

PRIMORDIAL GRAVITATIONAL WAVES AS A PROMISING TEST FOR INFLATIONARY MODELS

Maria Chiara Guzzetti*, Nicola Bartolo, Michele Liguori and Sabino Matarrese

*Dipartimento di Fisica e Astronomia G. Galilei, Università degli Studi di Padova,
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Based on: Guzzetti et al., *Gravitational waves from inflation*,
Riv. Nuovo Cim. 39, 09 (2016), arXiv:1605.01615.
Prepared as invited review for La Rivista del Nuovo Cimento

GRAVITATIONAL WAVES FROM INFLATION

ANY inflationary model

QUANTUM FLUCTUATIONS
of the gravitational field



gravitational wave
POWER SPECTRUM

$$P_T(k) = A_T(k_*) \left(\frac{k}{k_*} \right)^{n_T}$$

GRAVITATIONAL WAVES FROM INFLATION

primordial → **present time**

present time
**gw spectral
 energy density**

$$\Omega_{\text{GW}}(k, \tau_0) \equiv \frac{1}{\rho_c} \frac{d\rho_{\text{gw}}}{d \ln k} = \frac{1}{12} \left(\frac{k}{aH} \right)^2 T(k) P_T(k)$$

$$P_T(k) = A_T(k_*) \left(\frac{k}{k_*} \right)^{n_T}$$

GRAVITATIONAL WAVES FROM INFLATION

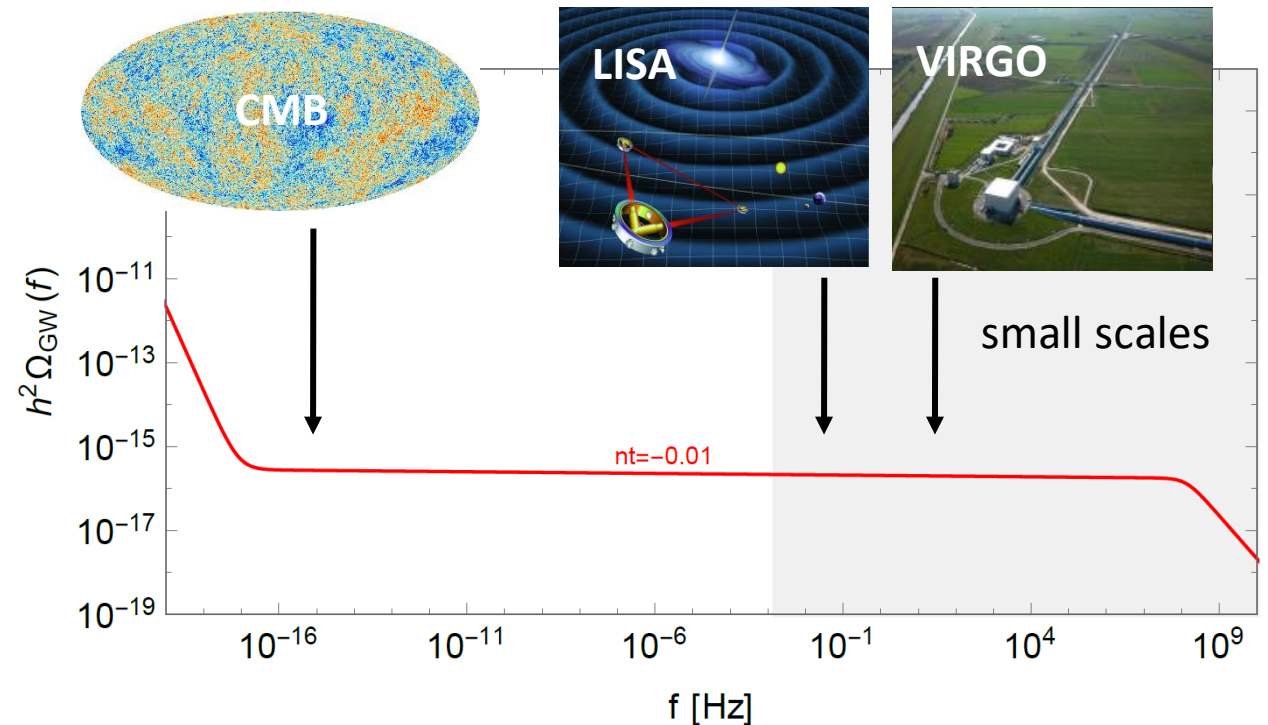
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➡ stochastic gravitational wave
background



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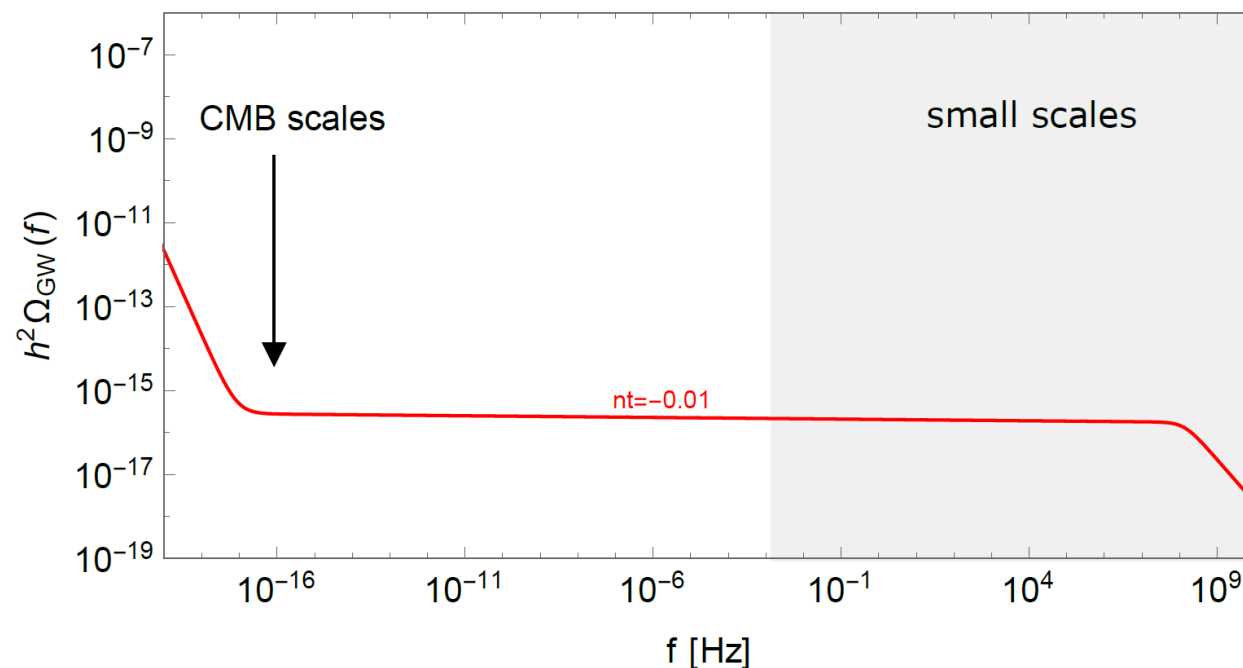
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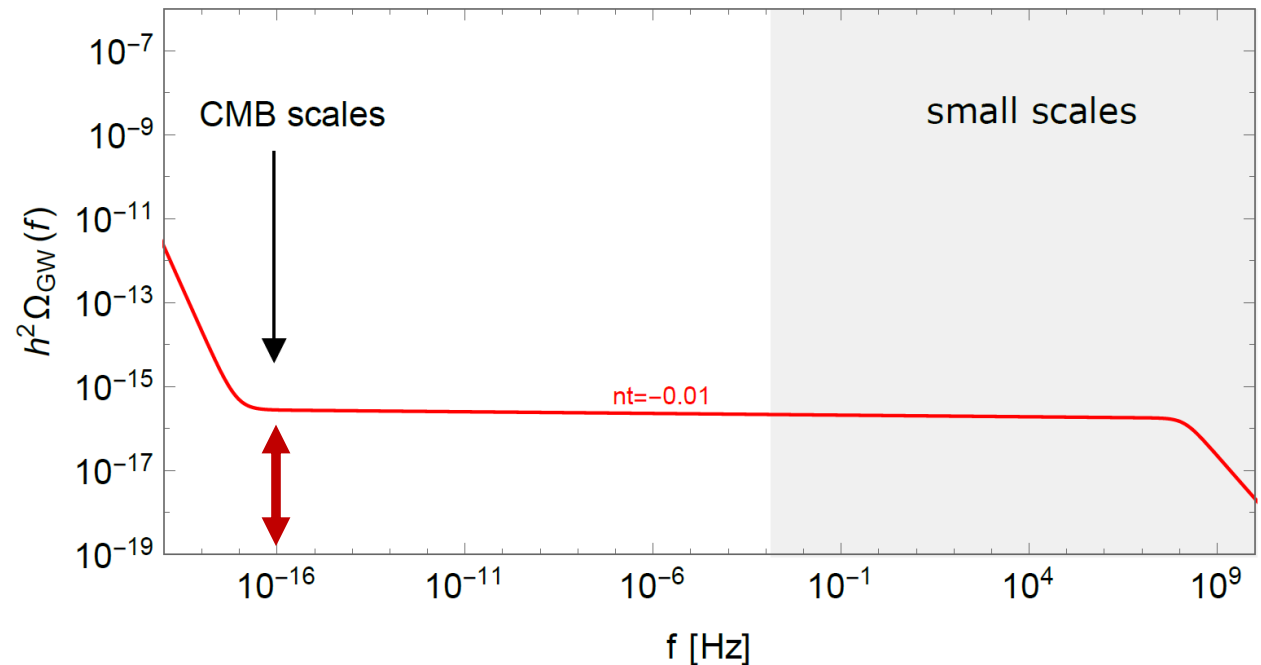
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- AMPLITUDE $A_T(k_*)$



GRAVITATIONAL WAVES FROM INFLATION

primordial → present time

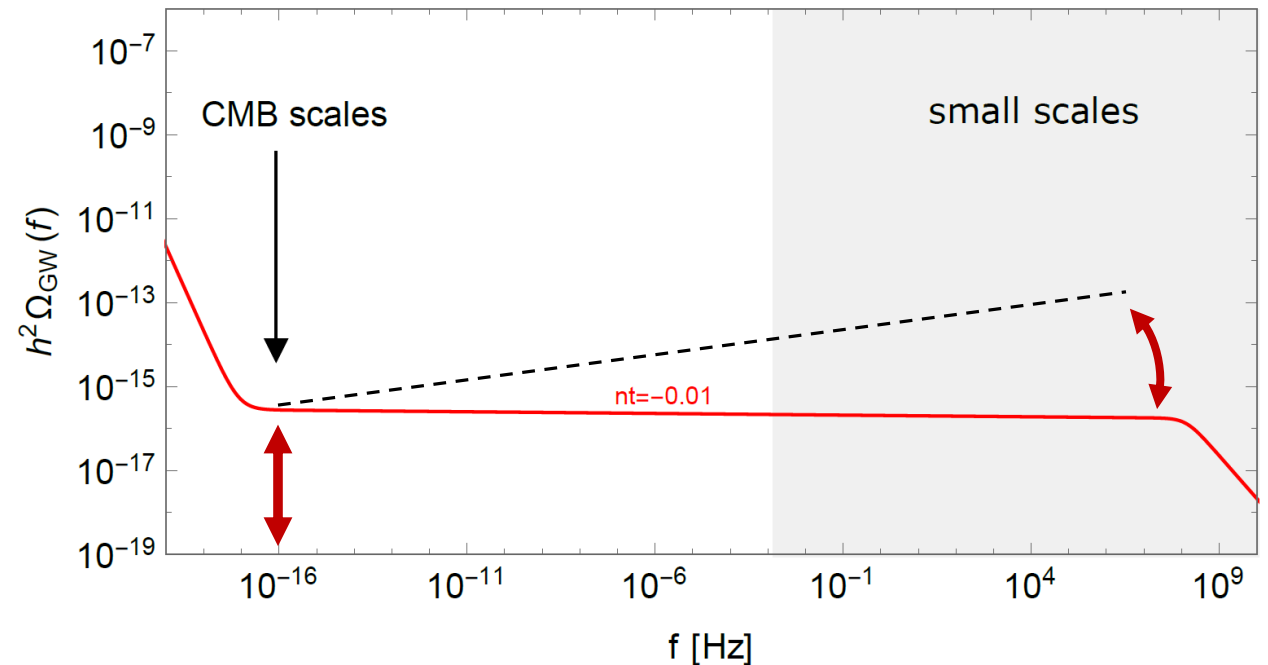
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background

- AMPLITUDE $A_T(k_*)$
- SPECTRAL INDEX n_t



FURTHER MECHANISMS OF GW PRODUCTION

ANY inflationary model \longrightarrow quantum fluctuations of the gravitational field

POSSIBLE EXTRA PRODUCTION

due to further fields besides the gravitational one

CLASSICAL gw production

$$h''_{ij} + 2\mathcal{H}h'_{ij} - \nabla^2 h_{ij} = \frac{2}{M_{\text{pl}}^2} \hat{\Pi}_{ij}^{lm} T_{lm} \quad \text{SOURCE TERM}$$

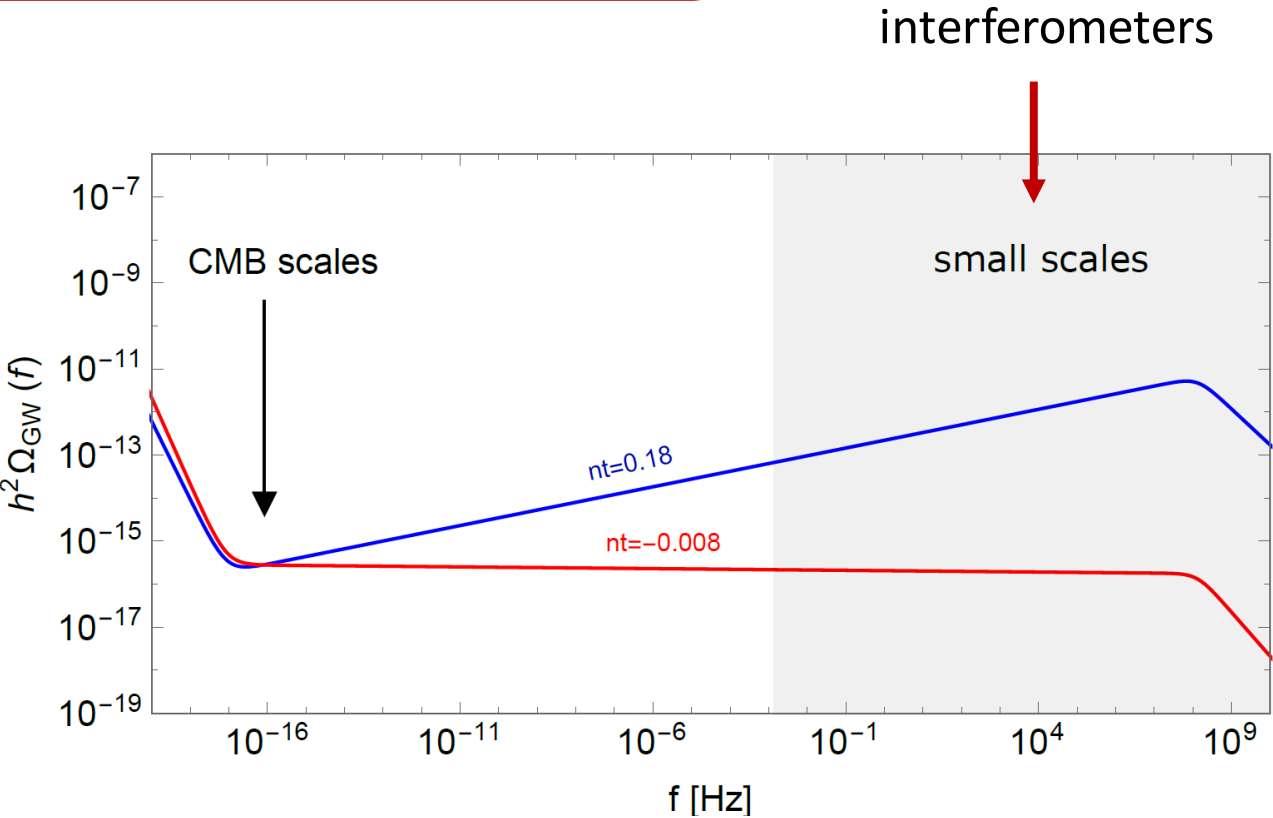
$$\Rightarrow \Omega_{\text{gw}} = \Omega_{\text{gw}}^{\text{vacuum}} + \Omega_{\text{gw}}^{\text{sourced}}$$

INFLATIONARY GRAVITATIONAL WAVES

$$\Omega_{\text{gw}} = \Omega_{\text{gw}}^{\text{vacuum}} + \Omega_{\text{gw}}^{\text{sourced}}$$

GW PRODUCTION	Discriminant	Specific discriminant	Examples of specific models
Vacuum oscillations quantum fluctuations of the gravitational field stretched by the accelerated expansion	theory of gravity	General Relativity	<i>single-field slow-roll</i> all other models in GR
		MC/EFT approach	G-Inflation Potential-driven G-Inflation EFT approach
		quantum fluctuations	<i>all models</i>
Classical production second-order GW generated by the presence of a source term in GW equation of motion	source term	fluctuations of extra scalar fields	inflaton+spectator fields curvaton
		gauge particle production	pseudoscalar inflaton+gauge field scalar infl.+pseudoscalar+gauge
		scalar particle production	scalar inflaton+ scalar field
		particle production during preheating	chaotic inflation hybrid inflation

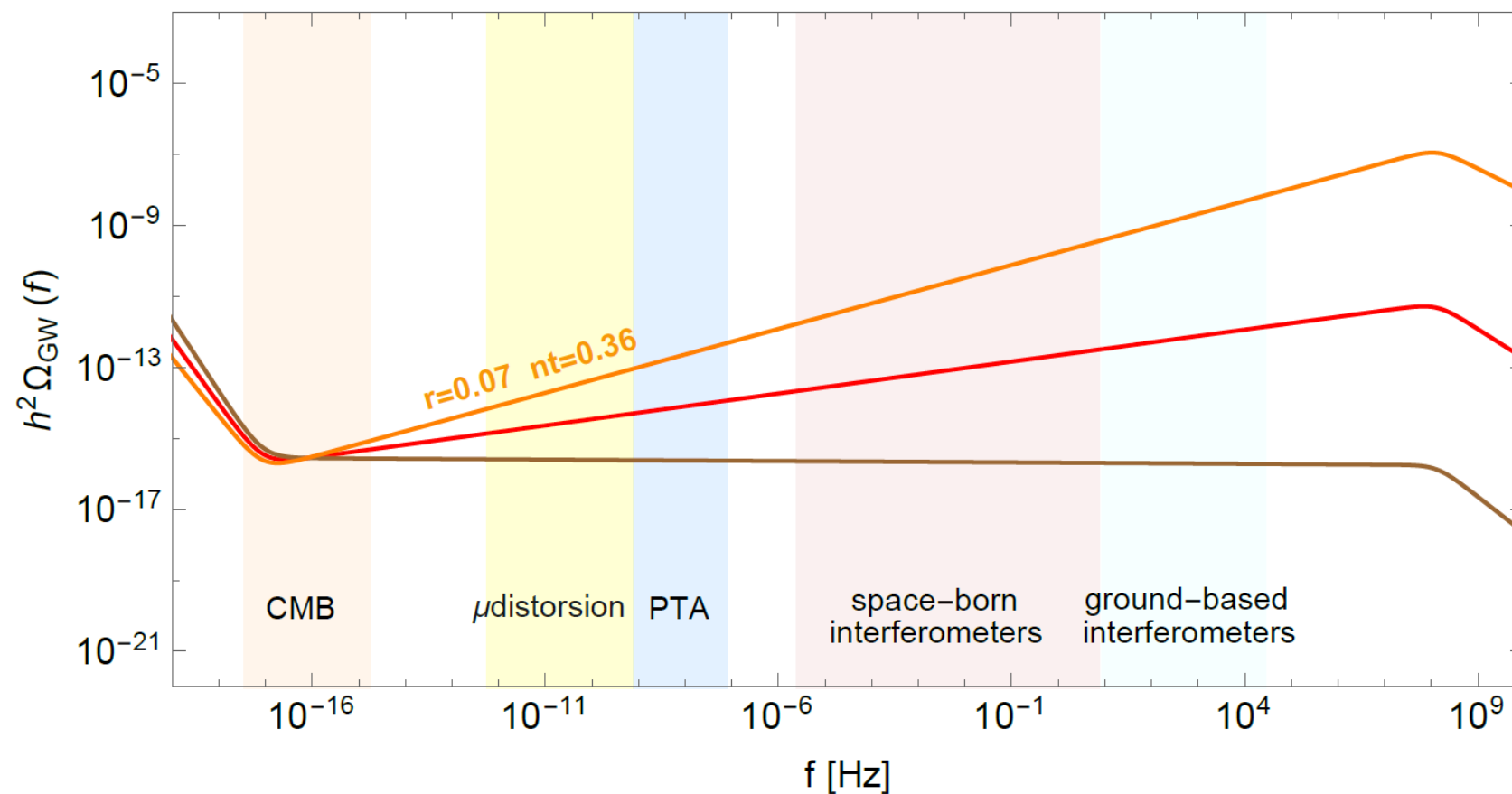
different gw signals



Taken from: Guzzetti et al., *Gravitational waves from inflation*, Riv. Nuovo Cim. 39, 09 (2016), arXiv:1605.01615

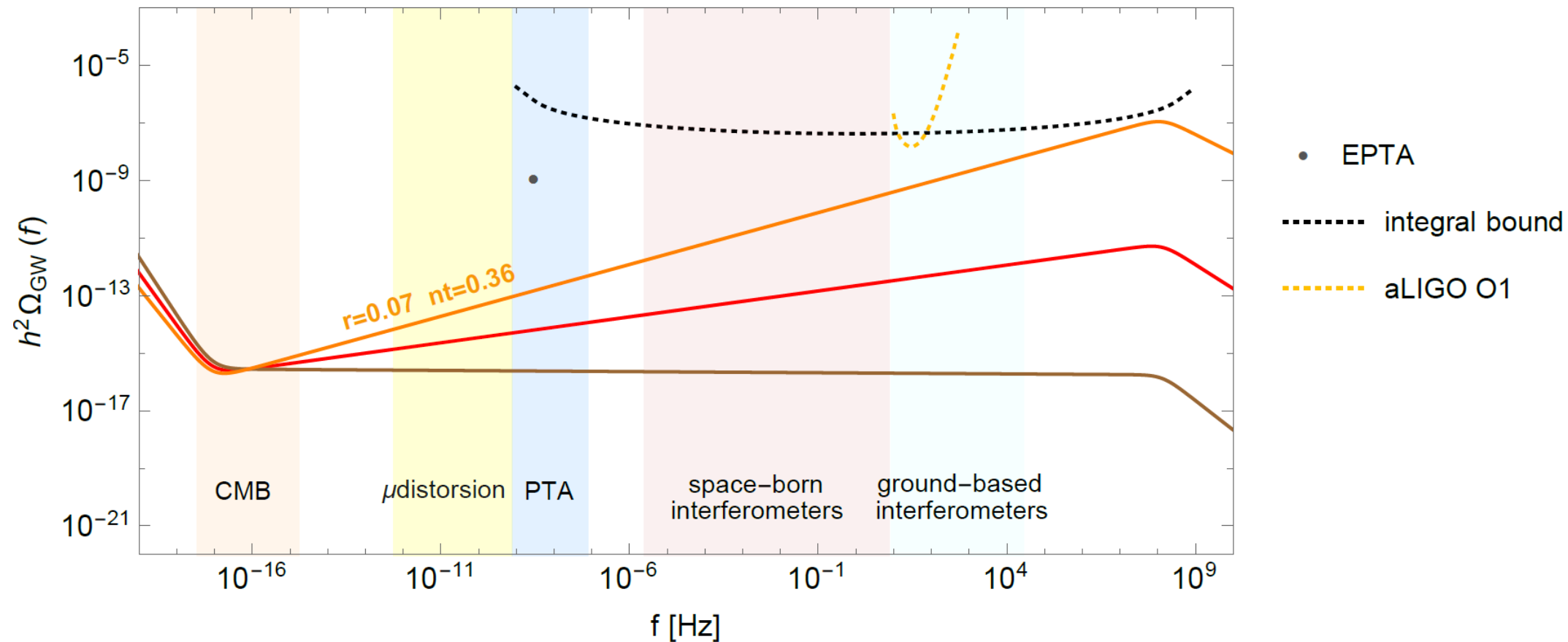
CURRENT BOUNDS AND OBSERVATIONAL PROSPECTS

CURRENT BOUNDS



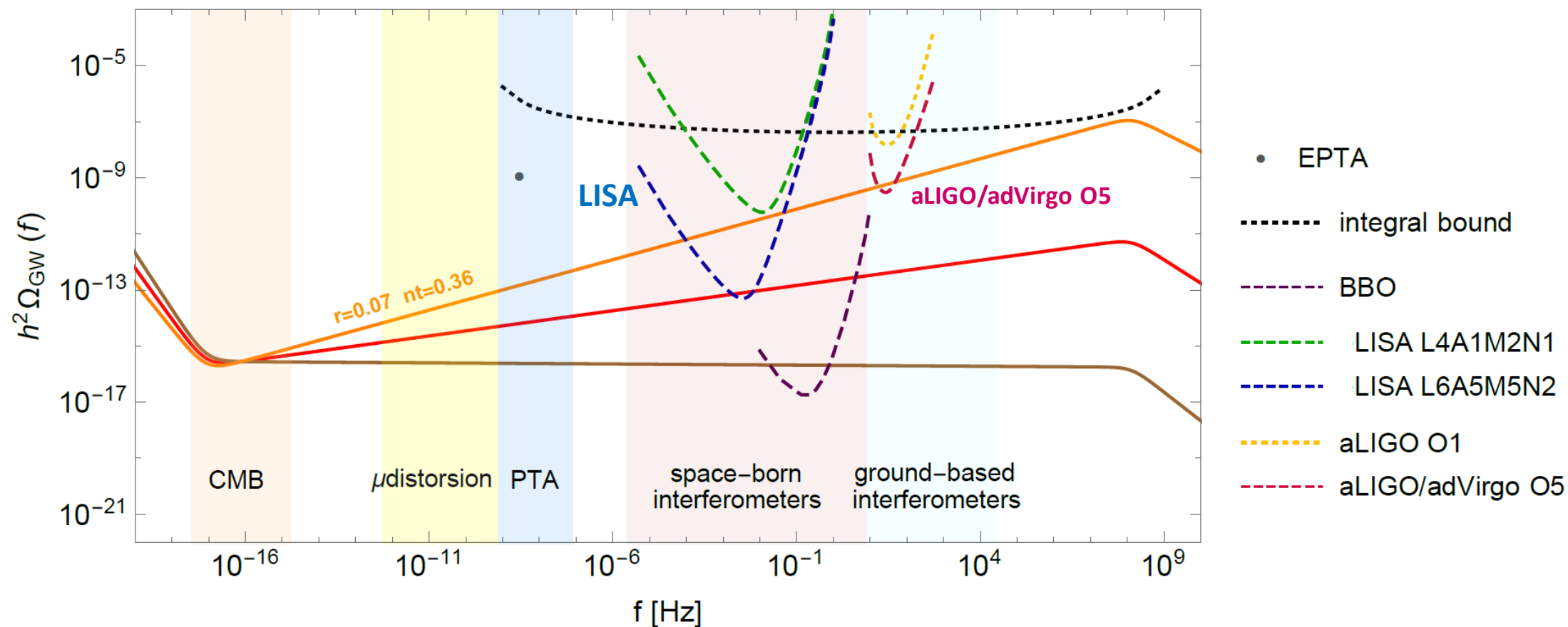
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CURRENT BOUNDS AND OBSERVATIONAL PROSPECTS



PROSPECTS FOR INFLATIONARY PHYSICS

- constraints on a specific inflationary model
- test of the inflationary consistency relation

CONSTRAINING SPECIFIC INFLATIONARY MODELS, AN EXAMPLE

INFLATION WITH SPECTATOR FIELD

inflaton + spectator field σ

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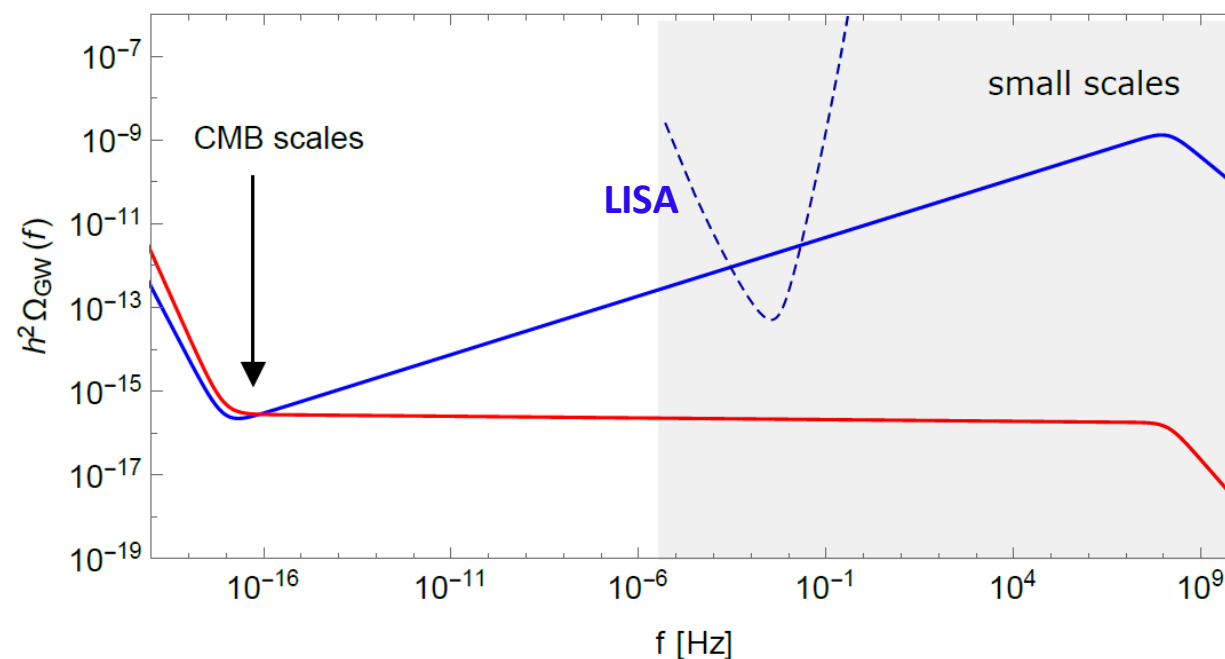
INFLATION WITH SPECTATOR FIELD

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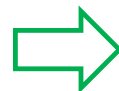
blue ?



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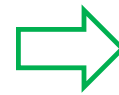
c_s
 σ speed of sound \longrightarrow gw
 amplitude

$s = \dot{c}_s / H c_s$ \longrightarrow gw
 speed of sound spectral index
 evolution

CONSTRAINING SPECIFIC INFLATIONARY MODELS, AN EXAMPLE

INFLATION WITH SPECTATOR FIELD

inflaton + spectator field σ



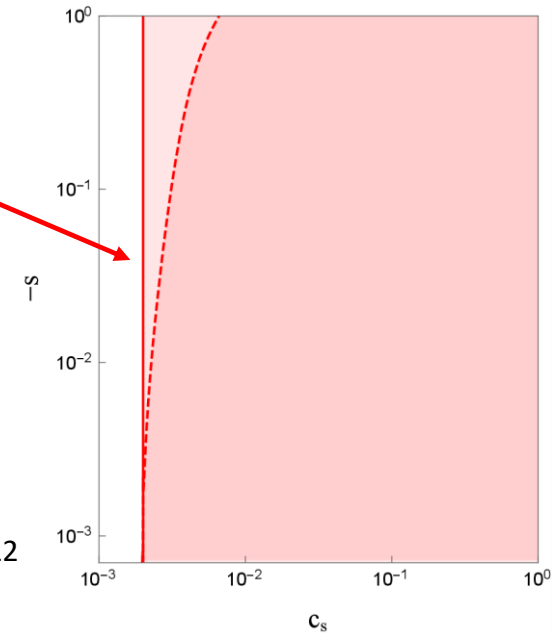
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speed of sound evolution \rightarrow gw spectral index

CMB



Bartolo et al., JCAP 1612, no.12
026 (2016), arXiv:1610.06481

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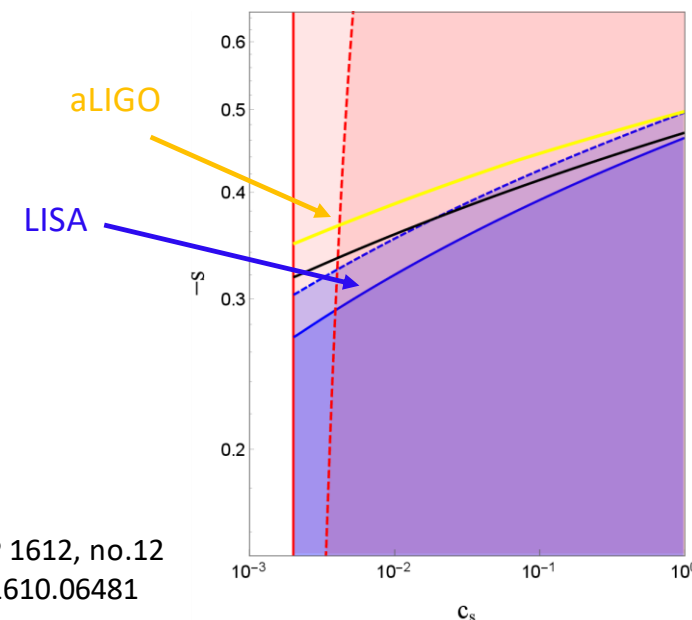
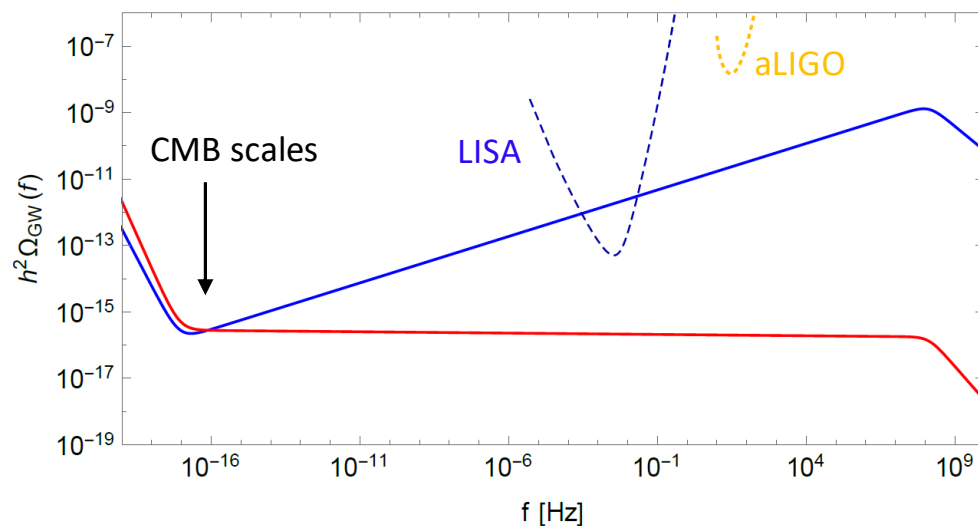
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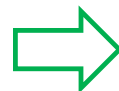


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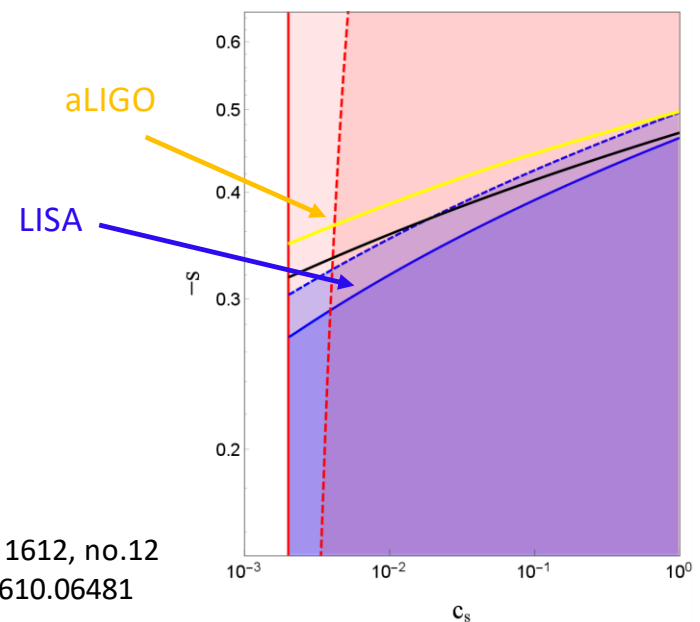
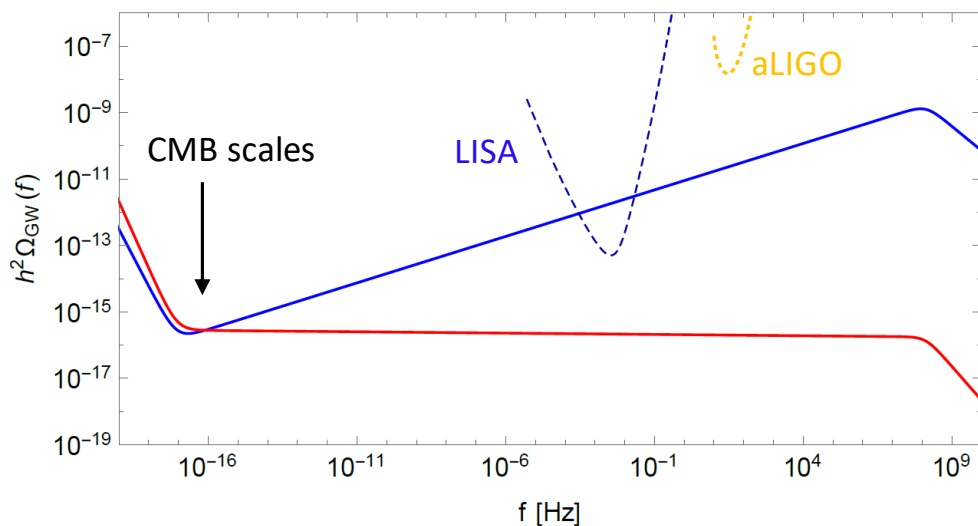
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experiments at small scales improve constraints on specific inflationary models, even in case of a non-detection

INFLATIONARY CONSISTENCY RELATION

single-field slow-roll inflation
(vacuum fluctuations)

$$r = -8n_T$$

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other inflationary models

VIOLATION ?

	Model	Tensor power-spectrum	Tensor spectral index		Consistency relation
GW signal due to vacuum fluctuations	Standard infl.	$P_T = \frac{8}{M_{\text{pl}}^2} \left(\frac{H}{2\pi}\right)^2$	$n_T = -2\epsilon$	red	$r = -8n_T$
	EFT inflation ^(a)	$P_T = \frac{8}{c_T M_{\text{pl}}^2} \left(\frac{H}{2\pi}\right)^2$	$n_T = -2\epsilon + \frac{2}{3} \frac{m^2}{\alpha H^2} \left(1 + \frac{4}{3}\epsilon\right)$	r/b	-
	EFT inflation ^(b)	$P_T = \frac{8}{c_T M_{\text{pl}}^2} \frac{2^{1+p}}{\pi} \Gamma^2\left(\frac{1}{2(1+p)}\right) \left(\frac{H}{2\pi}\right)^2$	$n_T = \frac{p}{1+p}$	blue	violation
	Gen. G-Infl.	$P_T = \frac{8}{M_{\text{pl}}^2} \gamma_T \frac{\mathcal{G}_T^{1/2}}{\mathcal{F}_T^{3/2}} \left(\frac{H}{2\pi}\right)^2$	$n_T = 3 - 2\nu_T$	r/b	-
	Pot.-driv. G-Infl.	$P_T = \frac{8}{M_{\text{pl}}^2} \left(\frac{H}{2\pi}\right)^2$	$n_T = -2\epsilon$	r/b	$r \simeq -\frac{32\sqrt{6}}{9} n_T$
Extra GW signal due to a source term	Particle prod.	$P_T^+ = 8.6 \times 10^{-7} \frac{4H^2}{M_{\text{pl}}^2} \left(\frac{H}{2\pi}\right)^2 \frac{e^{4\pi\ell}}{\xi^6}$	-	blue	violation
	Spectator field	$P_T \simeq 3 \frac{H^4}{c_S^{18/5} M_{\text{pl}}^4}$	$n_T \simeq 2 \left(\frac{2m^2}{3H^2} - 2\epsilon\right) - \frac{18}{5} \frac{\dot{c}_S}{H c_S}$	r/b	violation

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test
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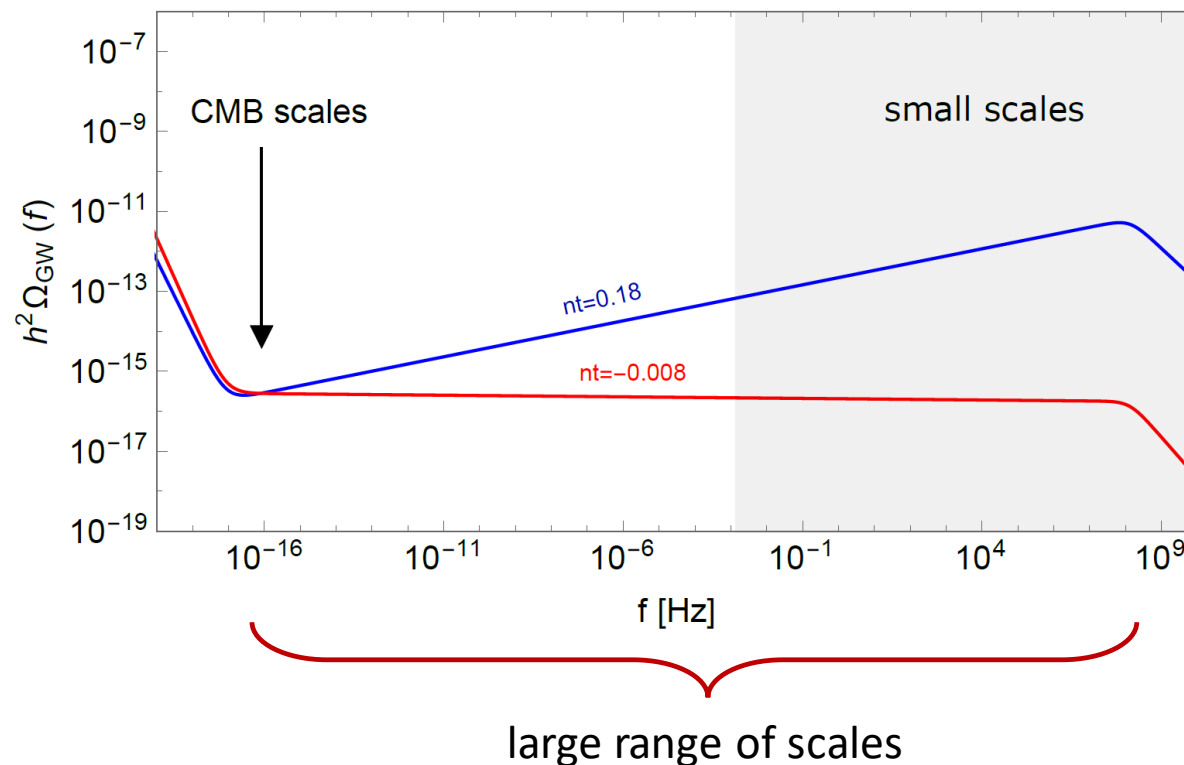
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experiments at **small scales**
are crucial in order to exploit
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laser interferometers scales



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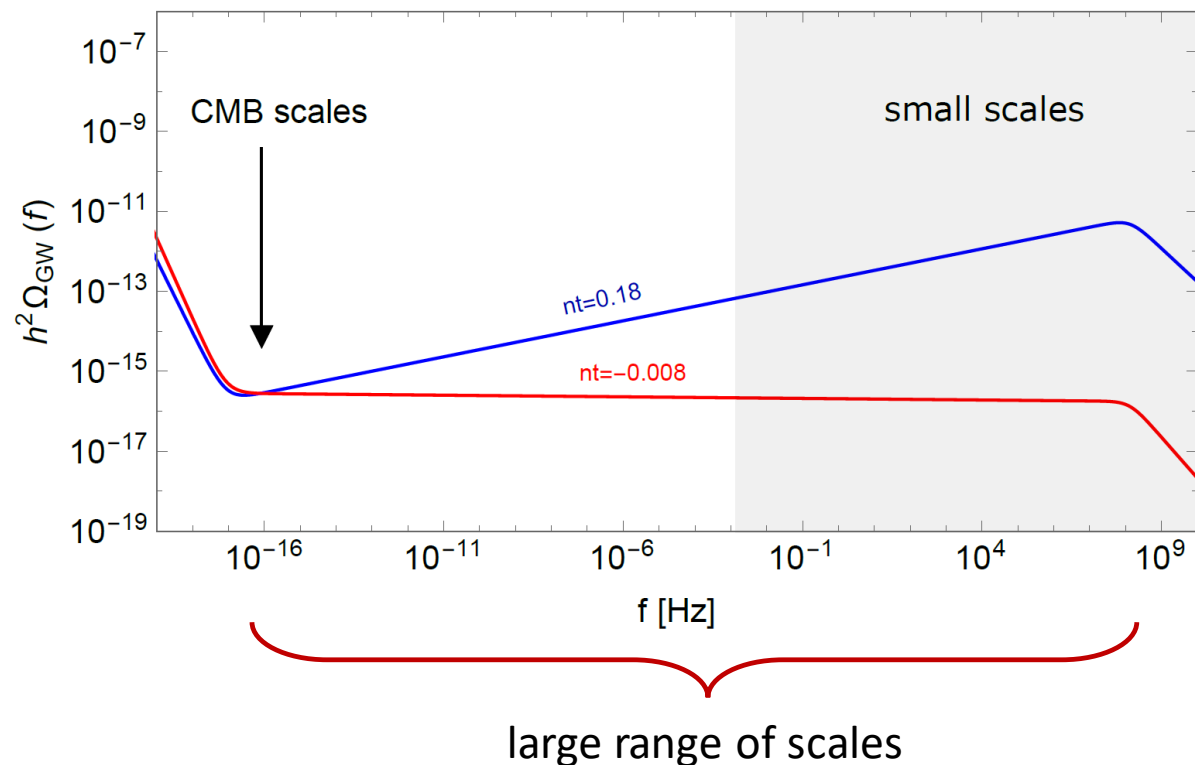
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experiments at small scales improve the
capabilities of testing the single-field slow-roll
inflationary model



CONCLUSIONS

INFLATIONARY GW → interesting signal in order to investigate the inflationary physics

exploiting experiments of direct detection at small scales:

- improvement of constraints on power-spectrum parameters
- improvement of constraints of specific inflationary models
- significant role in testing the inflationary consistency relation

Thank you!