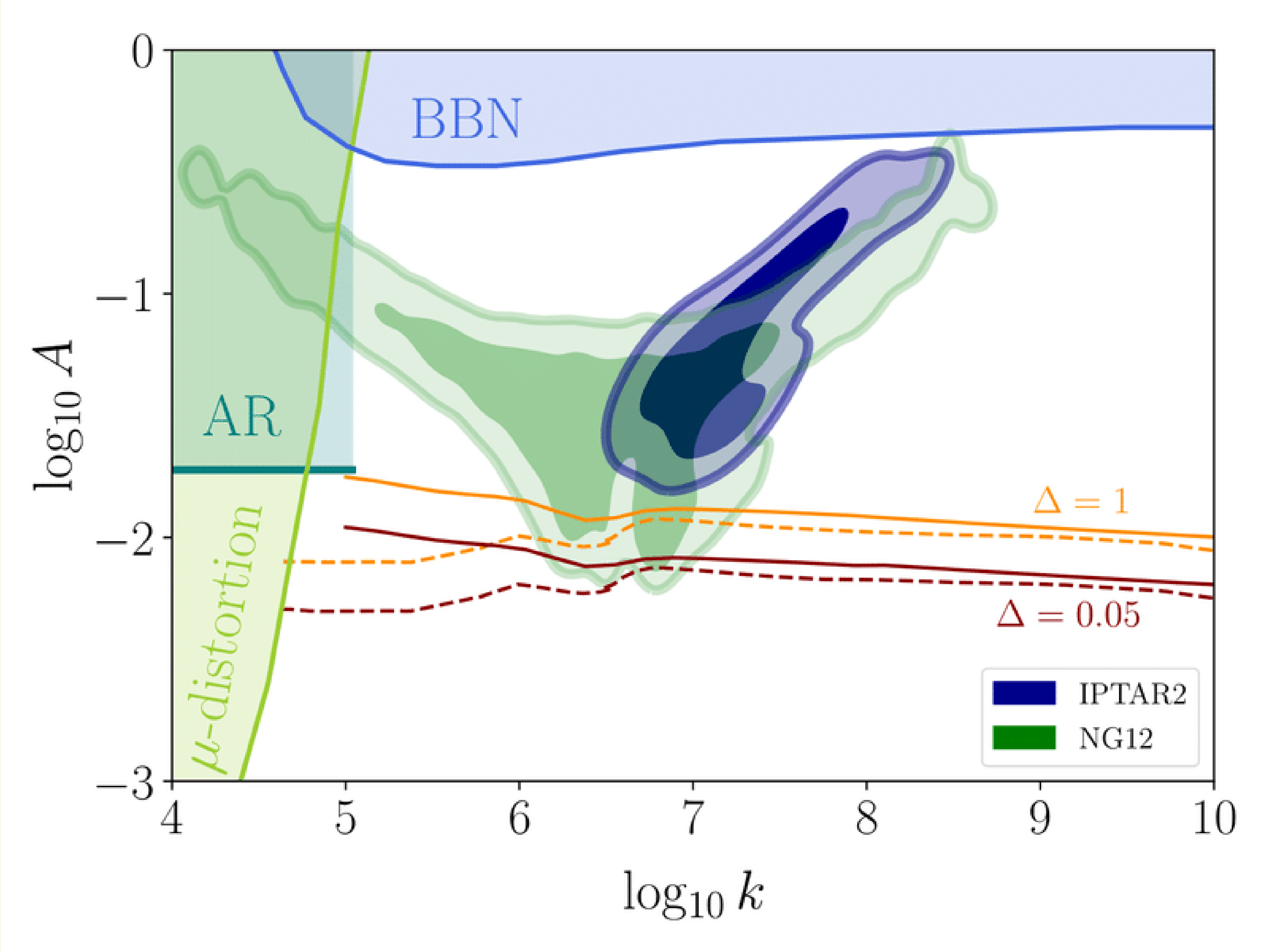


# CONCLUSION

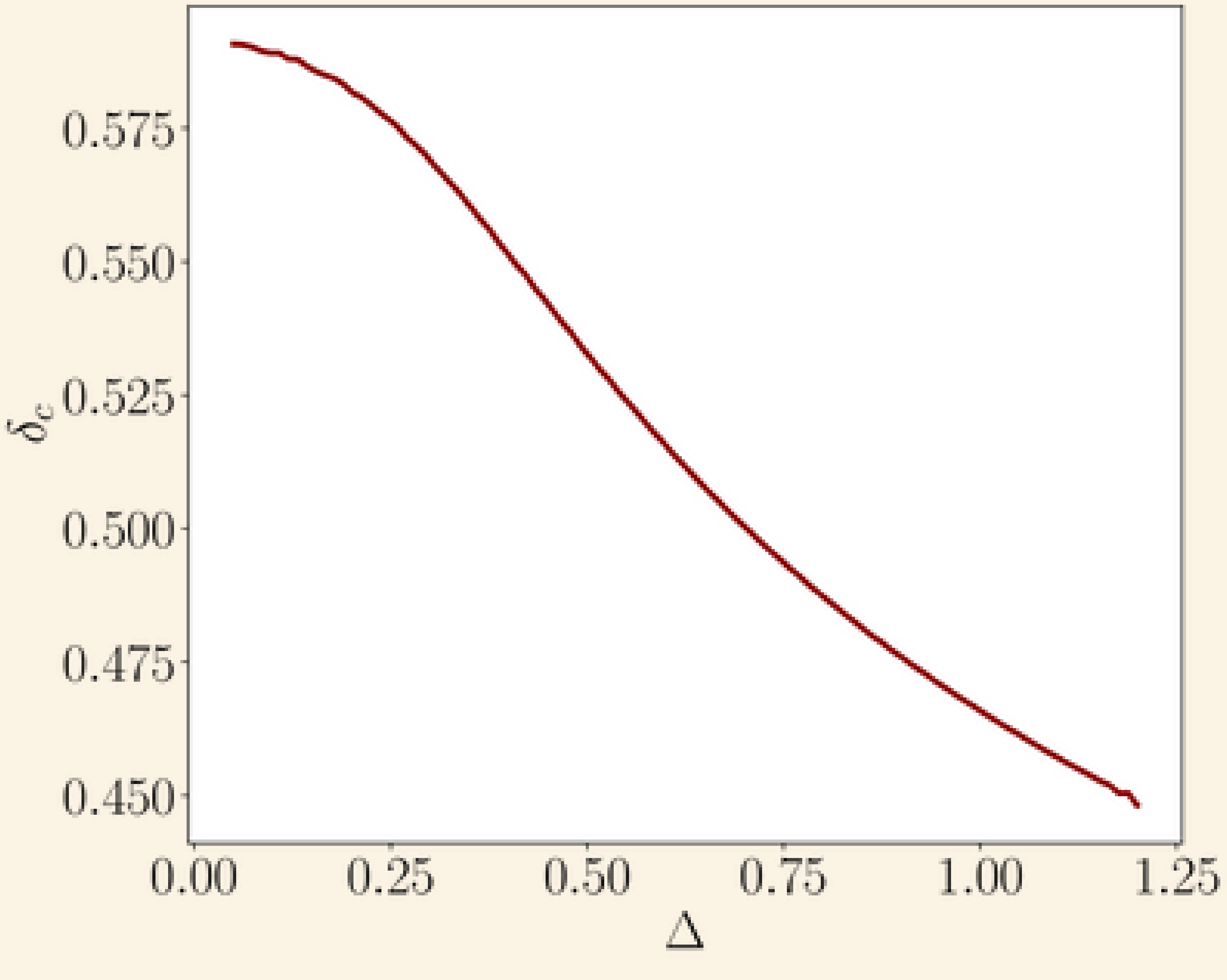
- Large amplitudes of the curvature power spectrum produce GW able to explain the signal observed in PTA

- Such large amplitudes would produce primordial black holes as well

- We have shown that the parameter space able to explain the signal would potentially produce too many PBHs compared to observational data

# CRITICAL THRESHOLD





# BACKUP

## CONSTRAINTS PBH