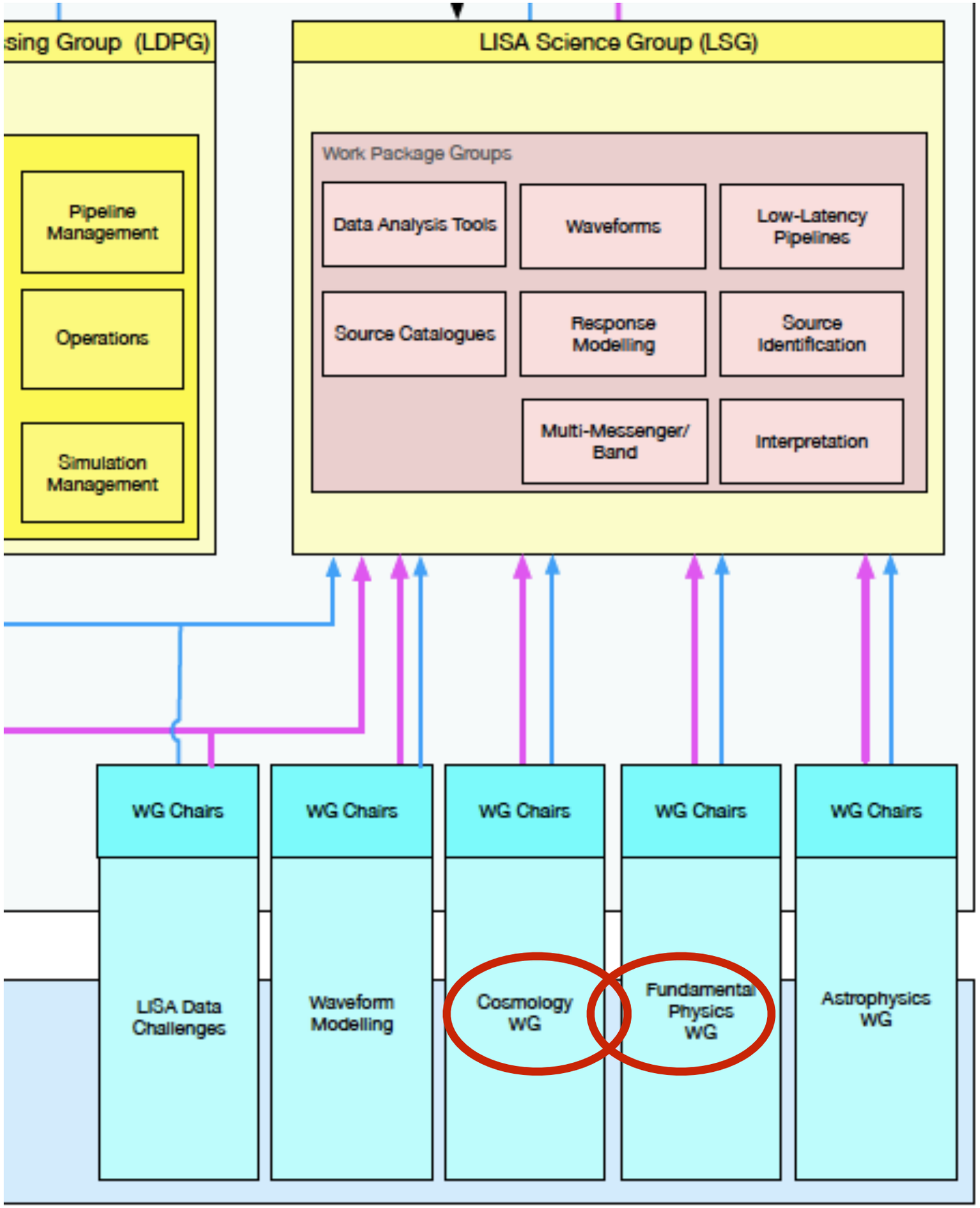
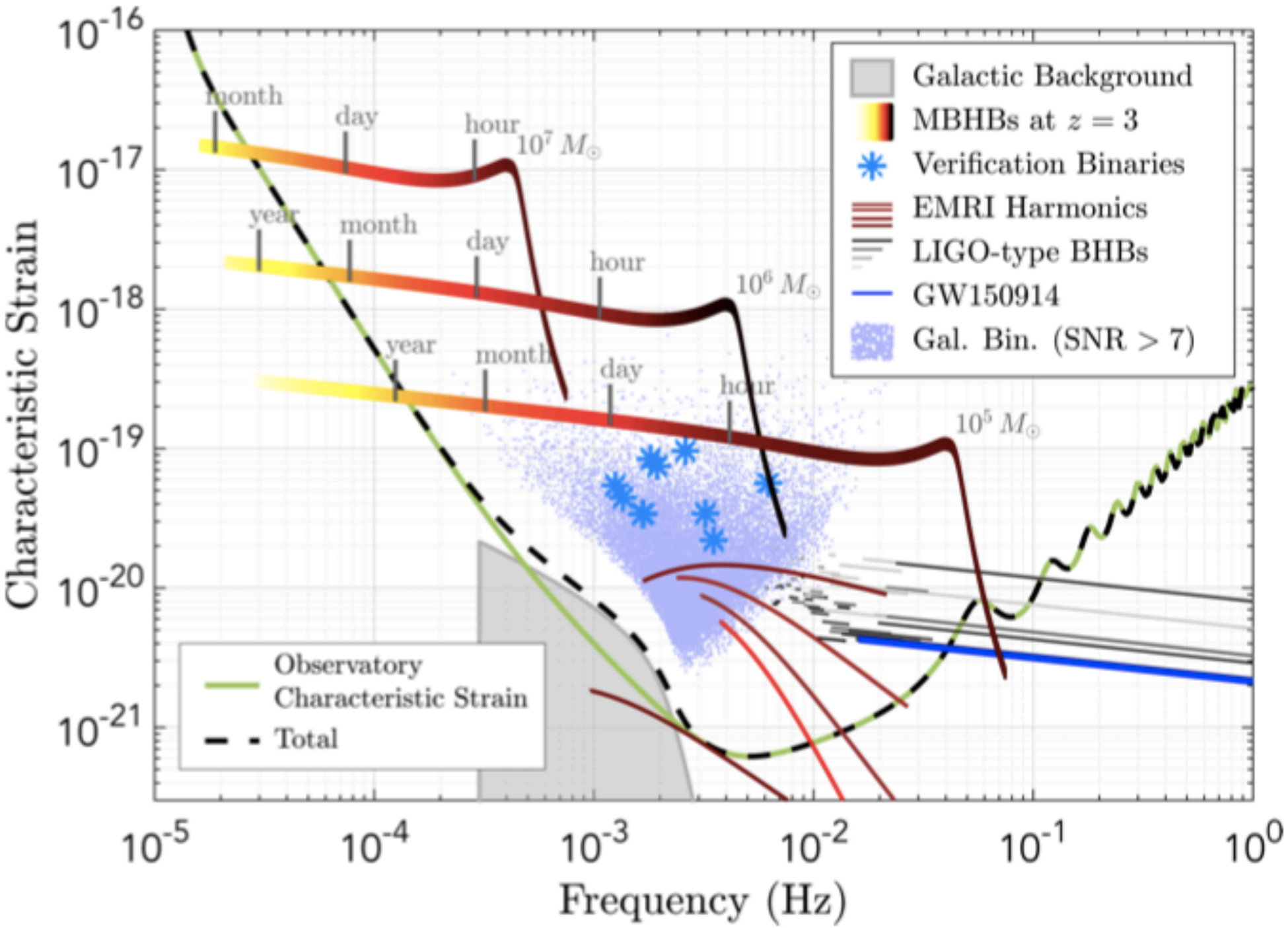
DISCUSSION ABOUT COSMOLOGY

WORKING GROUPS: interface consortium and scientific community



LISA sources



https://www.elisascience.org/files/publications/LISA_L3_20170120.pdf

Cosmology with LISA

- GW emission from binaries
- the stochastic GW background

✳ *test of the early universe and high energy phenomena* (mainly SGWB)

✳ *test of the accelerated expansion of the universe* (binaries)
  - standard sirens: Lambda, Dark Energy, Modified Gravity Michele
  - effective field theory approach Mark

✳ *cross-correlation of GW sources and Large Scale Structure* (both) Alvise

✳ *primordial black holes as dark matter* (both) Marco

the stochastic GW background from primordial sources: test of the early universe and high energy phenomena

amplification of vacuum fluctuations

$$\ddot{h}_{ij} + 3H\,\dot{h}_{ij} + k^2\,h_{ij} = 0$$

active source (tensor anisotropic stresses)

$$\ddot{h}_{ij} + 3H\,\dot{h}_{ij} + k^2\,h_{ij} = 16\pi G\,\Pi_{ij}^{TT}$$

$$\epsilon_* = L_* H_* \qquad\qquad f_c = f_* \frac{a_*}{a_0} = \frac{2\cdot 10^{-5}}{\epsilon_*}\,\frac{T_*}{1\,\mathrm{TeV}}\,\mathrm{Hz}$$

characteristic frequency today

CMB
anisotropies

Inflation

GW

Cosmological dark age
(reheating, baryogenesis, phase
transitions, dark matter,...)

light
elements

BBN

h_{ij}

γ

M_{Pl} $\leq 10^{16}$ GeV 10^9 GeV EW QCD MeV eV

CMB LIGO LISA PTA CMB

SGWB sources in the early universe : inflation-related

- irreducible SGWB from inflation
  - also sourced by second order scalar perturbations
- beyond the irreducible SGWB from inflation
  - particle production during inflation (scalar, gauge fields… coupled to the inflaton)
  - spectator fields
  - breaking symmetries (space-dependent inflaton, massive graviton)
  - modified gravity during inflation (massive GWs with $c \neq 1$)
  - primordial black holes
- alternatives to inflation
  - pre big-bang
  - cyclic/ekpirotic
  - string gas cosmology
- preheating and non-perturbative phenomena
  - parametric amplification of bosons/fermions
  - symmetry breaking in hybrid inflation
  - decay of flat directions
  - oscillons

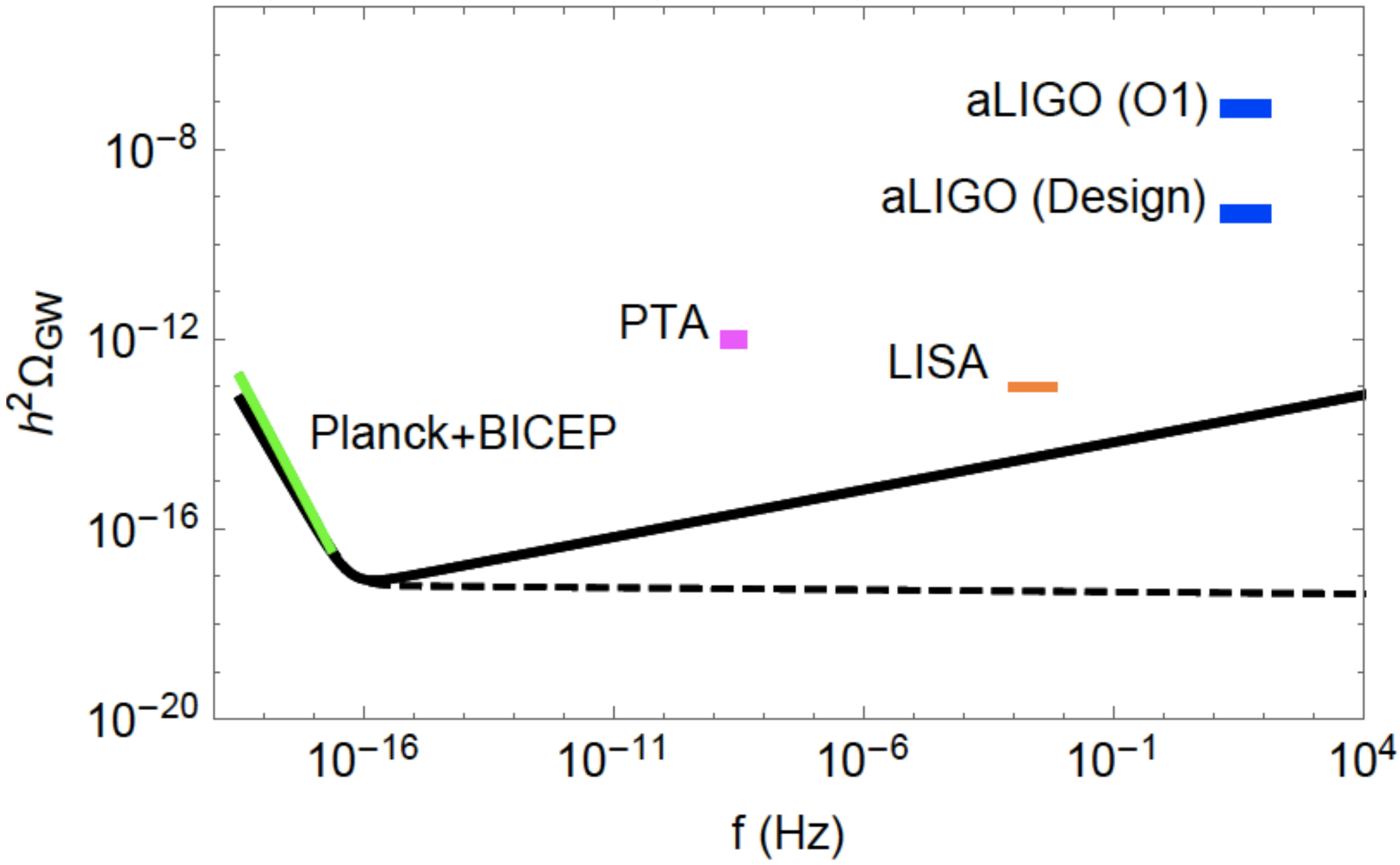
CC and Figueroa arXiv:1801.04268

SGWB sources in the early universe : phase transition-related

- first order phase transition
  - true vacuum bubble collision
  - sound waves
  - turbulence
- cosmic topological defects
  - irreducible SGWB from topological defect networks
  - decay of cosmic string loops
- thermal SGWB (standard model plasma)

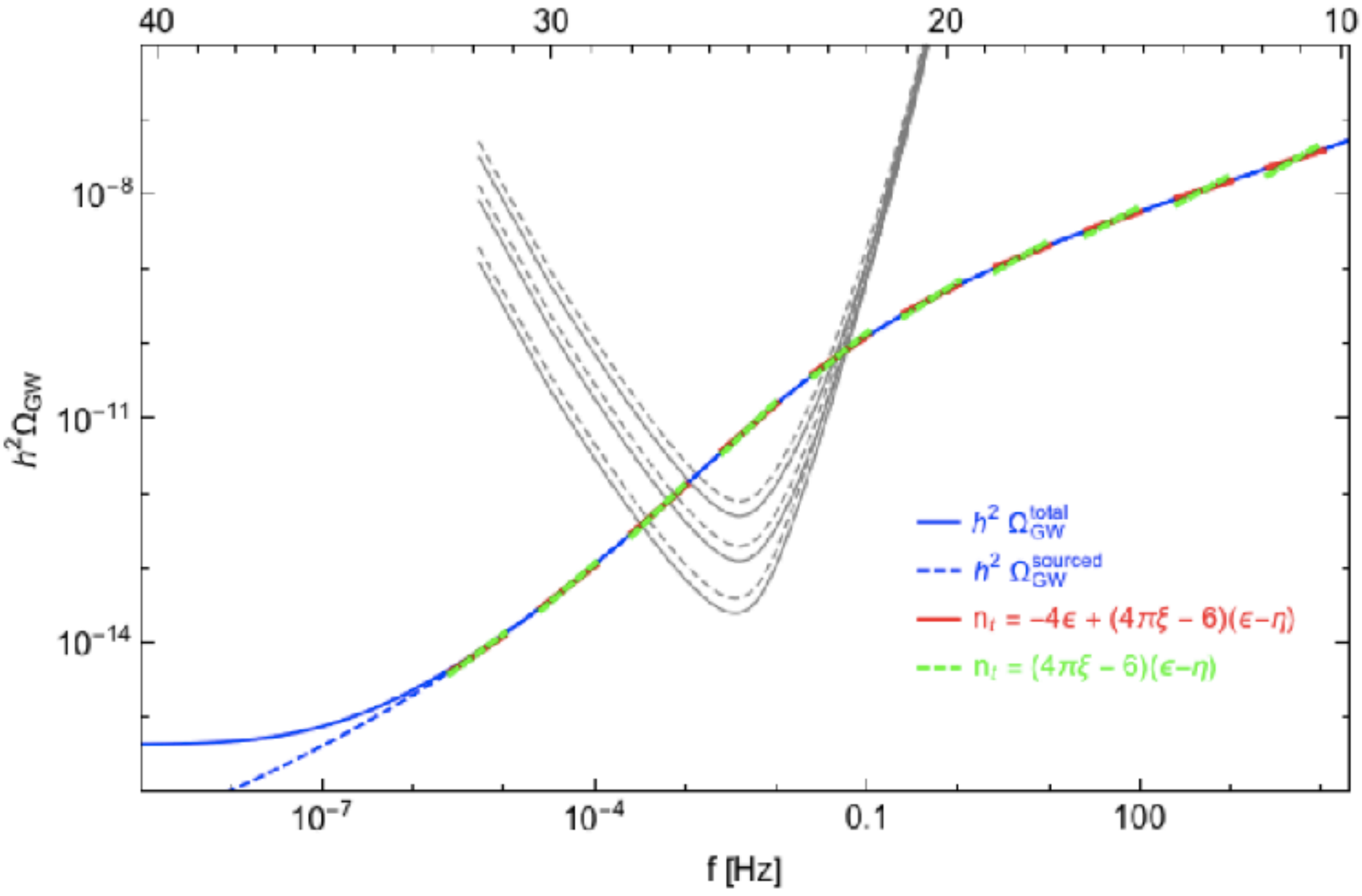
CC and Figueroa arXiv:1801.04268

SGWB sources in the early universe : inflation-related



just one example: inflaton-gauge field coupling

$$\Delta\mathcal{L} = -\frac{1}{4\Lambda}\phi F_{\mu\nu}\tilde{F}^{\mu\nu}$$



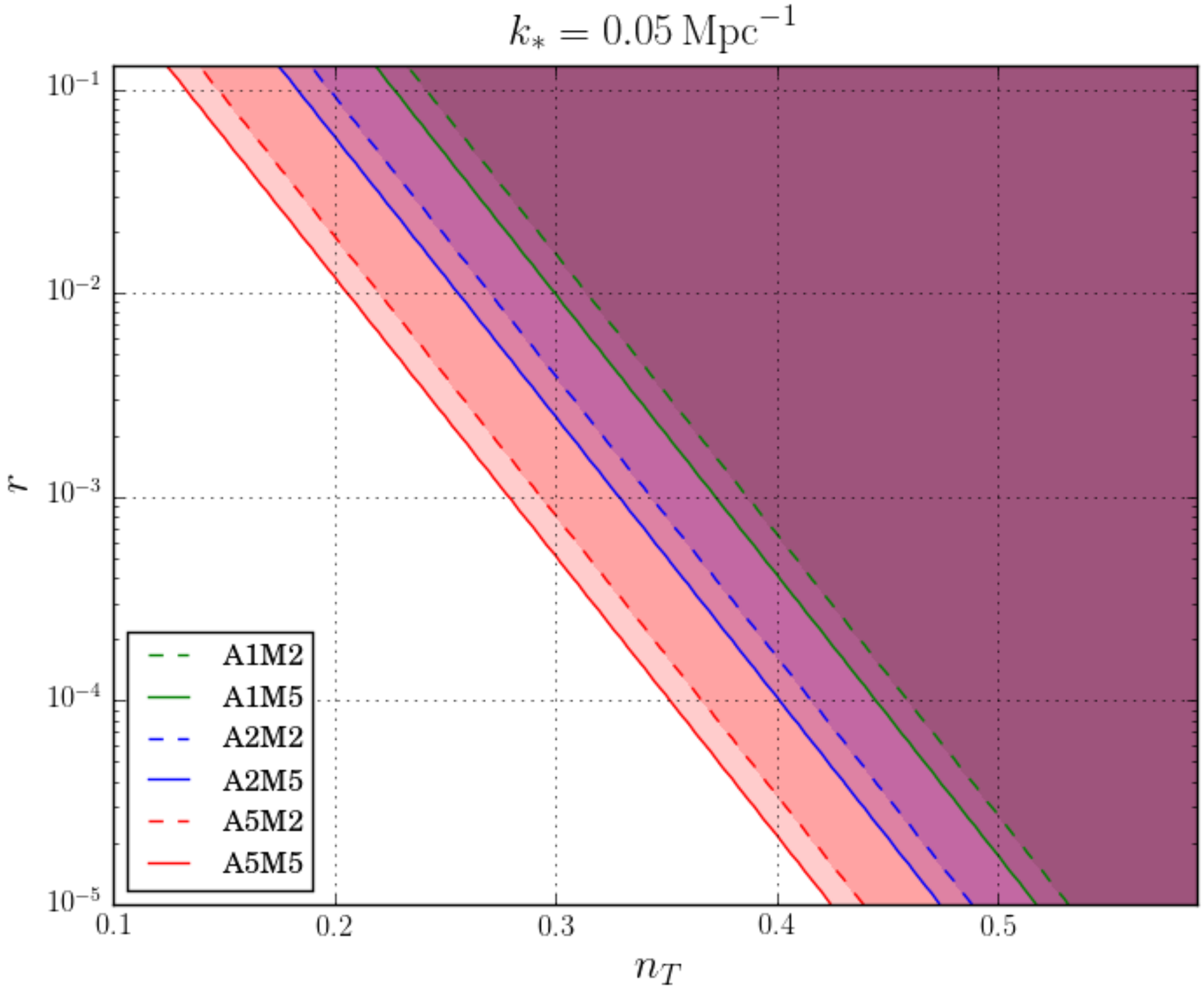
$$\Lambda = \frac{M_{Pl}}{35}$$

quadratic inflaton potential

OTHER SIGNATURES:
non-gaussianity, chirality

N. Bartolo et al, arXiv:1610.06481
N. Bartolo et al, arXiv:1806.02819

general constraints on (r,n_T) from LISA



N. Bartolo et al, arXiv:1610.06481

SGWB sources : phase transition-related first order PT

- LISA is sensitive to energy scales 10 GeV - 100 TeV

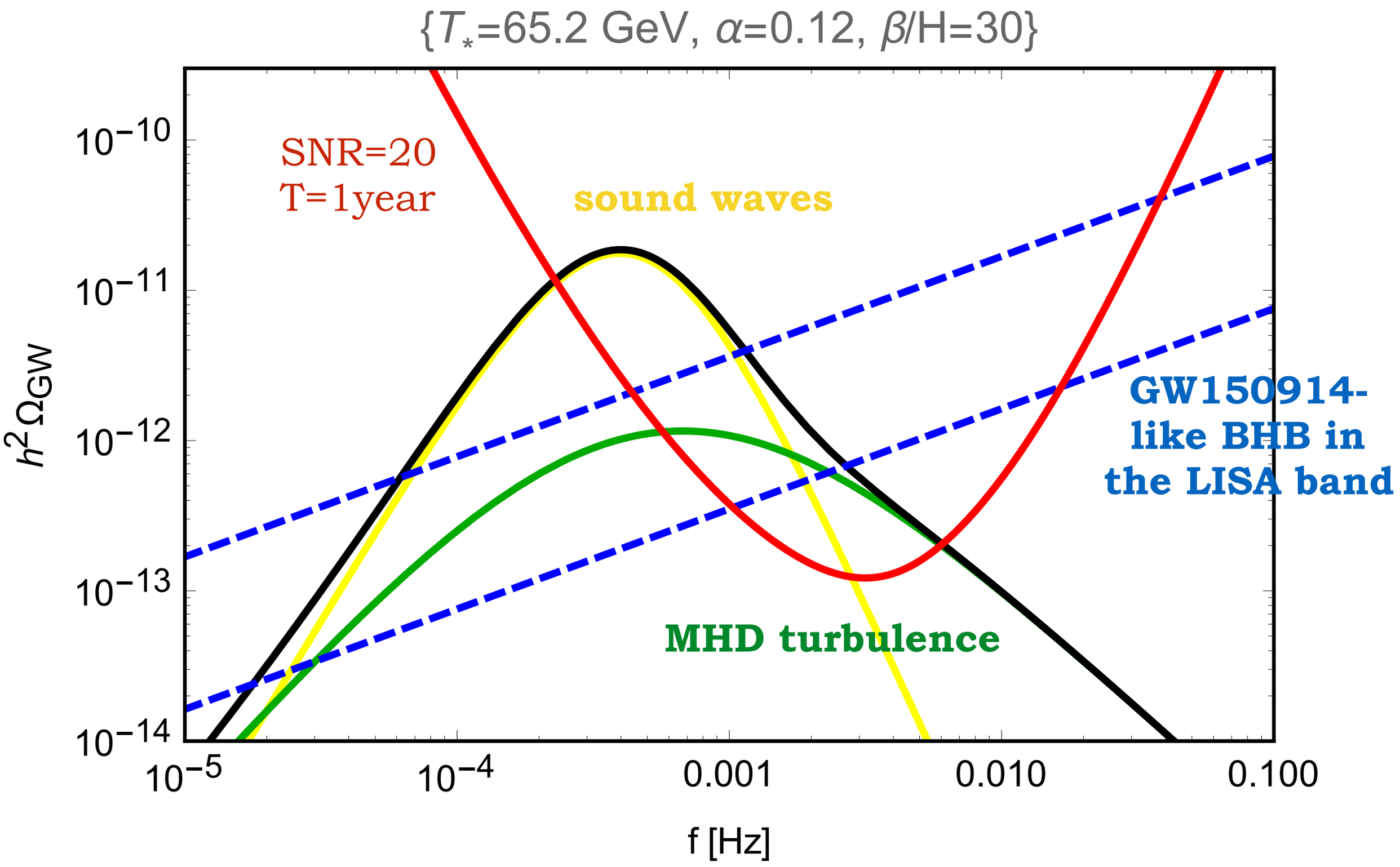
- LISA can probe the EWPT in BSM models …
  - singlet extensions of MSSM
  - direct coupling of Higgs sector with scalars
  - SM plus dimension six operator

- … and beyond the EWPT
  - Dark Matter sector
  - Warped extra dimensions

connections with baryon asymmetry, dark matter : LISA as a complementary probe of BSM physics

CC et al, arXiv:1512.06239

Example of signal from FOPT + foreground

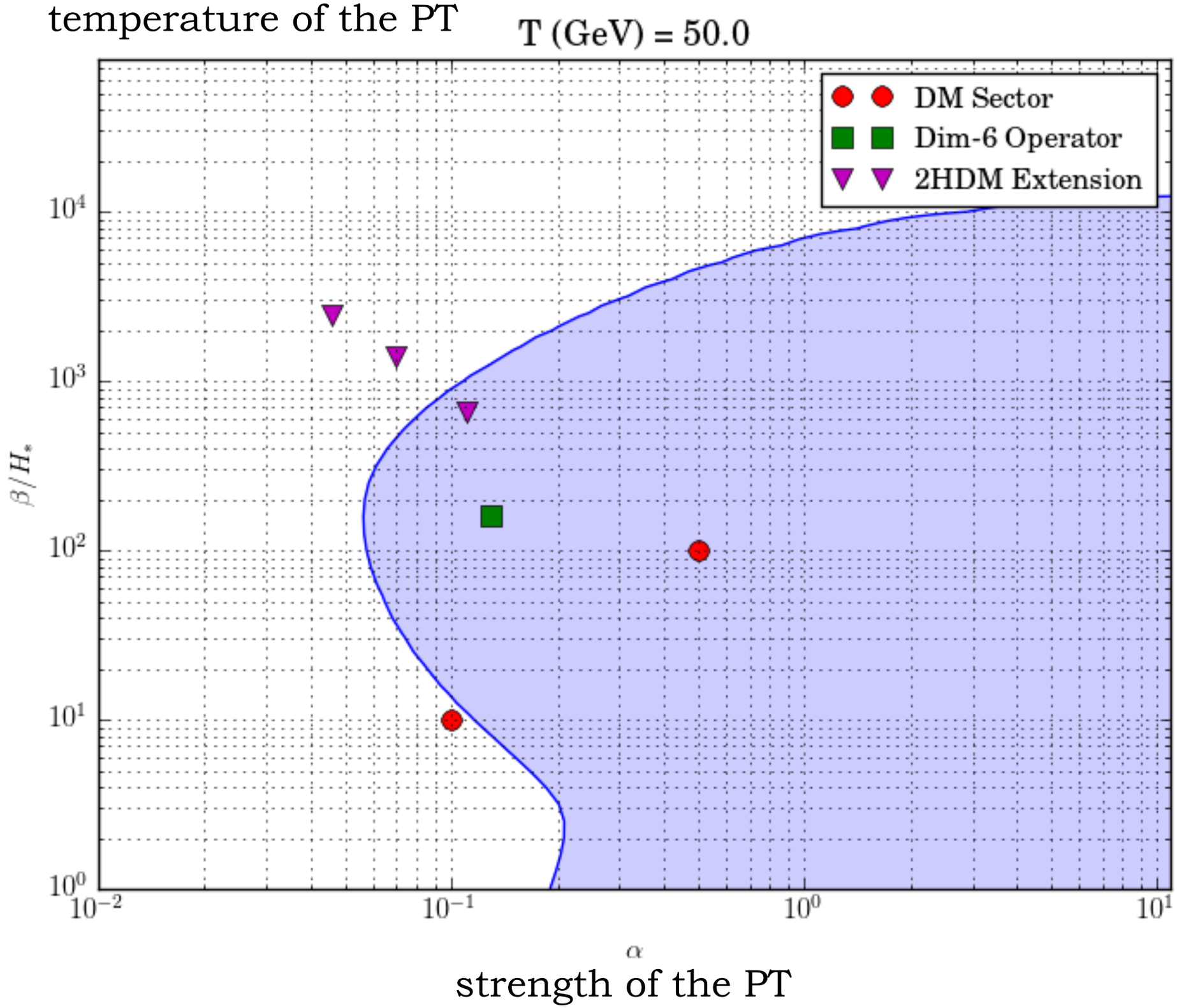


Example of detection prospects for FOPT at LISA

temperature of the PT

inverse duration of the PT with respect to Hubble time

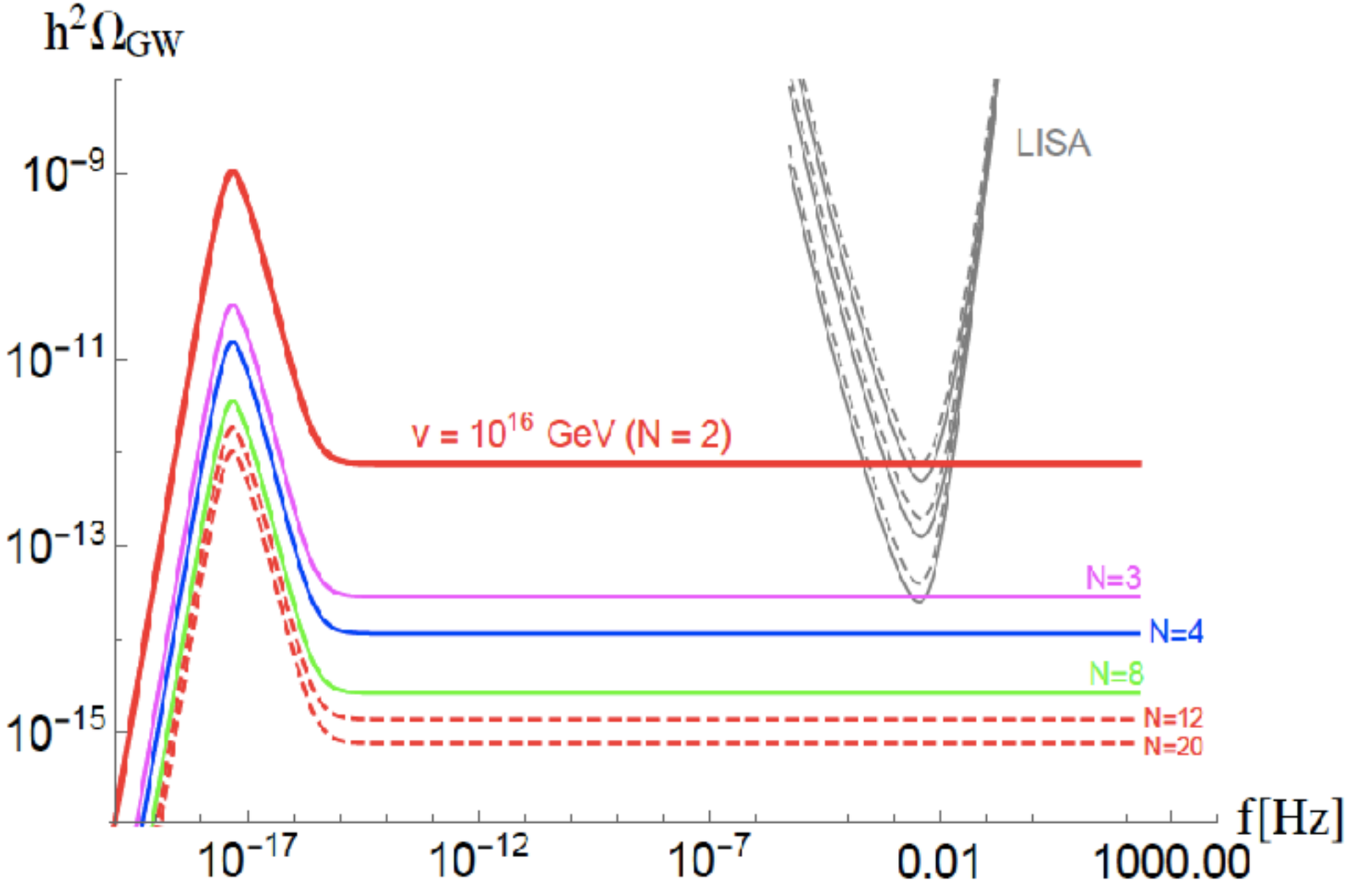
(ϵ_*)



strength of the PT

SGWB sources : phase transition-related topological defects

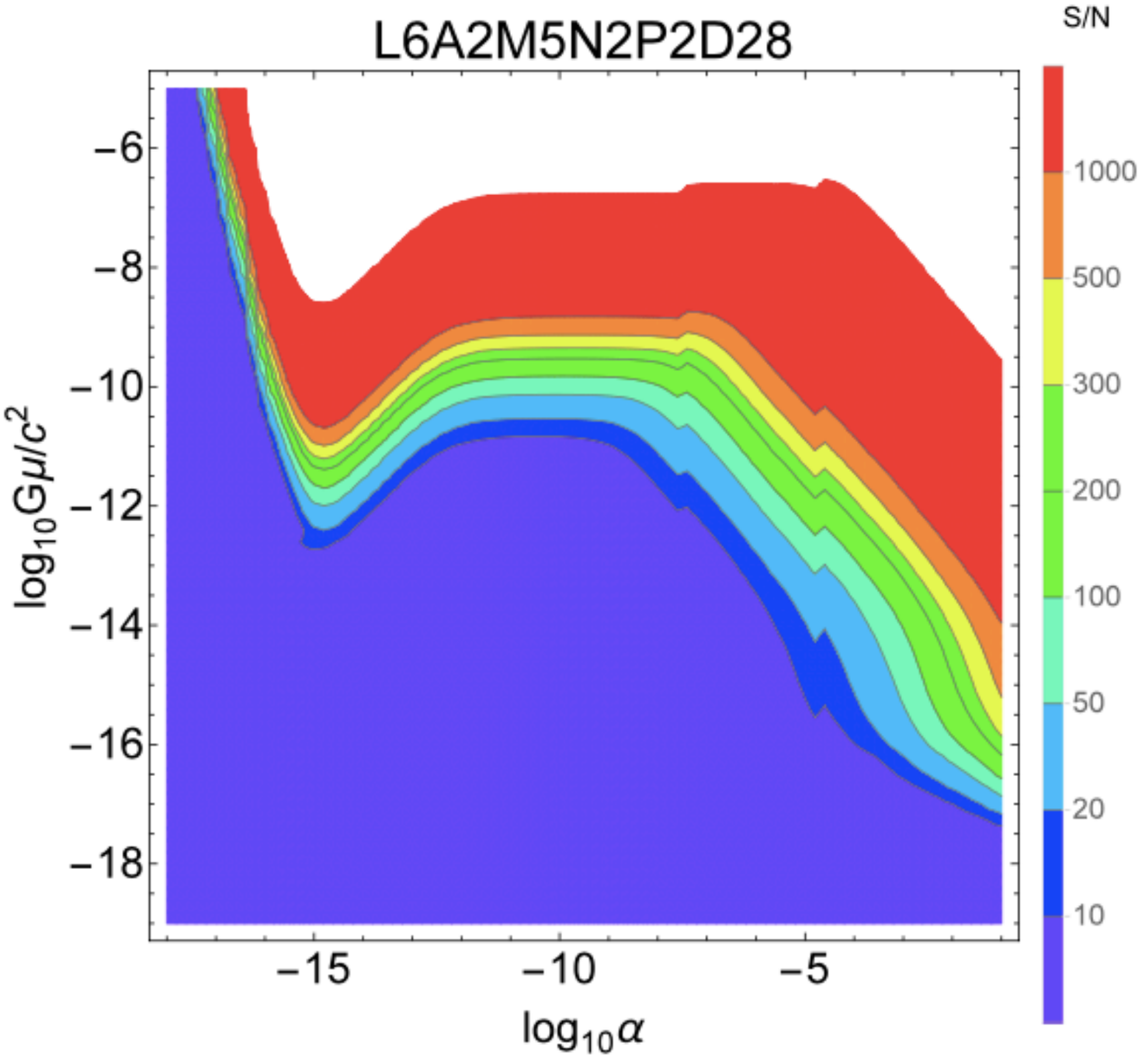
irreducible SGWB from a network of defects :
SSB of O(N) global symmetry



CC and Figueroa arXiv:1801.04268

Bounds on Nambu-Goto strings, loop size

S. Sanidas, LISA internal (old) $G\mu < 10^{-17}$



Current
NanoGRAV

$G\mu < 1.3 \cdot 10^{-10}$

future
CMB B-modes

$G\mu < 10^{-9}$

Future SKA

$G\mu < 10^{-13}$

Janssen et al 2015

Conclusions

- LISA has a great potential to constrain early universe scenarios through the observation of a SGWB
- inflationary models, EW symmetry breaking and beyond…
- provided we can distinguish the signal from noise and astrophysical foregrounds
- provided we can ascertain the origin of the SGWB once we measure it