

Inflation WG activity in LISA

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...moving to INFN PADOVA

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LISA Cosmology WG Workshop

Helsinki

OUTLINE

-  Introduction
-  Inflation WG activity so far
-  Possible future projects

Work Packages Connection

- * WP 8.11 or 5.7 ? (Characterization of SGWB)
 - non-Gaussianity
 - anisotropy
 - chirality
 - signal reconstruction
- * sWP 8.3-8.9 (Primordial Black Holes)
- * WP 8.3 ? (scalar non-Gaussianity and BH formation)

Inflation WG activity so far

- “Figures of merit” of potentially interesting scenarios

[Bartolo N. et al '16]

- New formalism to probe non-G and chirality

V. Domcke's Talk

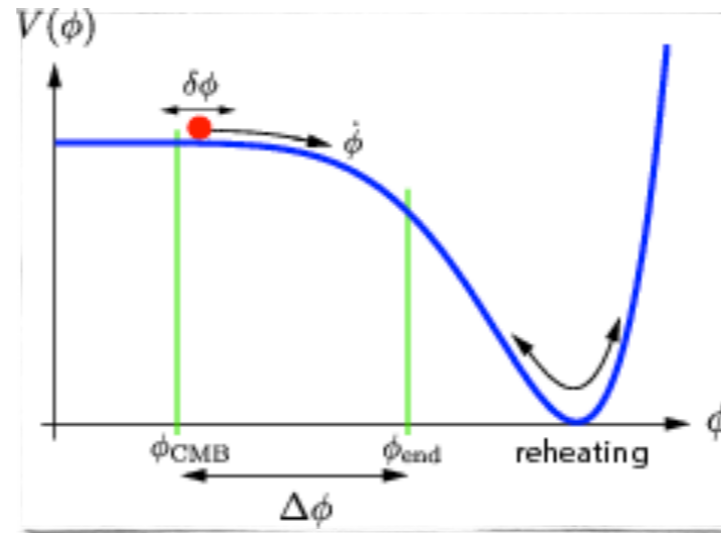
[Bartolo N. et al '18]

- Reconstruction of SGWB with LISA

M. Pieroni's Talk

[To appear]

Observational windows of inflation



	k [Mpc^{-1}]	$N_{\text{estim.}}$
CMB / LSS	$10^{-4} - 10^{-1}$	56 - 63
y - & μ -distortions	$10^{-1} - 10^4$	45 - 56
$P_\zeta \rightarrow \text{PBH} \rightarrow \text{GW @ PTA}$	$10^4 - 10^5$	41 - 44
$P_\zeta \rightarrow \text{PBH} \rightarrow \text{GW @ LISA}$	$10^5 - 10^7$	38 - 41
$P_\zeta \rightarrow \text{PBH} \rightarrow \text{GW @ AdvLIGO}$	$10^7 - 10^8$	35 - 37
$P_{\delta g} \rightarrow \text{GW @ PTA}$	$10^6 - 10^8$	36 - 40
$P_{\delta g} \rightarrow \text{GW @ LISA}$	$10^{11} - 10^{14}$	22 - 28
$P_{\delta g} \rightarrow \text{GW @ AdvLIGO}$	$10^{16} - 10^{17}$	15 - 17

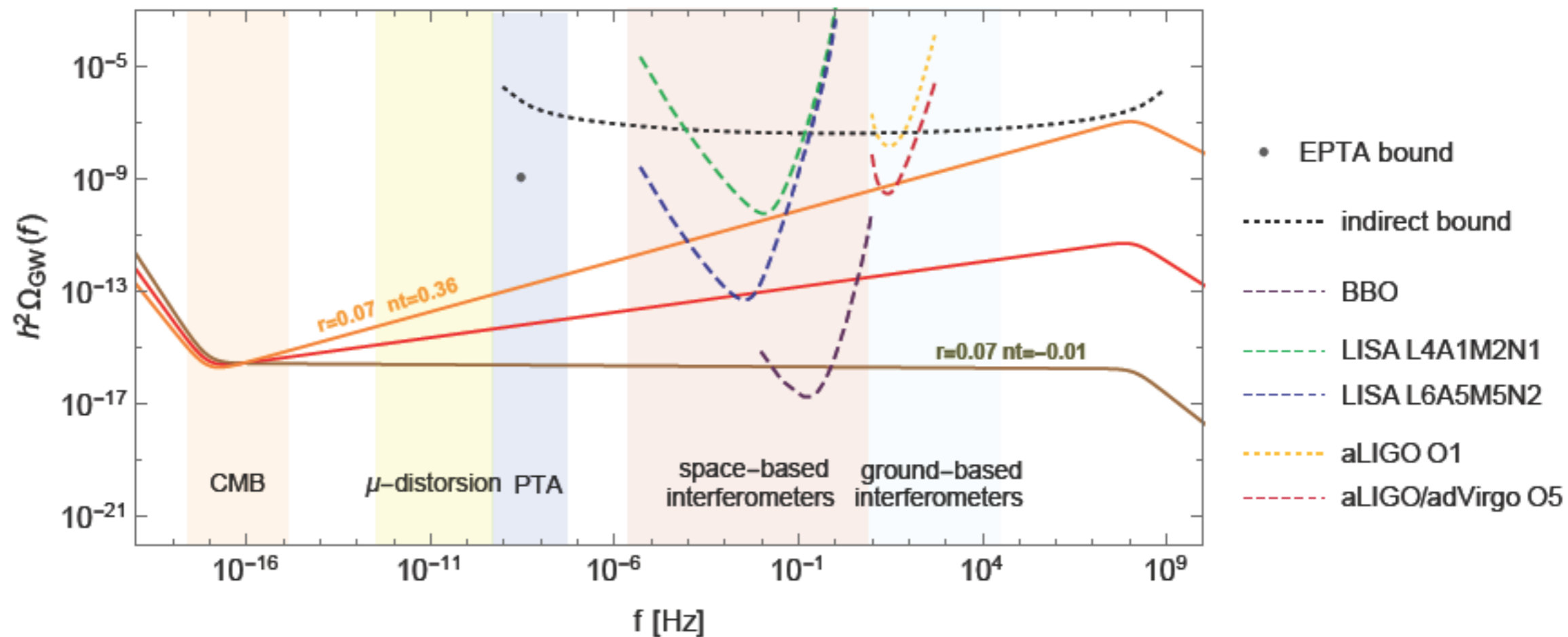
$$N \equiv \int_{t_i}^{t_f} H dt$$

e-folding number

[J. Garcia-Bellido, M. Peloso, C. Unal '16]

LISA=>Possibility to test regions for which we have poor information

Current constraints on GW energy density



[Guzzetti, M.C. et al., (1605.01615)]

Potentially interesting scenarios

Inflationary GWs generated by the amplification of the vacuum fluctuations
have an amplitude **OUT** of LIGO and LISA range

- Presence of extra degrees of freedom during inflation

L. Sorbo's talk

- New patterns of symmetry during inflation

- Merging of Primordial BHs after inflation

J. Garcia-Bellido's talk

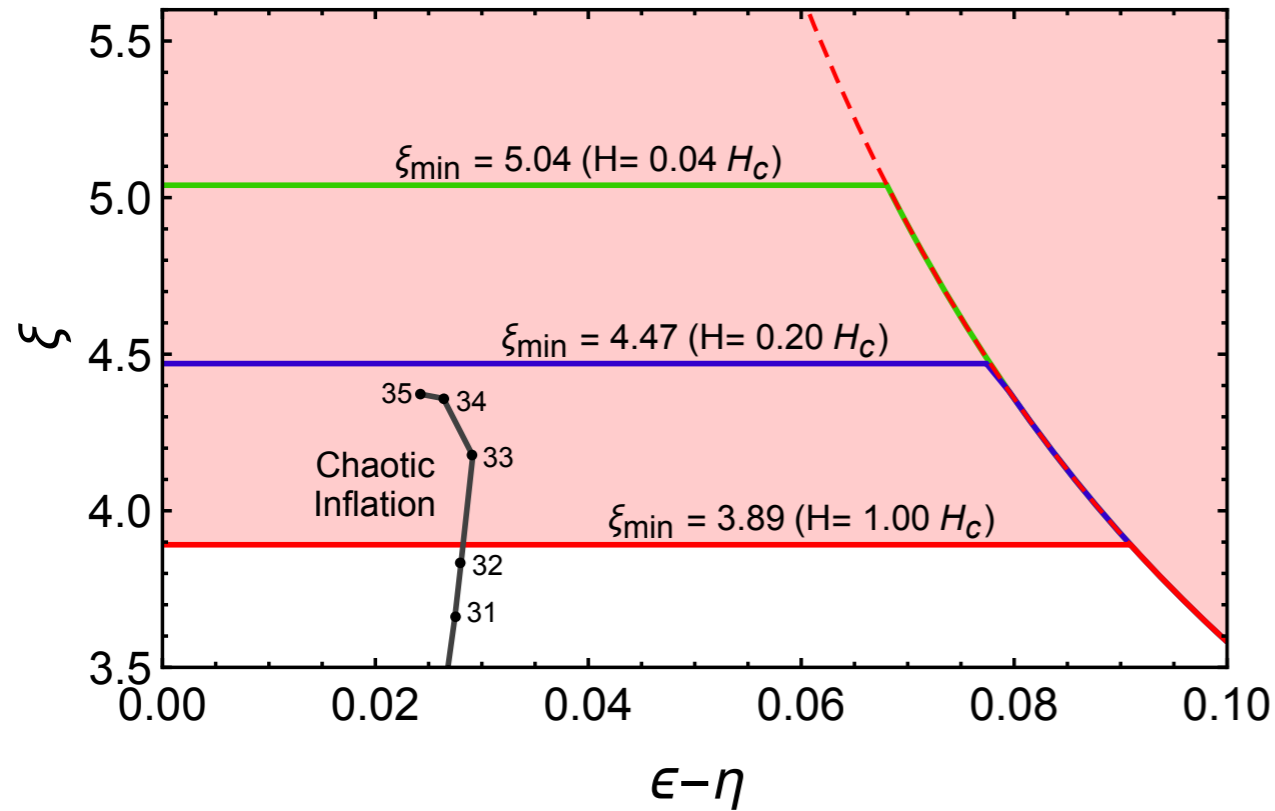
- . . .

Inflaton-vector field coupling

$$\mathcal{L} \supset -\frac{\varphi}{4f} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

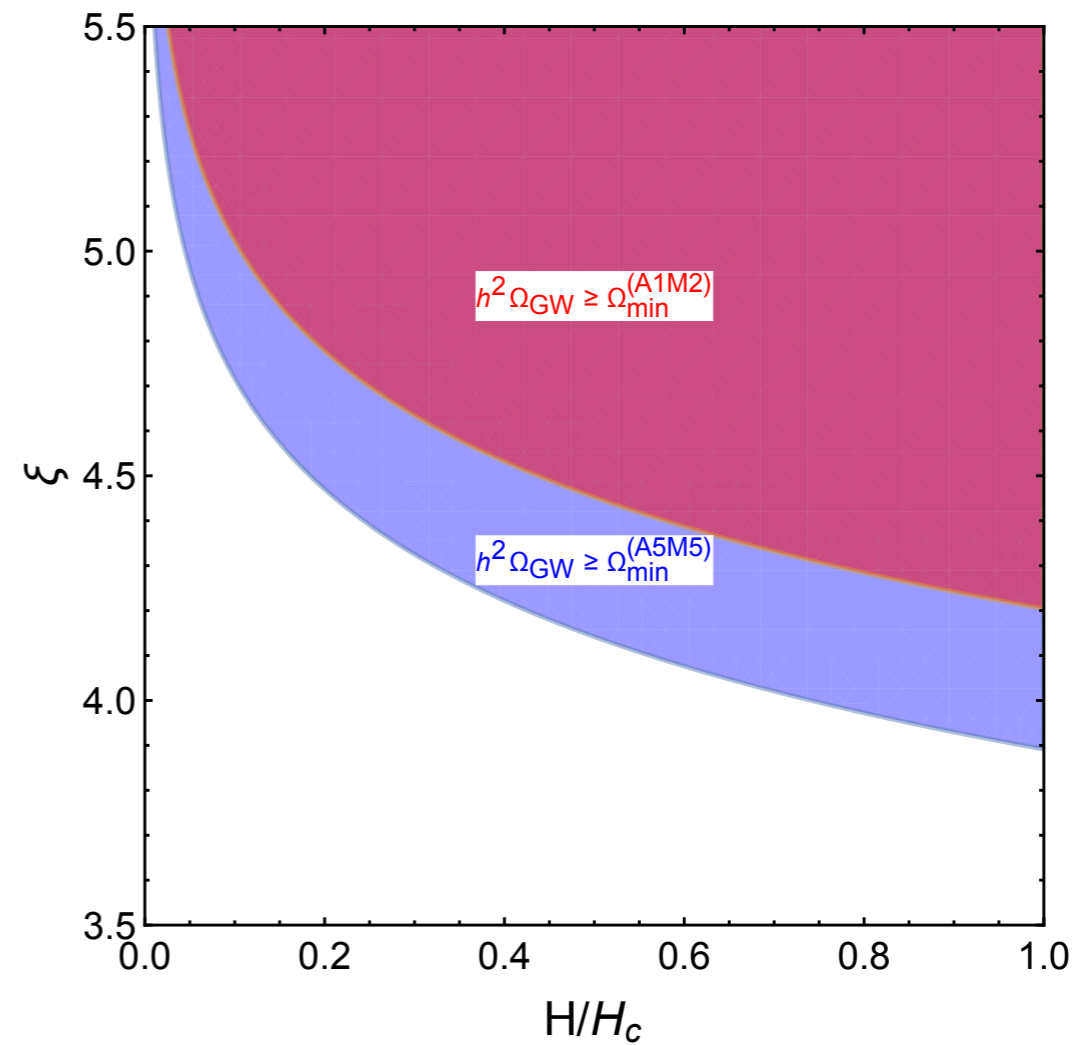
$$\xi \equiv \frac{\dot{\varphi}}{2fH}$$

A5M5 (Best Config.)



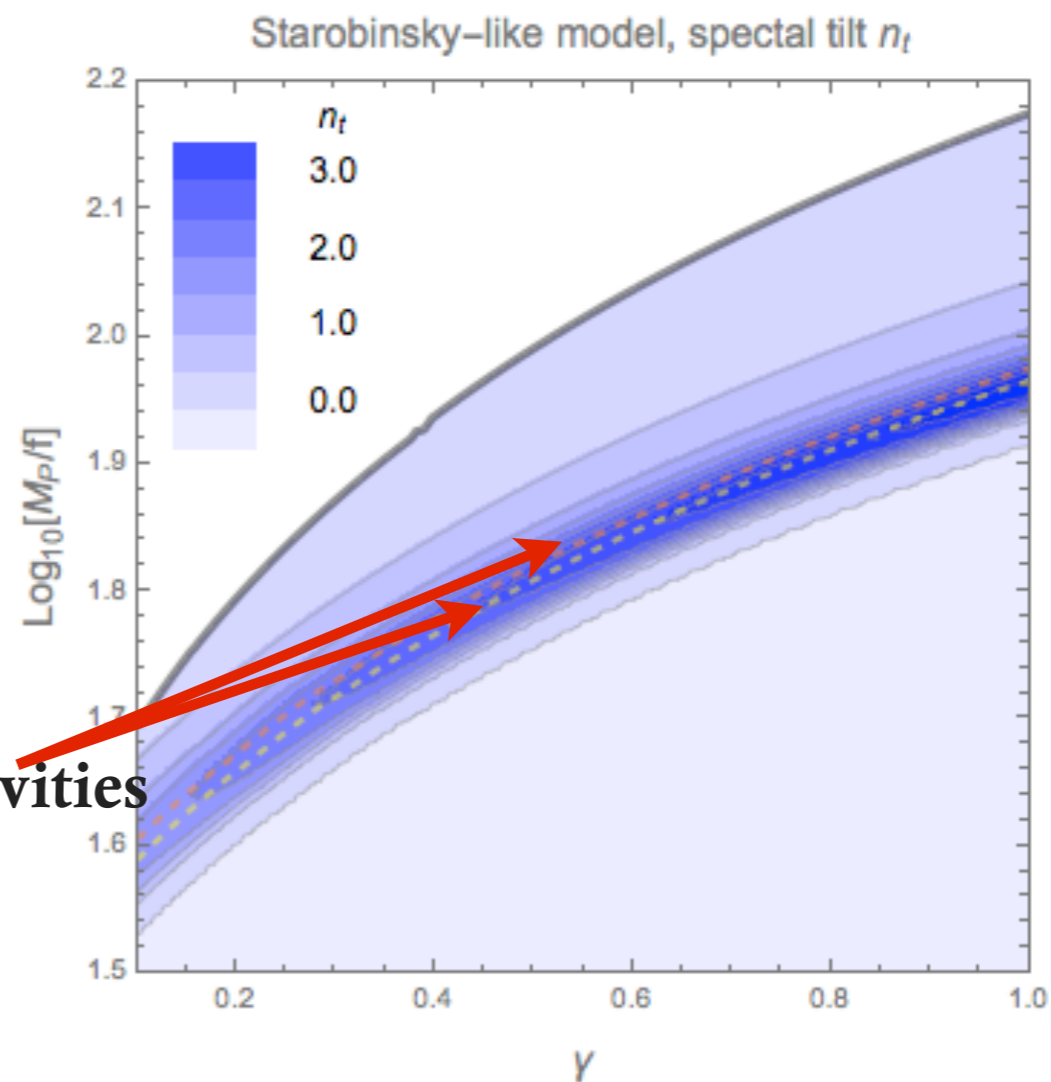
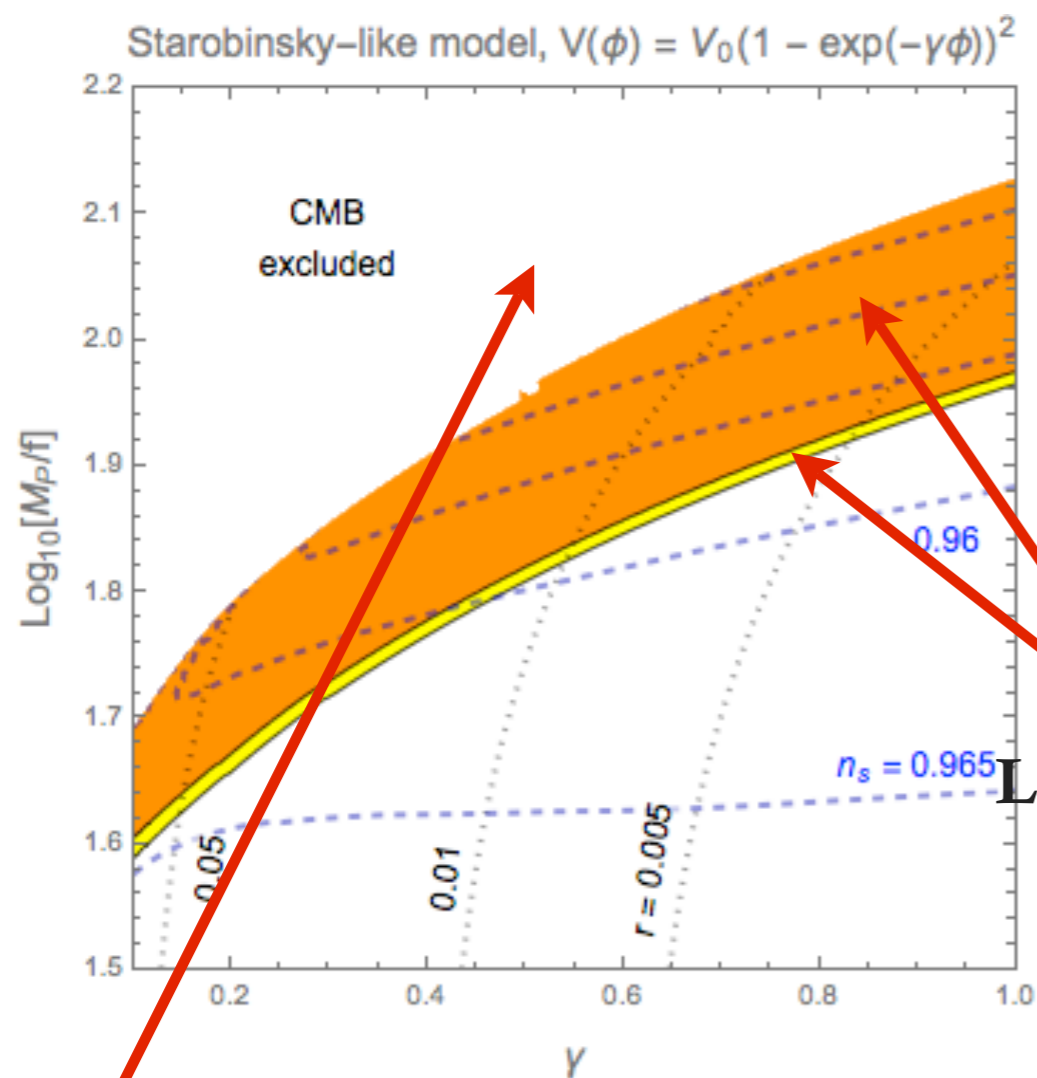
$$H_c \sim 2.6 \cdot 10^{-5} M_{Pl} \simeq 6.4 \cdot 10^{13} \text{ GeV}$$

$$\epsilon_H \equiv -\frac{\dot{H}}{H^2}, \quad \eta \equiv -\frac{\ddot{\phi}}{H\dot{\phi}}$$



LISA complementary to CMB

[Bartolo N. et al '16]



LISA sensitivities

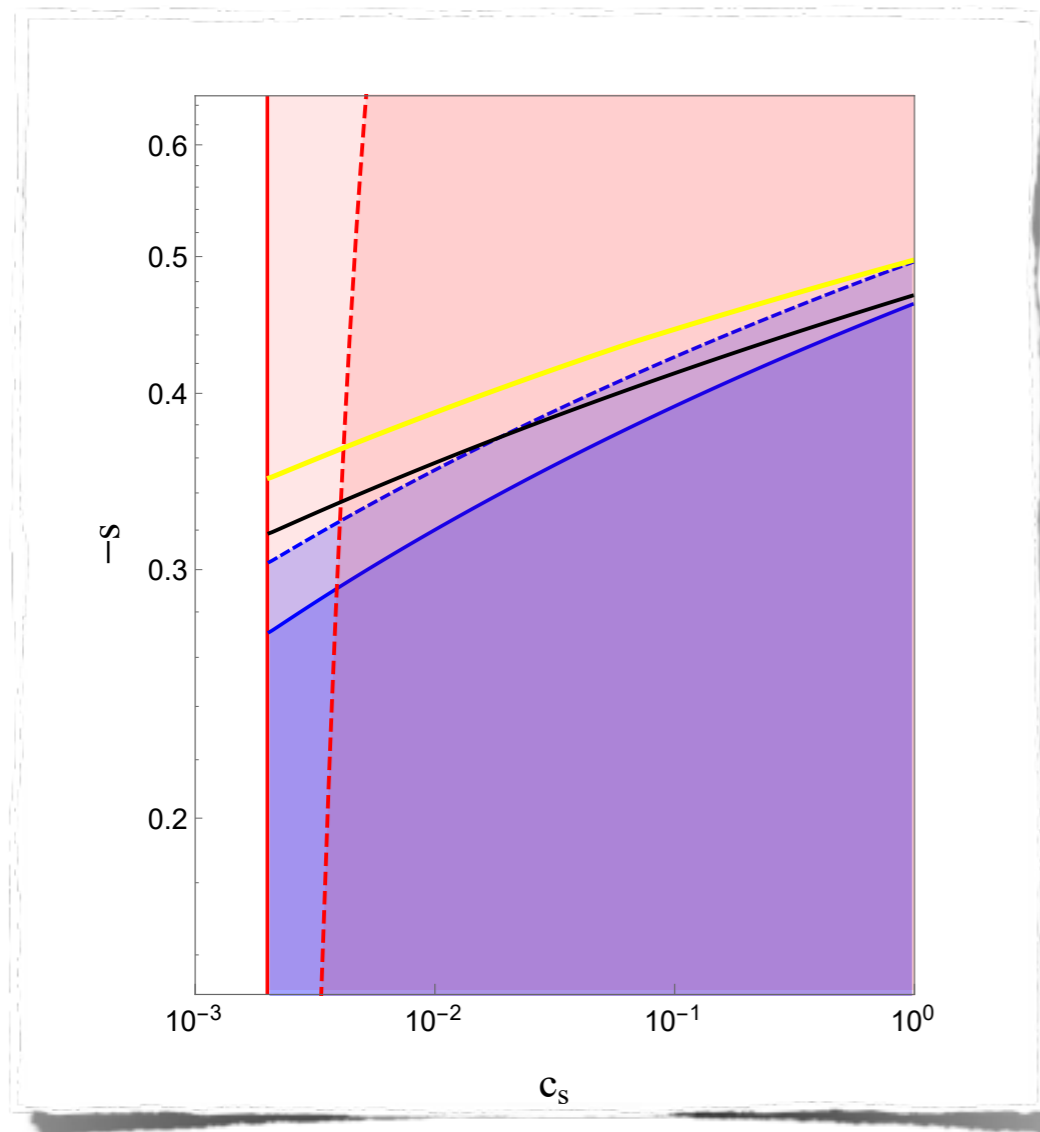
non-Gaussianity, mu-distorsion (+LIGO)

complementarity between CMB and direct GW observations

Extra (spectator) scalar field during inflation

$$\mathcal{L} \supset P(X, \sigma)$$

$$s \equiv \frac{\dot{c}_s}{H c_s} \neq 0$$



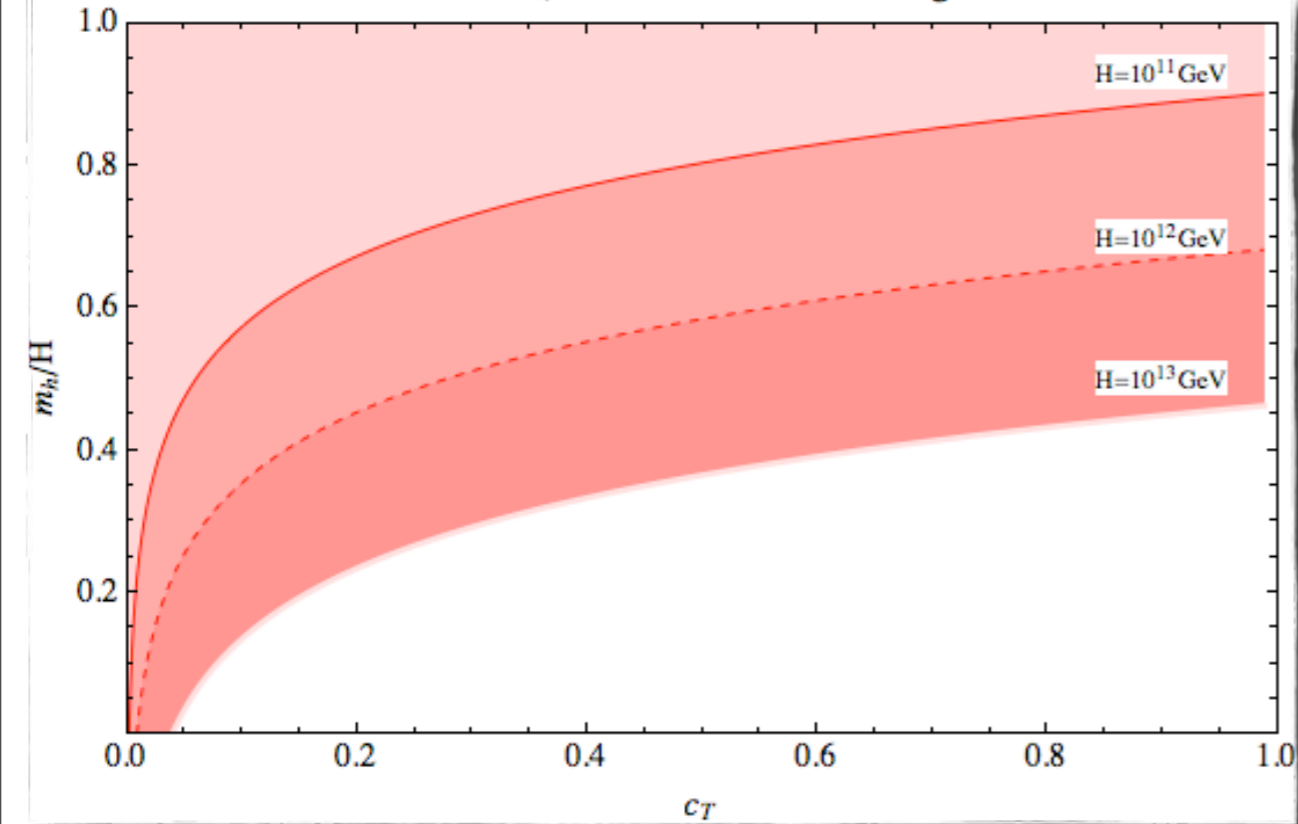
- indirect
- aLIGO O1
- LISA A5M5
- LISA A1M2

c_s -> speed of sound

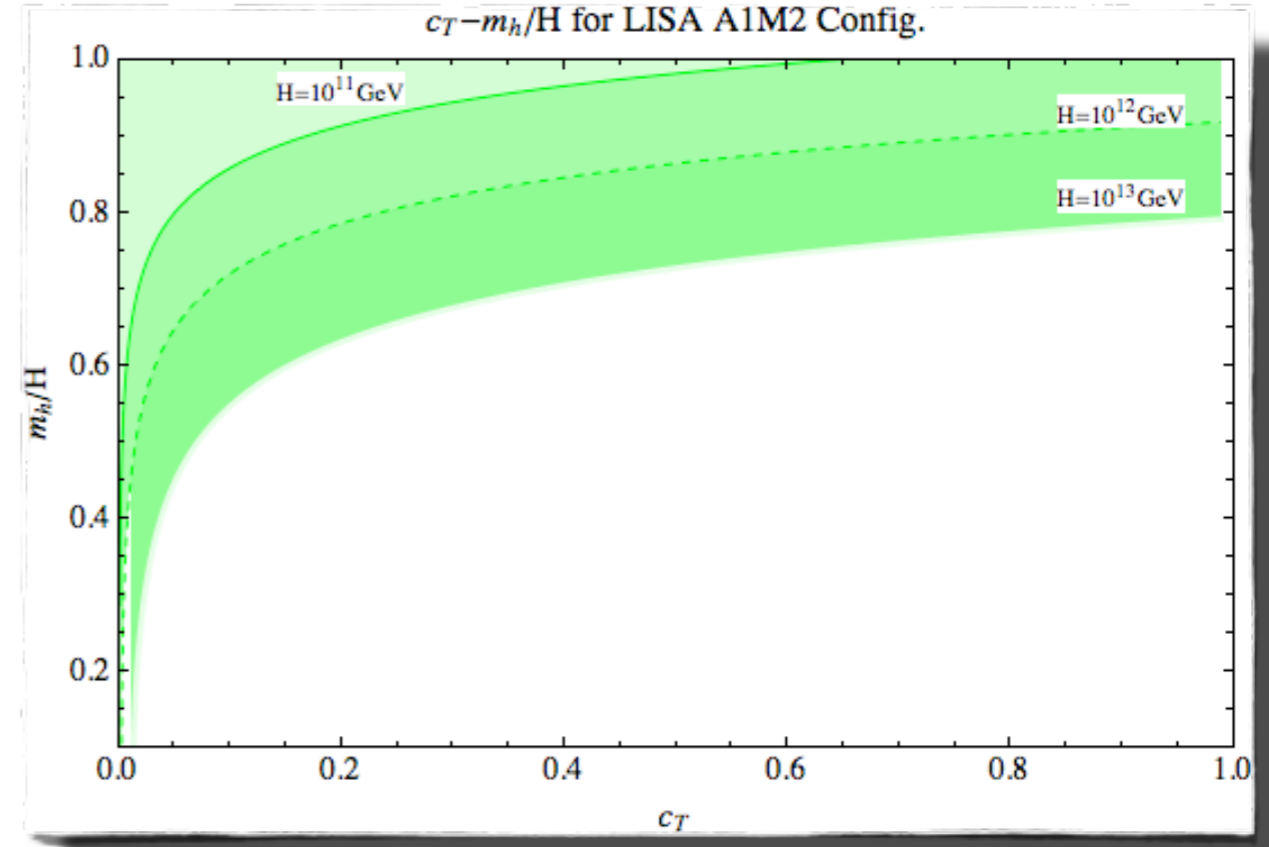
s -> variation of speed of sound

Effective theory for (massive) tensor during inflation

$c_T - m_h/H$ for LISA A5M5 Config.



$c_T - m_h/H$ for LISA A1M2 Config.

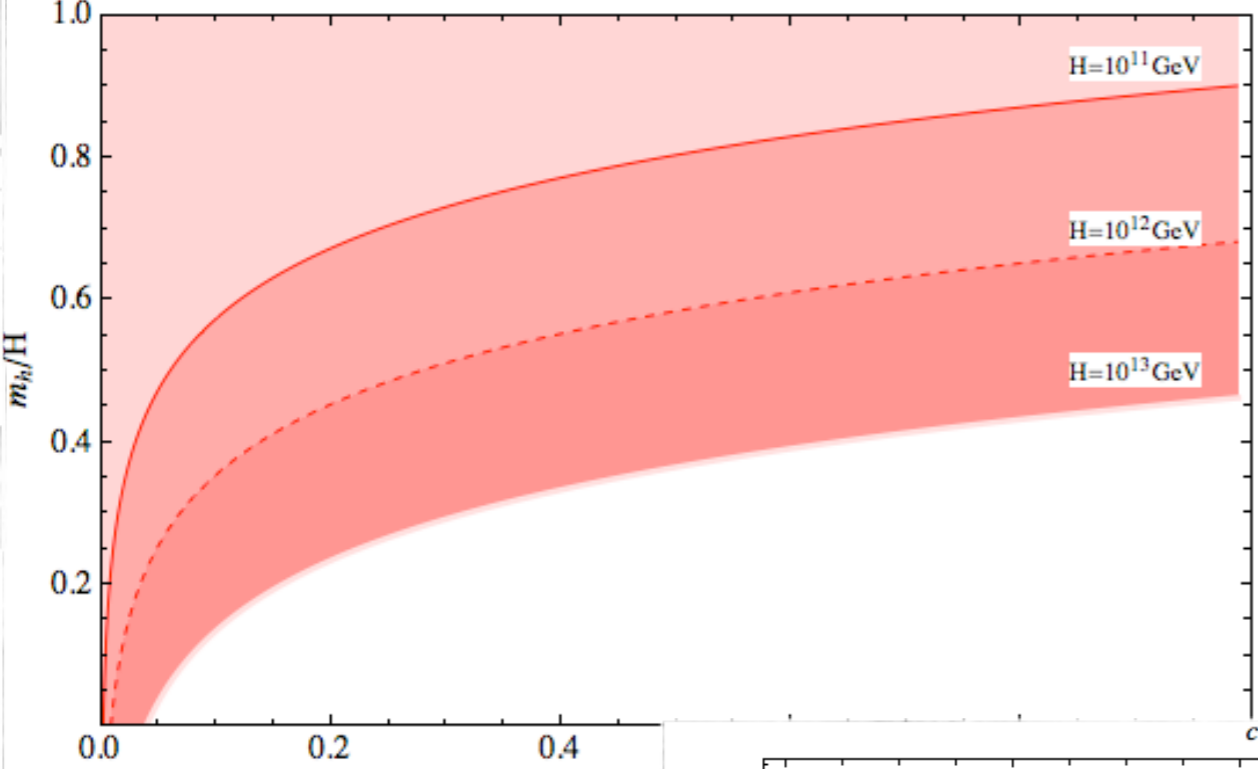


$c_T \rightarrow$ tensor sound speed

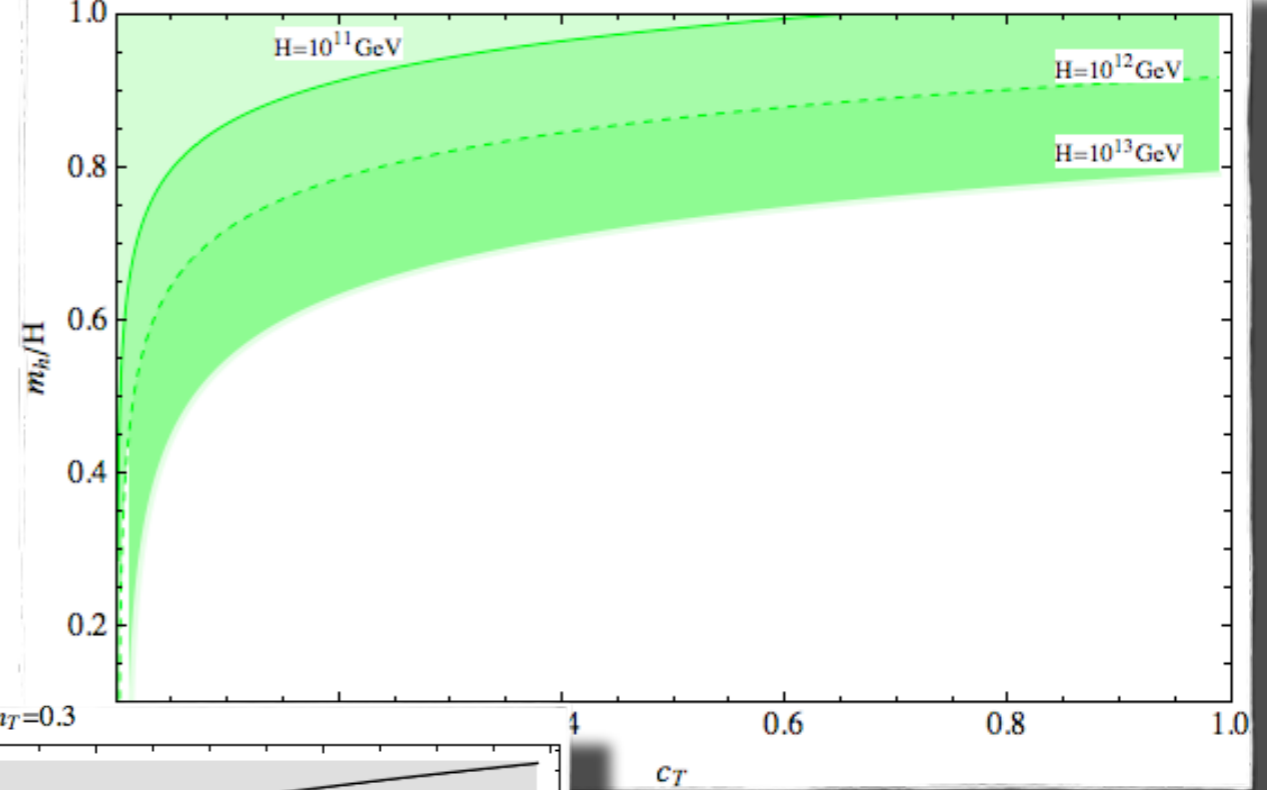
$$S_h = \frac{M_{Pl}^2}{4} \int d\eta d^3x a^2(\eta) \left\{ (h'_{ij})^2 - c_T^2 (\partial_l h_{ij})^2 - m^2 h_{ij}^2 \right\} .$$

Effective theory for (massive) tensor during inflation

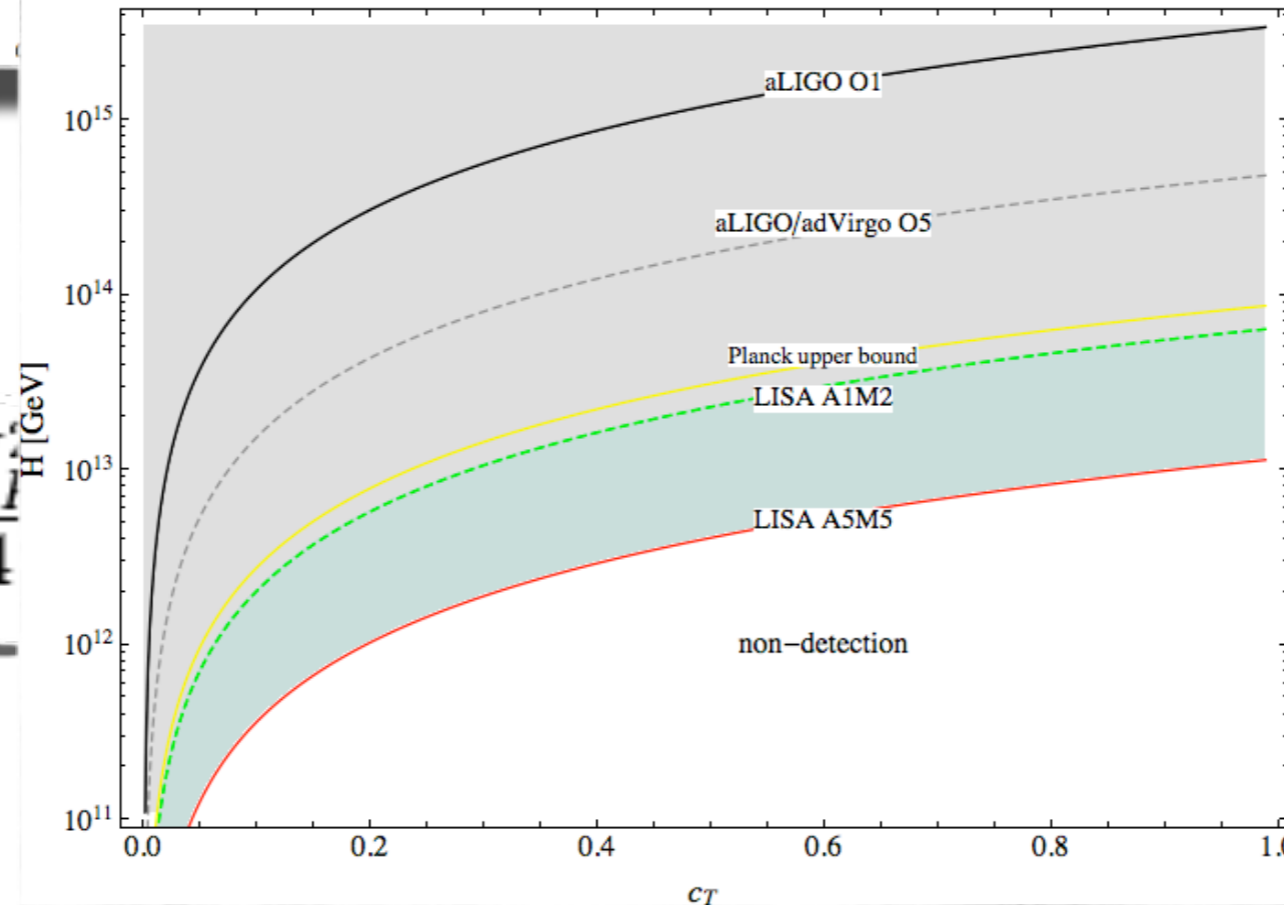
$c_T - m_h/H$ for LISA A5M5 Config.



$c_T - m_h/H$ for LISA A1M2 Config.



$c_T - H$ for $n_T=0.3$



$$S_h = \frac{M_p^2}{4} \dot{H}^2$$

$c_T \rightarrow$ tensor sound speed

$$m^2 h_{ij}^2 \}$$

LISA WG workshop @ Mainz

What about measuring non-Gaussianity and
PARITY VIOLATION with LISA?

What about reconstructing the SGWB with LISA?

Status of TENSOR non-Gaussianity

CMB “constraints” only about **EQUILATERAL CONFIGURATION**

$$f_{\text{NL}}^{\text{tens}} = \frac{5}{18} \frac{B_h^{++\pm}(k, k, k)}{P_\zeta^2(k)}$$

$$10^{-2} \times f_{\text{NL}}^{\text{tens}}(\text{parity even}) = 4 \pm 16$$

$$10^{-2} \times f_{\text{NL}}^{\text{tens}}(\text{parity odd}) = 80 \pm 110$$

[Shiraishi et al '15]

B-mode polarization data STILL MISSING

Limits on mixed (scalar-tensor) correlator

$\langle B T T \rangle$

$$g_{tss} = -48 \pm 28$$

[from WMAP data]

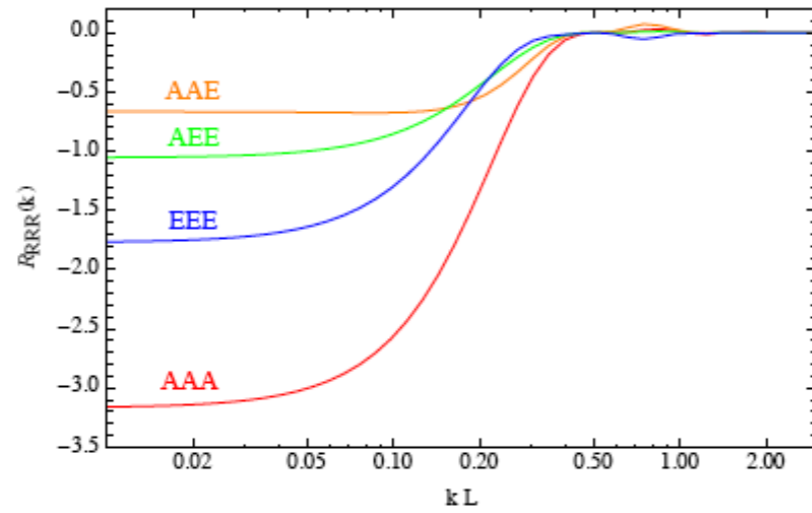
[Shiraishi et al '17]

V. Domcke's talk...

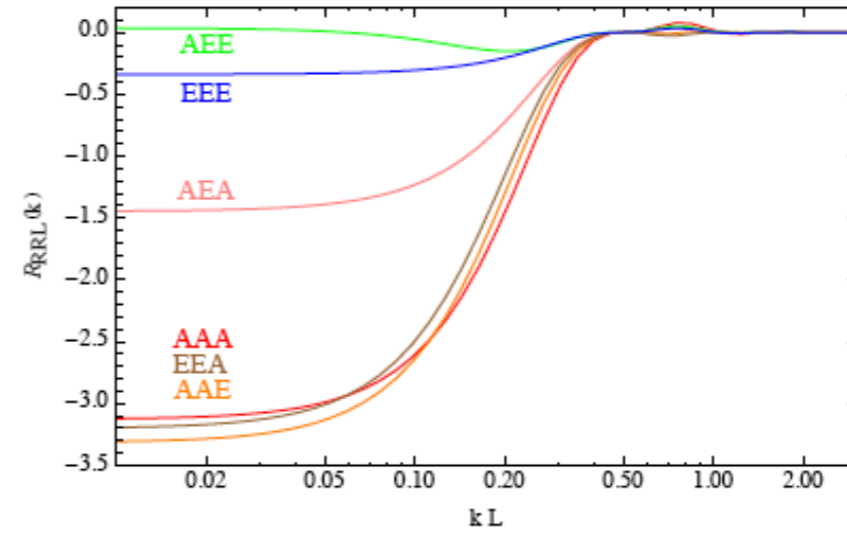
$$\mathcal{R}_{LLL} = \mathcal{R}_{RRR}$$

\neq

$$\mathcal{R}_{LLR} = \mathcal{R}_{RRL}$$



\neq

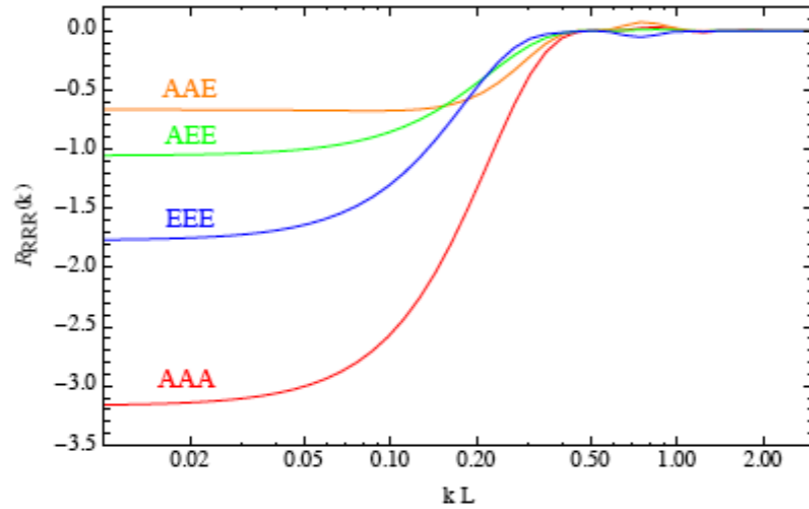


V. Domcke's talk...

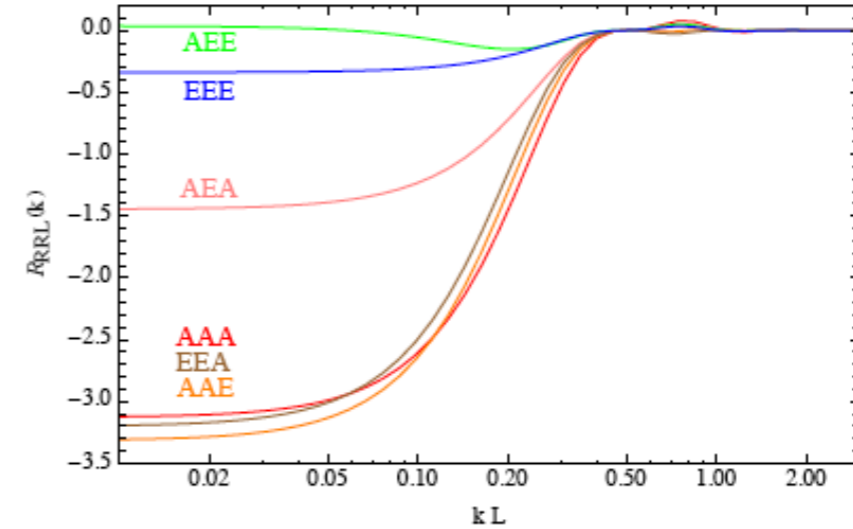
$$\mathcal{R}_{LLL} = \mathcal{R}_{RRR}$$

\neq

$$\mathcal{R}_{LLR} = \mathcal{R}_{RRL}$$

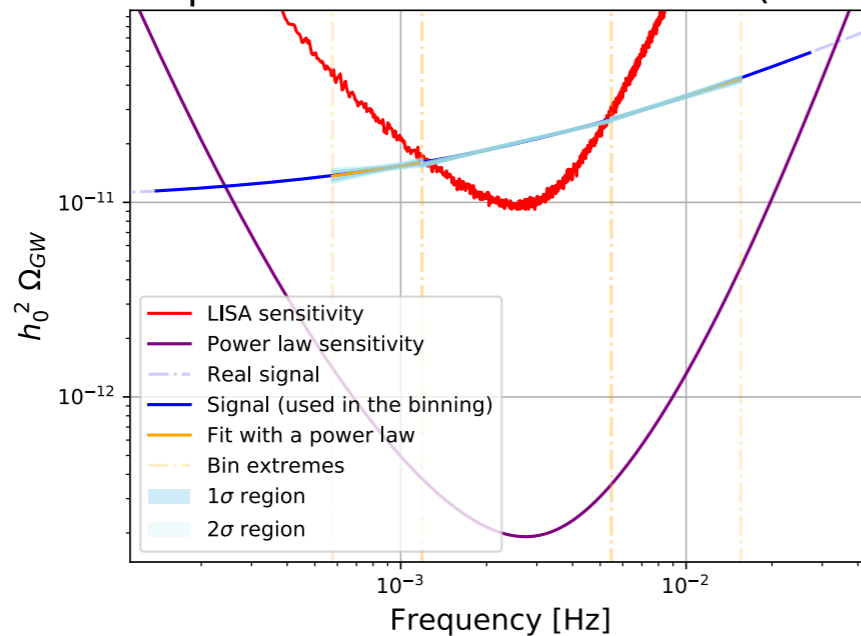


\neq

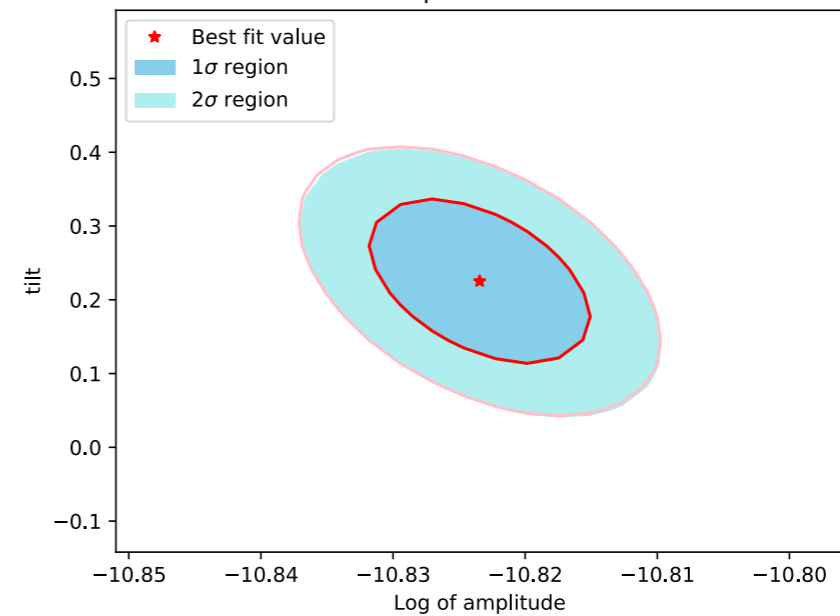


M. Pieroni's talk...

Two parameters reconstruction (3 bins)



Contour plot bin number 1

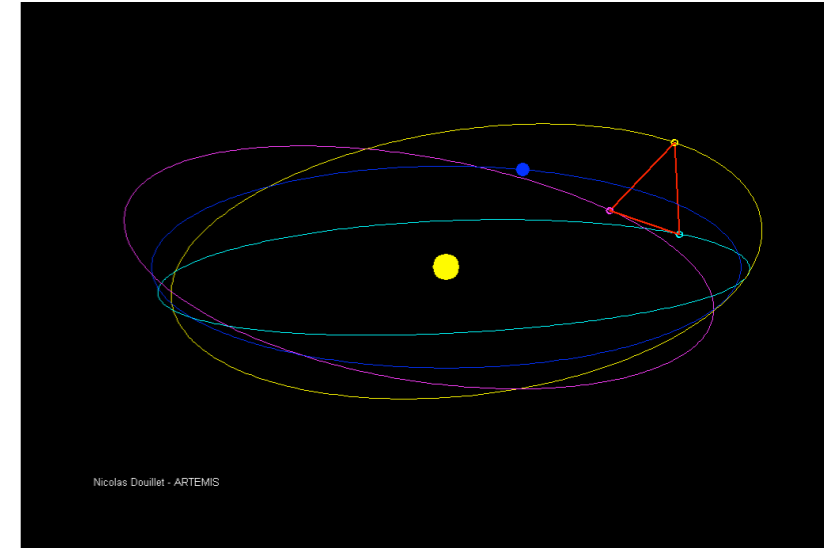


Possible future WG projects

- “Figures of merit” for interesting primordial scenarios (Non-abelian model, pre-big bang models, String gas cosmology, etc)
- Apply bispectrum techniques to specific models
- Extend GW bispectrum techniques to other GW experiments

•••

- Take into account the motion of LISA and other real effects



- Anisotropies from Early Universe cosmology

- Probe extra-polarization states with 3 arm config.

...

- Improvements of GWBinner code

- Connection to LDC

- ...

Who is interested please contact
Dani Figueroa and/or Angelo Ricciardone
and join to the WG discussion in the afternoon

Thank you!

