Primordial stochastic GW backgrounds

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Summary

- a SGWB could be produced from processes operating in the very early universe
- the amazing thing: because of the weakness of the gravitational interaction, one can in principle detect the signal arising *from epochs much before the decoupling of photons (CMB)*
- this provides access to physics *beyond the standard model of particle physics* to which we have no access so far
- however, because of this, we don't know which processes may have operated to produce GWs at those early epochs
- current predictions on the SGWB from the early universe are uncertain and based on speculations about generating processes
- it is a *discovery space: no guaranteed source but great payoff if detection*

Summary

- there are a variety of predictions in terms of amplitude and spectral shape of the SGWB from cosmological sources (see examples later on)

- in order to be able to identify the source and claim a detection it is fundamental to:

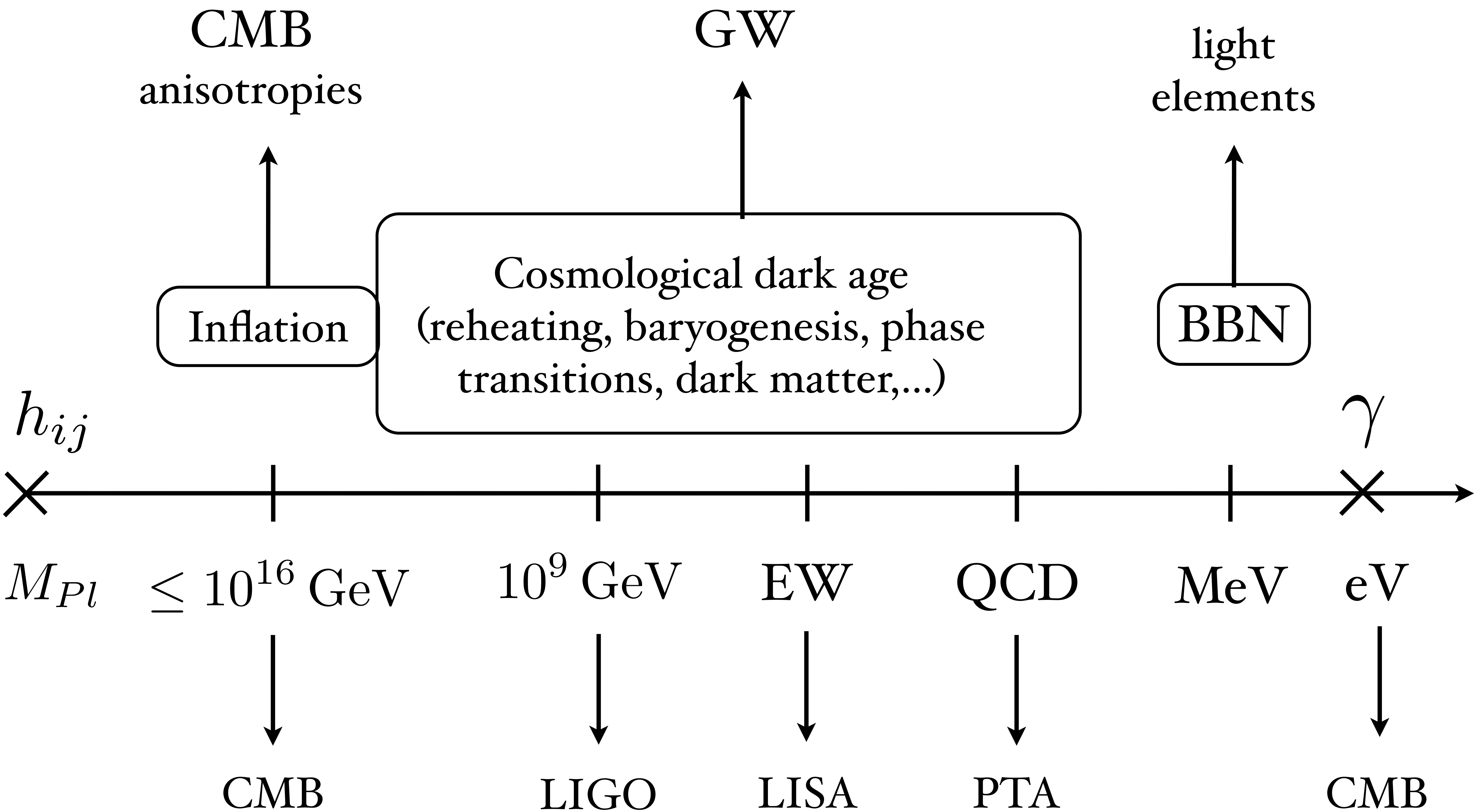
    1. characterise the *spectral shape* with the measurement

    2. characterise all *astrophysical foregrounds*

    3. characterise the *noise of the detector*

- very ambitious task, but in the end *it all depends on the SNR of the SGWB* because of the weakness of the gravitational interaction the universe is transparent to GW

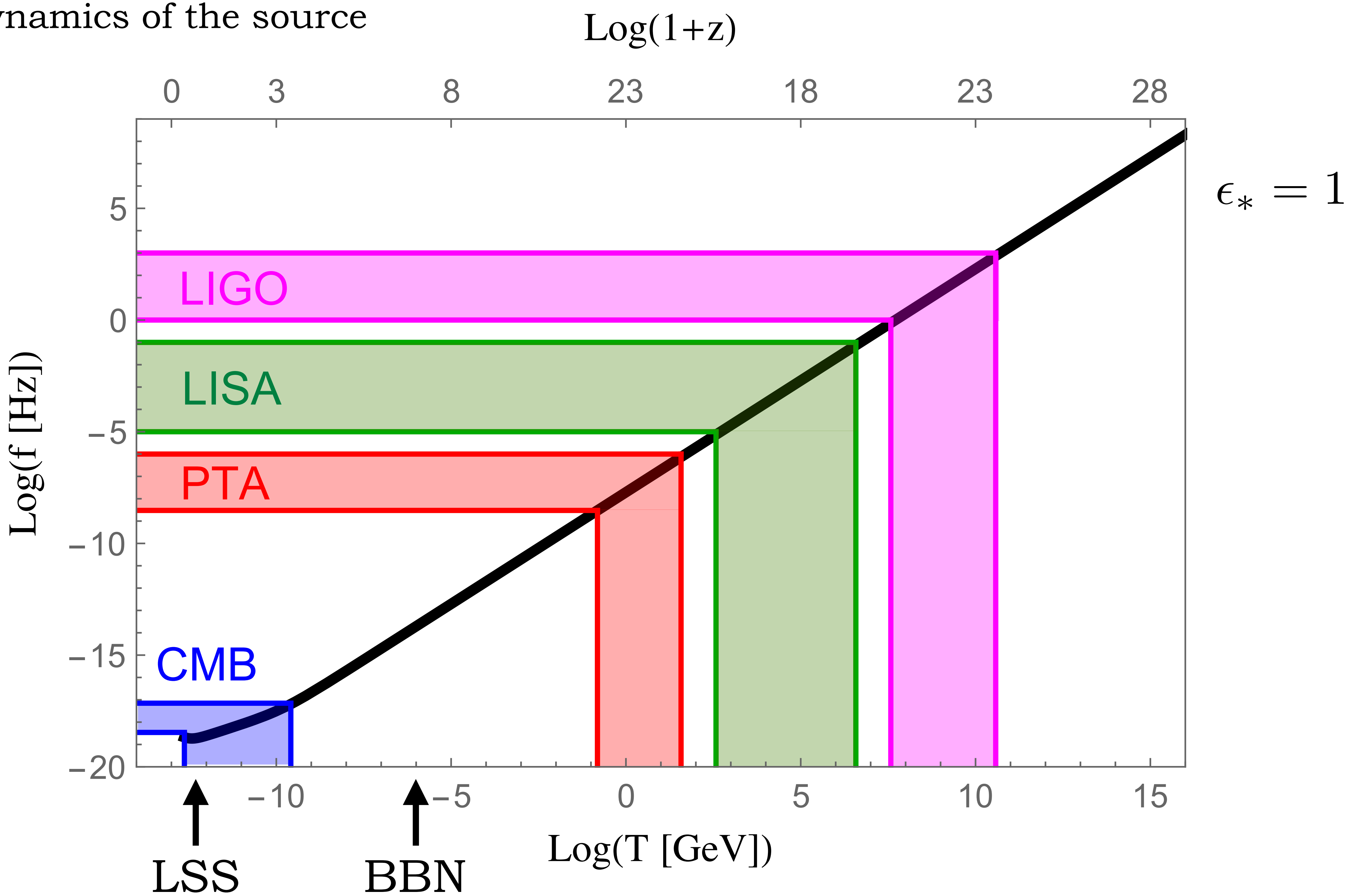
$$\frac{\Gamma(T)}{H(T)} \sim \frac{G^2\,T^5}{T^2/M_{Pl}} \sim \left(\frac{T}{M_{Pl}}\right)^3 < 1$$



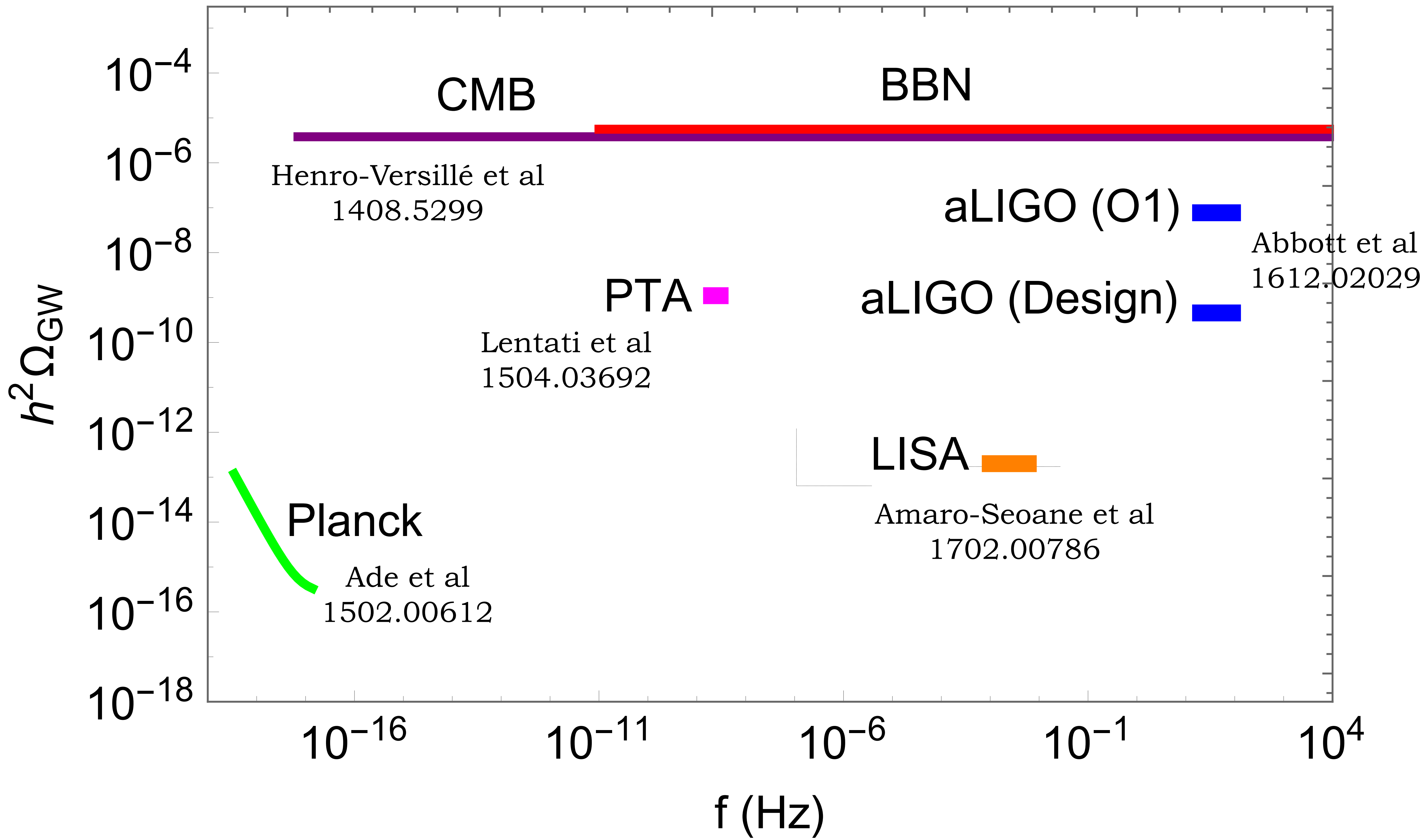
$$f_* = \frac{H(T_*)}{\epsilon_*}$$

parameter depending on the dynamics of the source

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

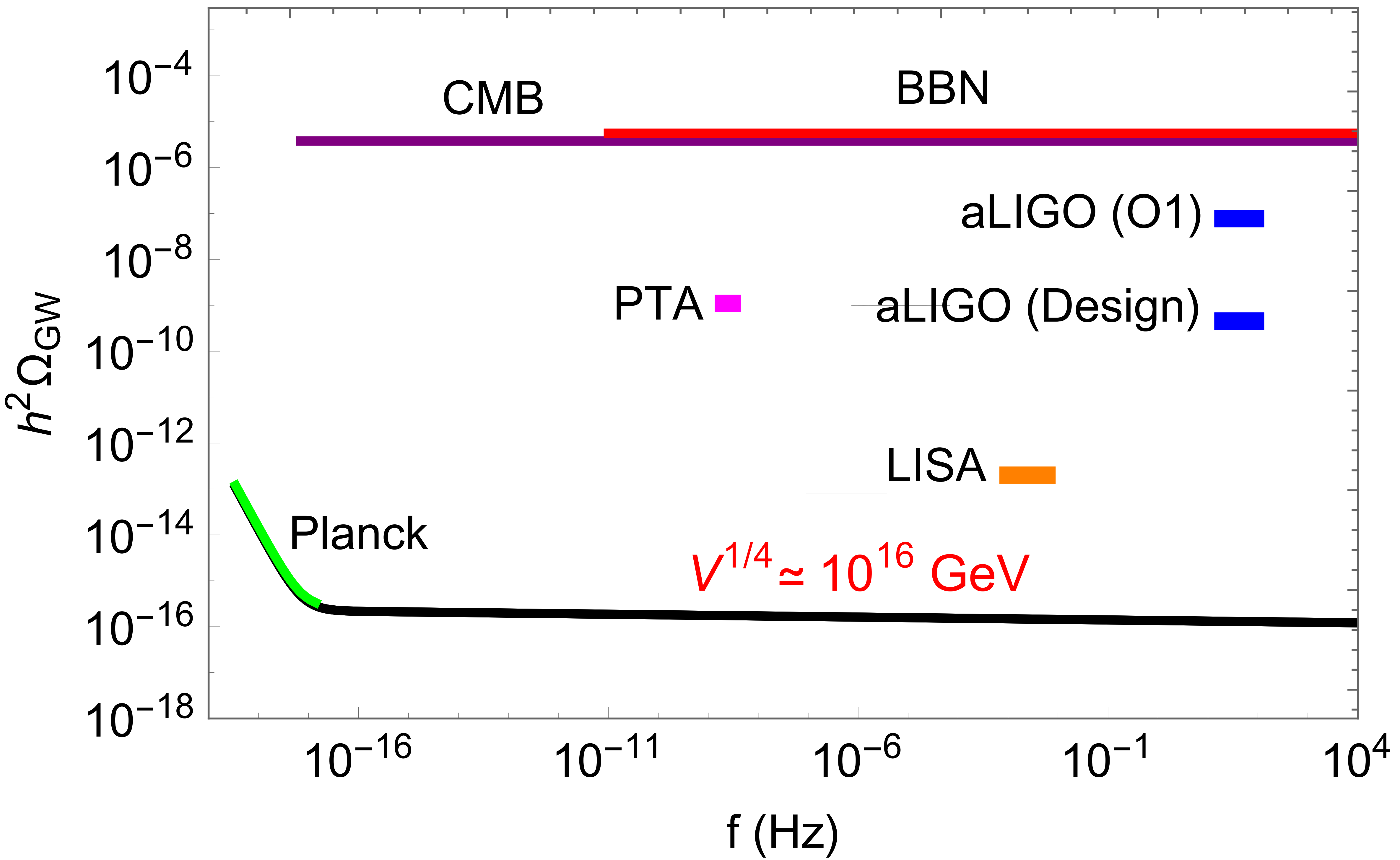


Observational bounds/sensitivities for GWSB



Observational bounds/sensitivities for GWSB

signal from a *simple slow roll inflation model* :
beyond the reach of direct detection

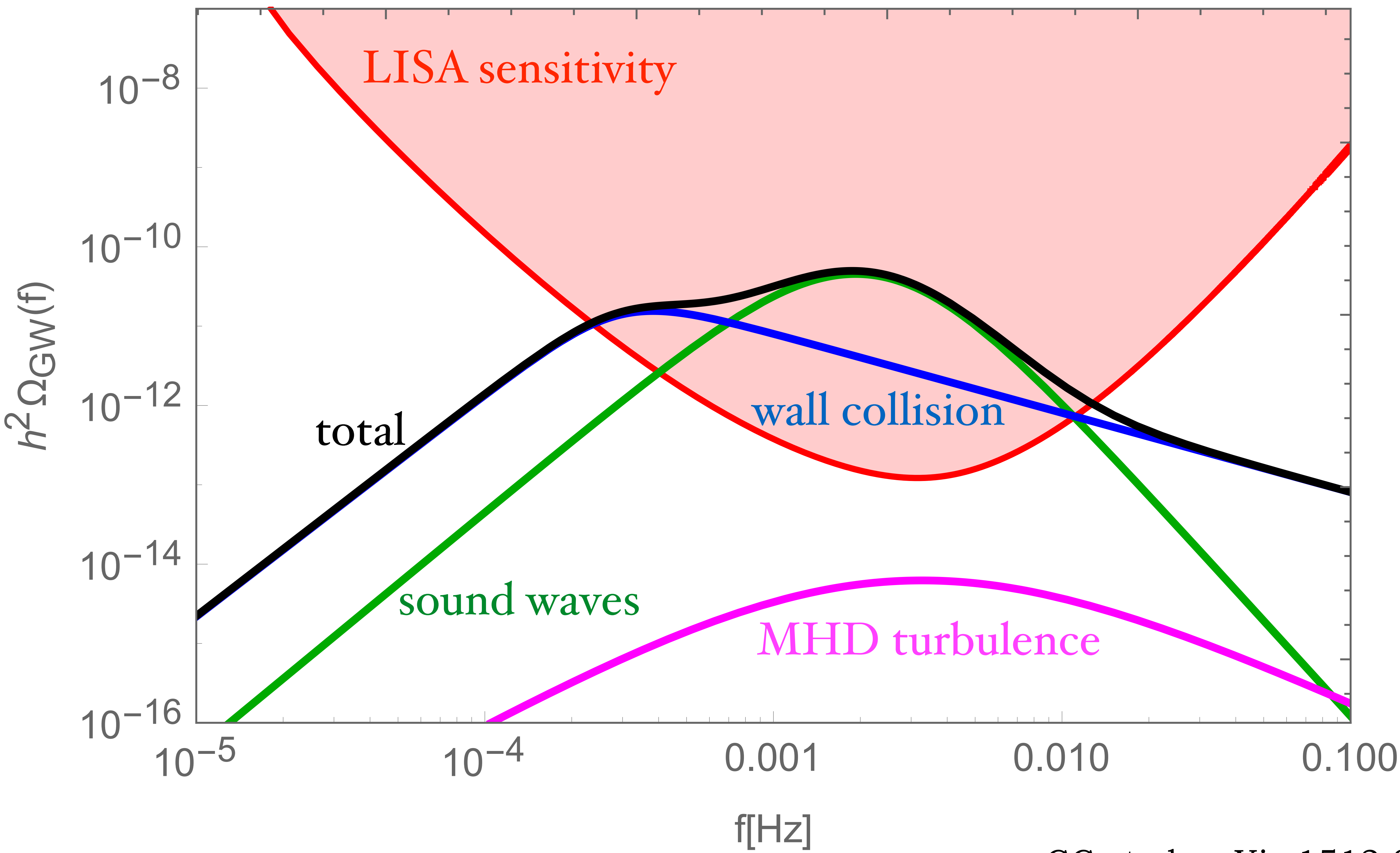


other possible sources of GW in the early universe more promising for direct detection

- “non-standard” inflation
  - particle production during inflation
  - fluid stiffer than radiation after inflation
  - preheating after inflation
  - phase transitions at the end or during inflation
  - …
- first order phase transitions
- cosmic strings
- other topological defects e.g. domain walls
- primordial black holes
- scalar field self-ordering
- …

First order phase transitions: example of signal

note the very peculiar peak structure



CC et al, arXiv:1512.06239

Detection prospects for LISA

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

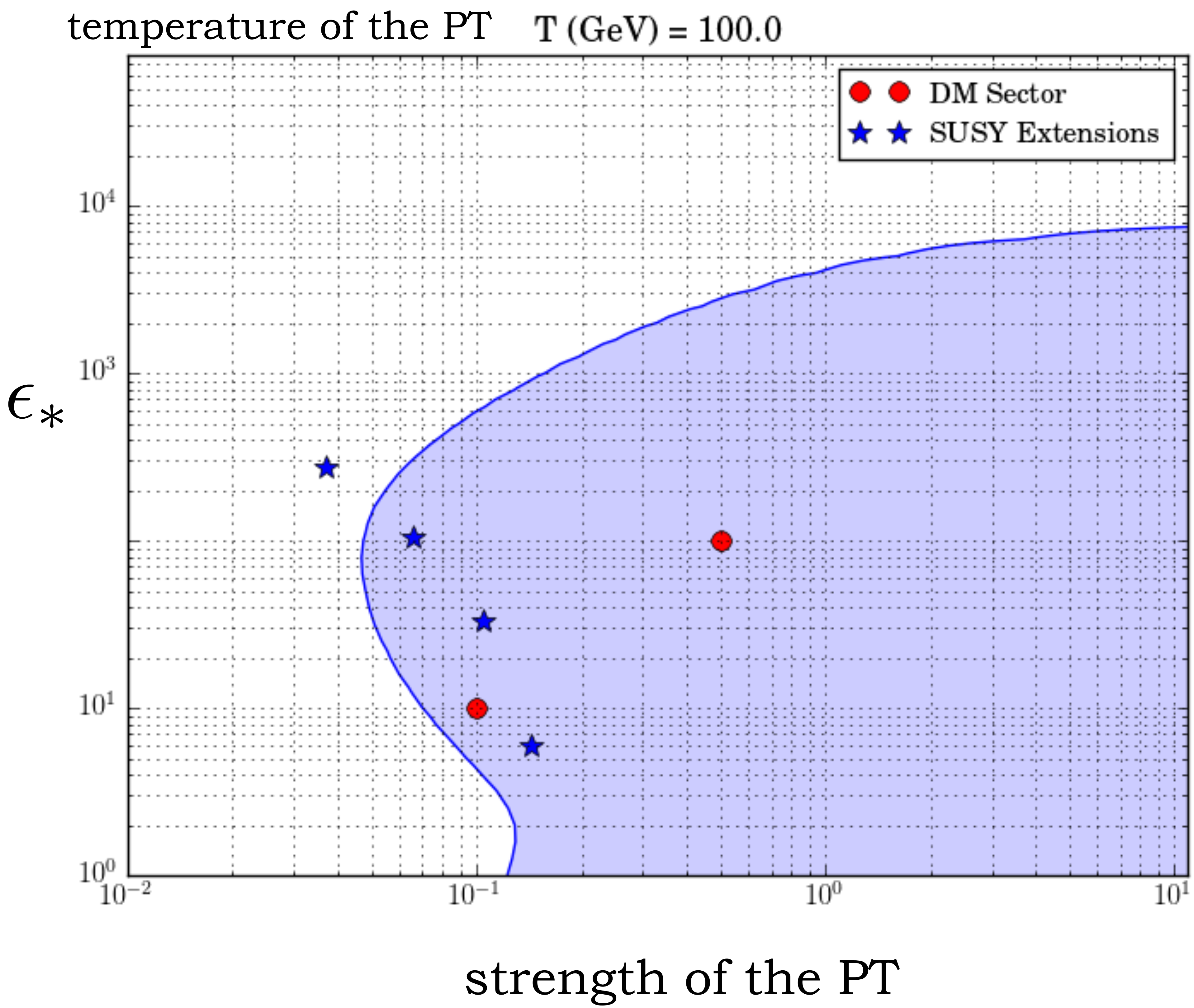
- LISA can probe the EWPT in BSM models …
  - singlet extensions of MSSM (Huber et al 2015)
  - direct coupling of Higgs sector with scalars (Kozackuz et al 2013)
  - SM plus dimension six operator (Grojean et al 2004)

- … and beyond the EWPT
  - Dark Matter sector : provides DM candidate and confining PT (Schwaller 2015)
  - Warped extra dimensions : PT from the dilaton/radion stabilisation in RS-like models (Randall and Servant 2015)

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

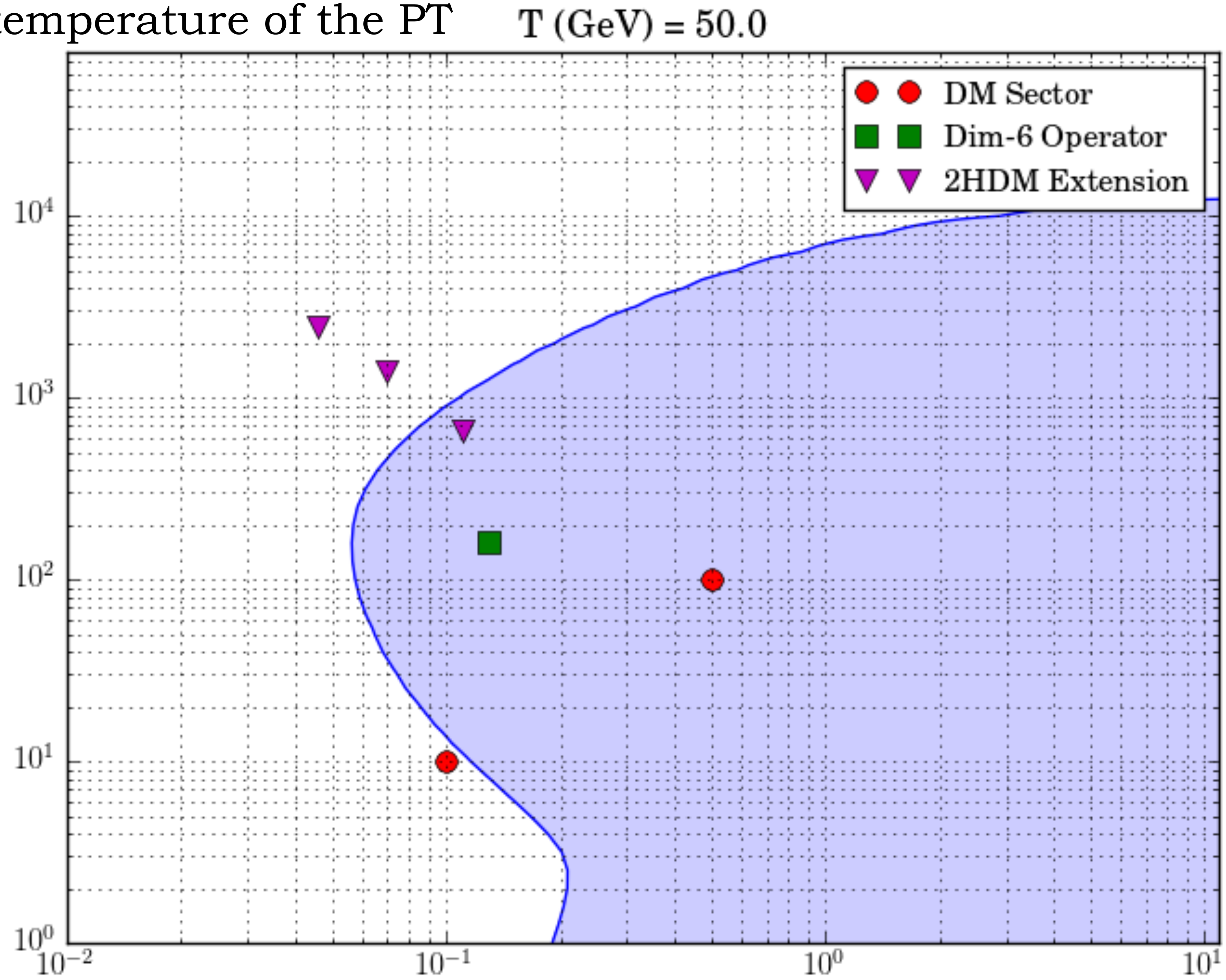
CC et al, arXiv:1512.06239

Example of detection prospects for LISA for EWPT: access to BSM physics!



Example of detection prospects for LISA for EWPT: access to BSM physics!

temperature of the PT

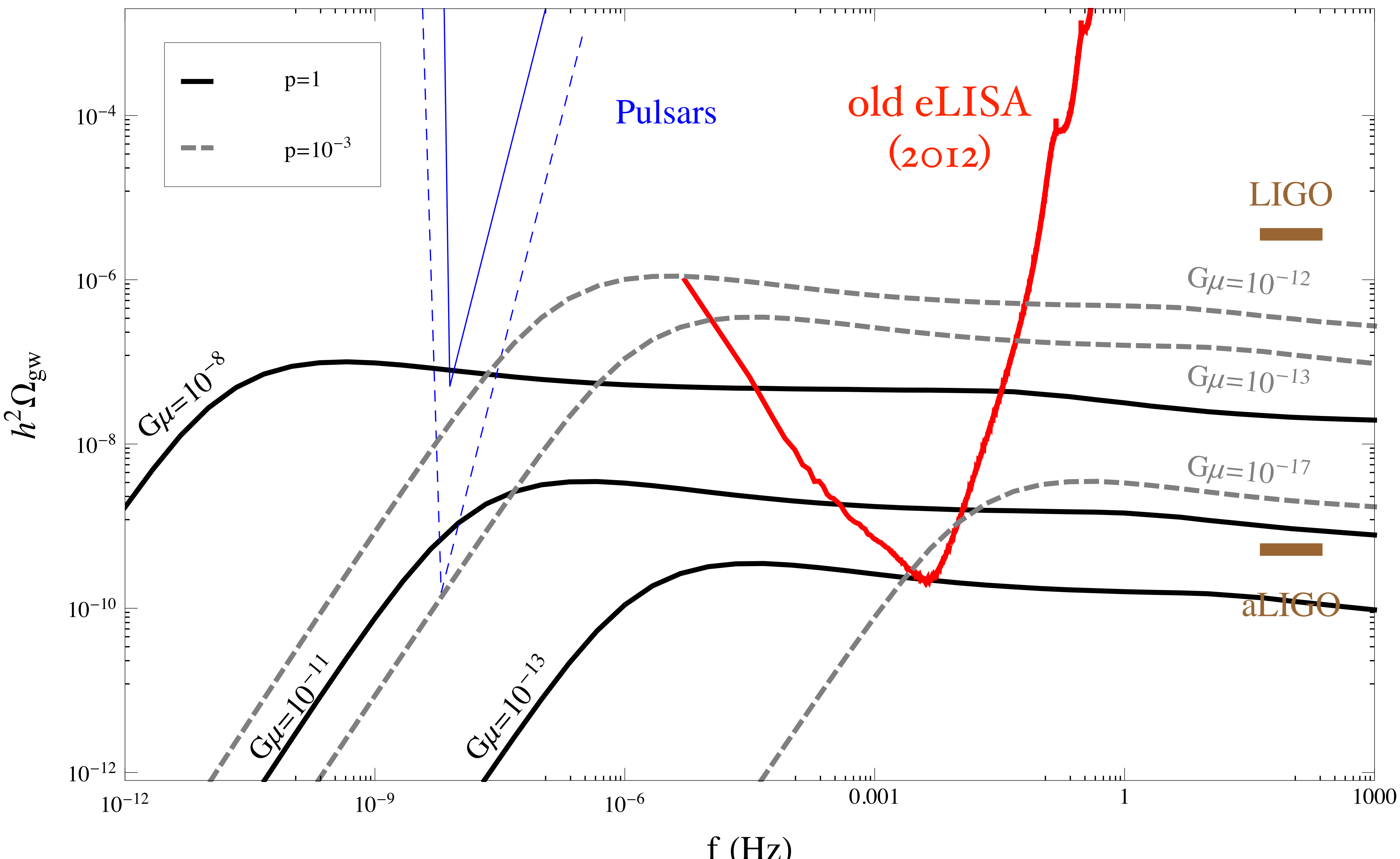


ϵ_*

strength of the PT

Nambu-Goto strings

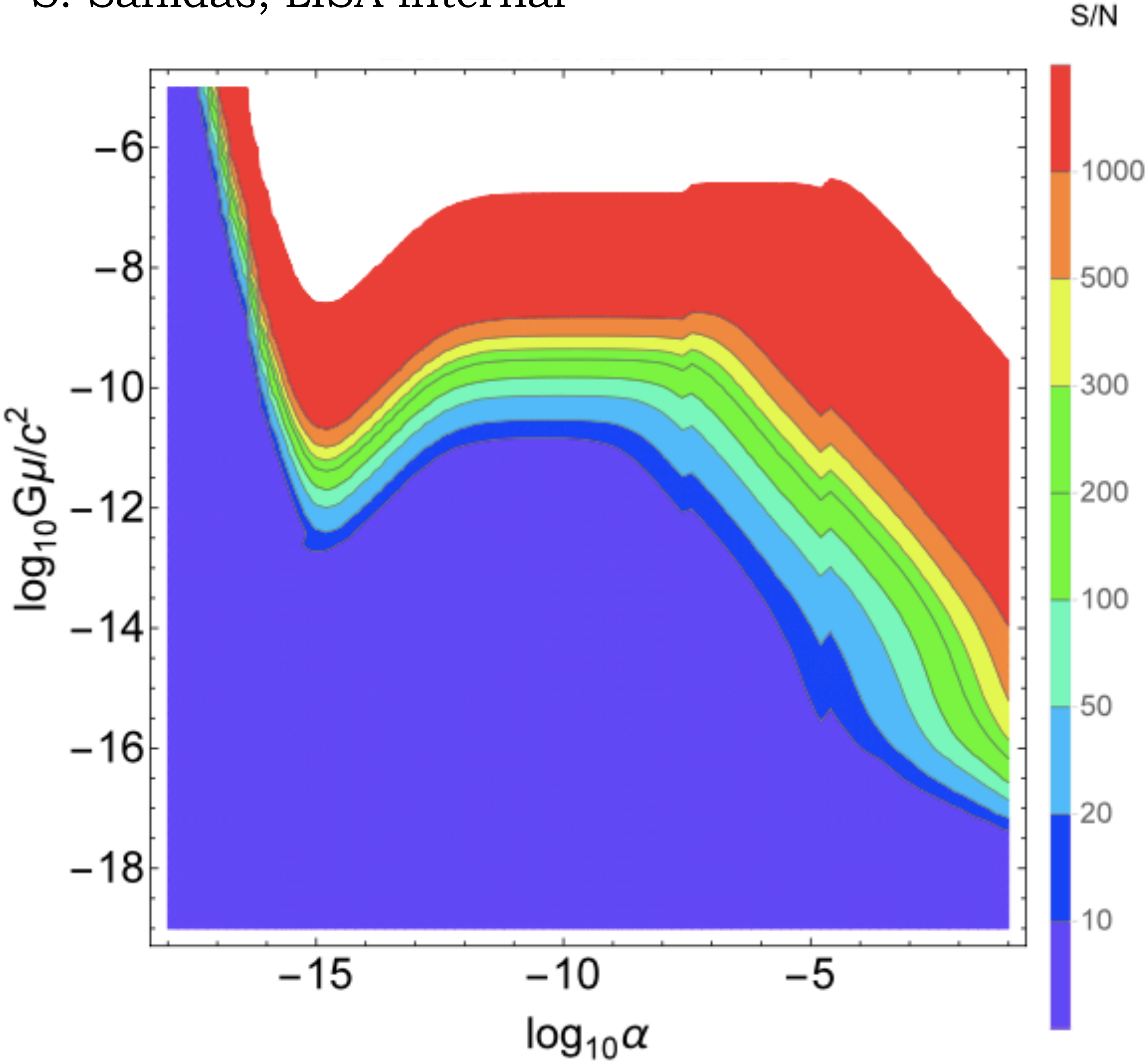
- model dependent GW signal : here large loops
- spectral shape extended in frequency because of continuous production



Binetruy et al 2012

Bounds on Nambu-Goto strings, loop size

S. Sanidas, LISA internal



Current NanoGRAV

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

future CMB B-modes

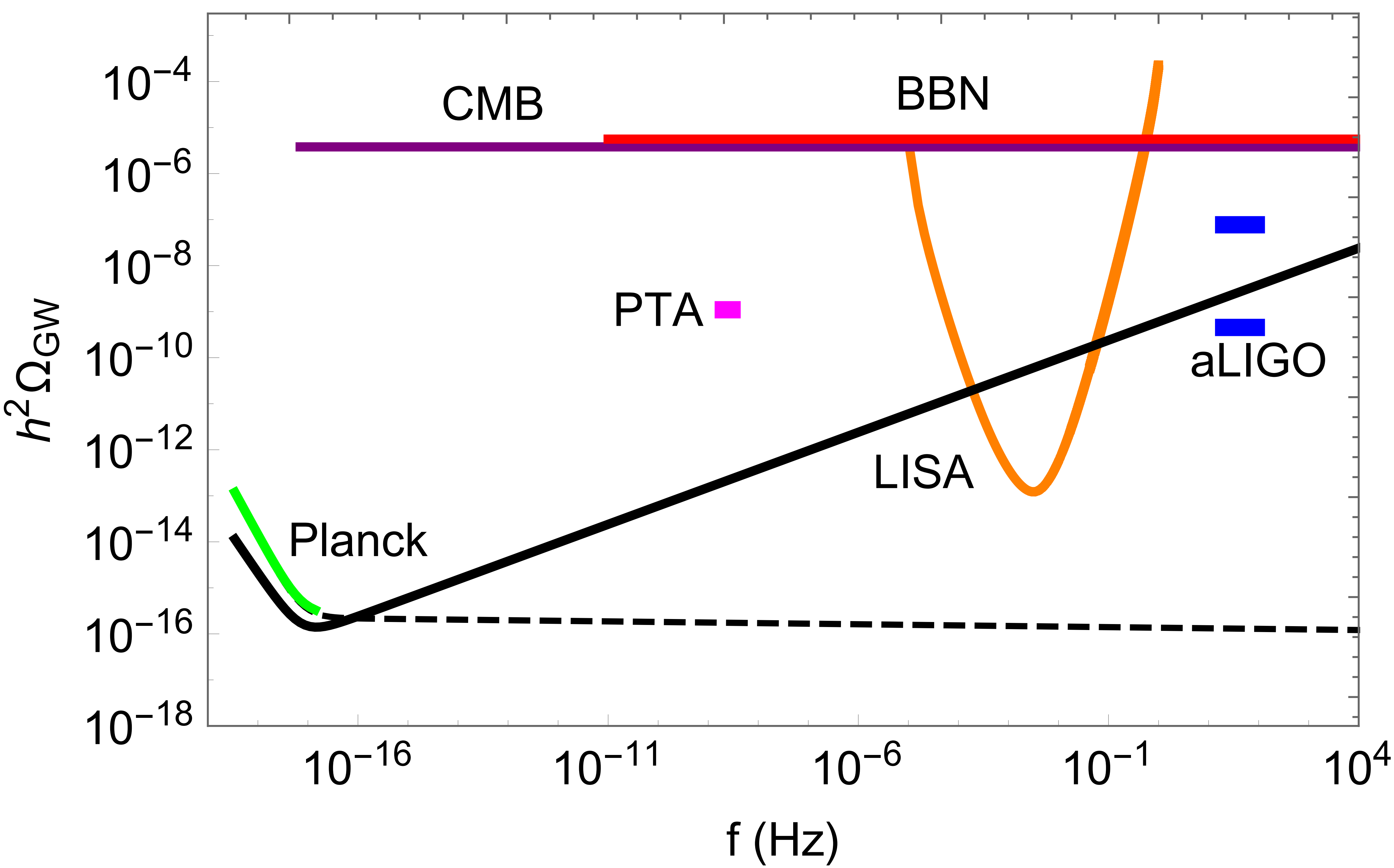
$$G\mu < 10^{-9}$$

Future SKA

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

Janssen et al 2015

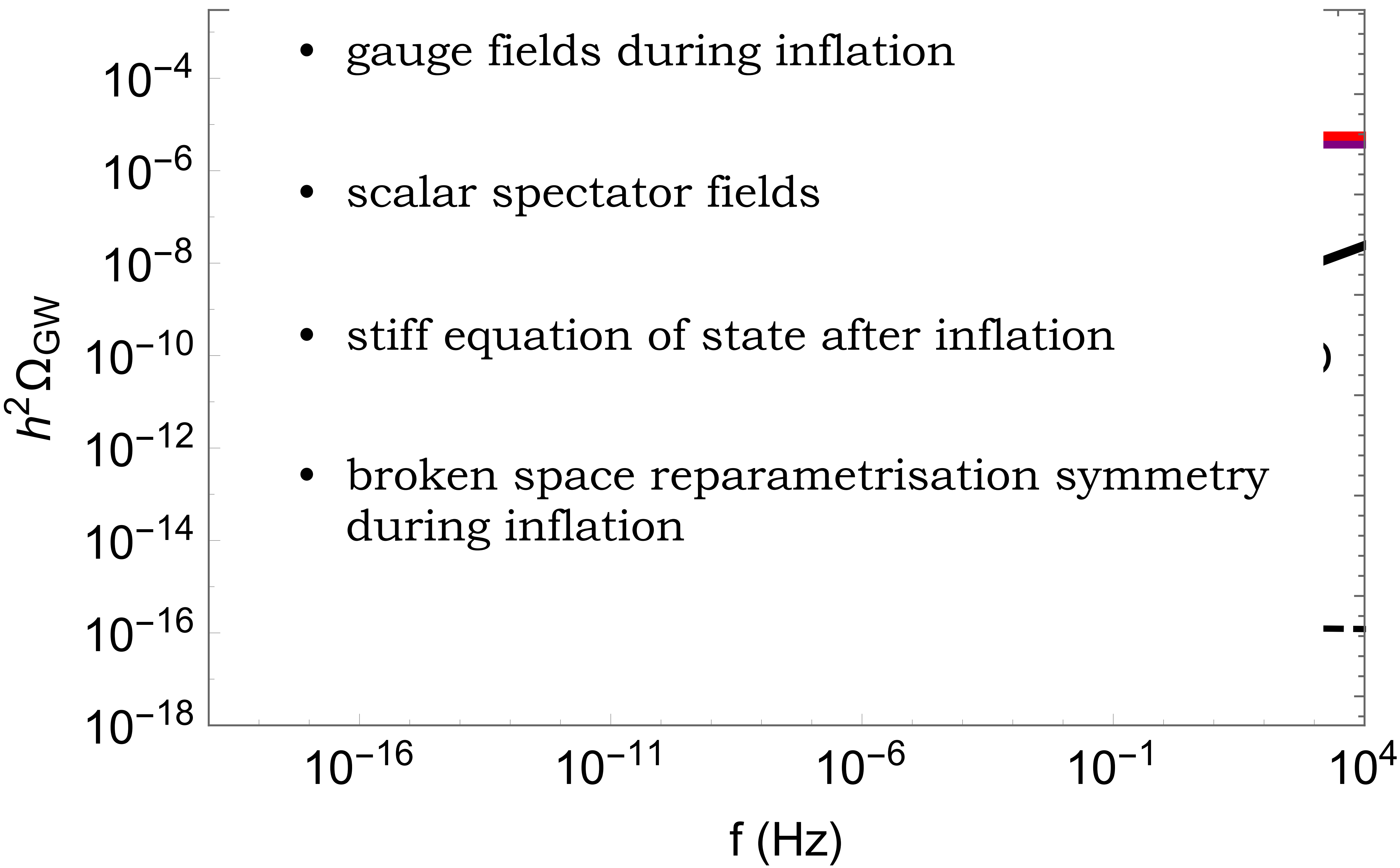
“Non-standard inflation”



“Non-standard inflation”

N. Bartolo et al, 1610.06481

- gauge fields during inflation
- scalar spectator fields
- stiff equation of state after inflation
- broken space reparametrisation symmetry during inflation



"Non-standard inflation"

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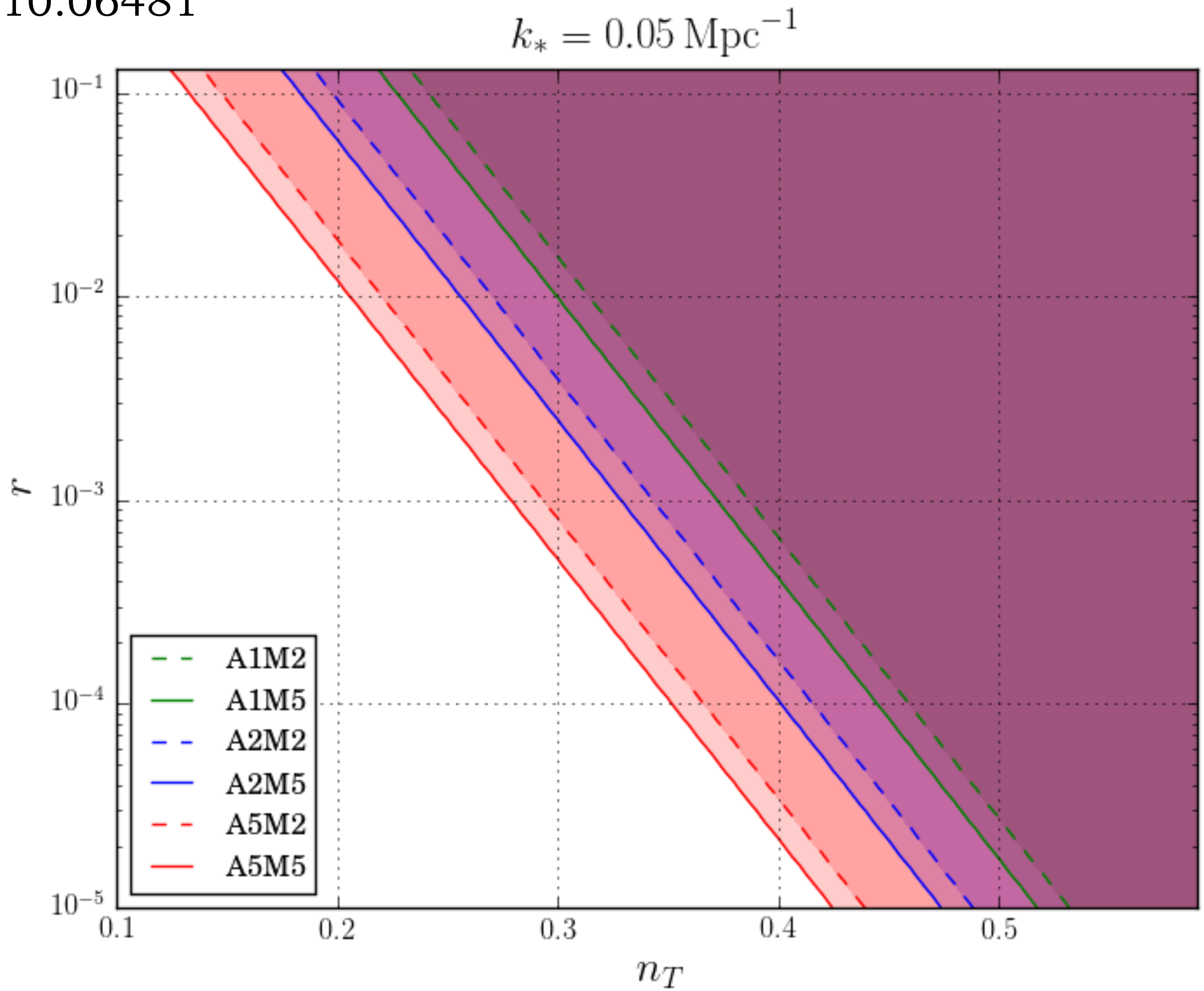


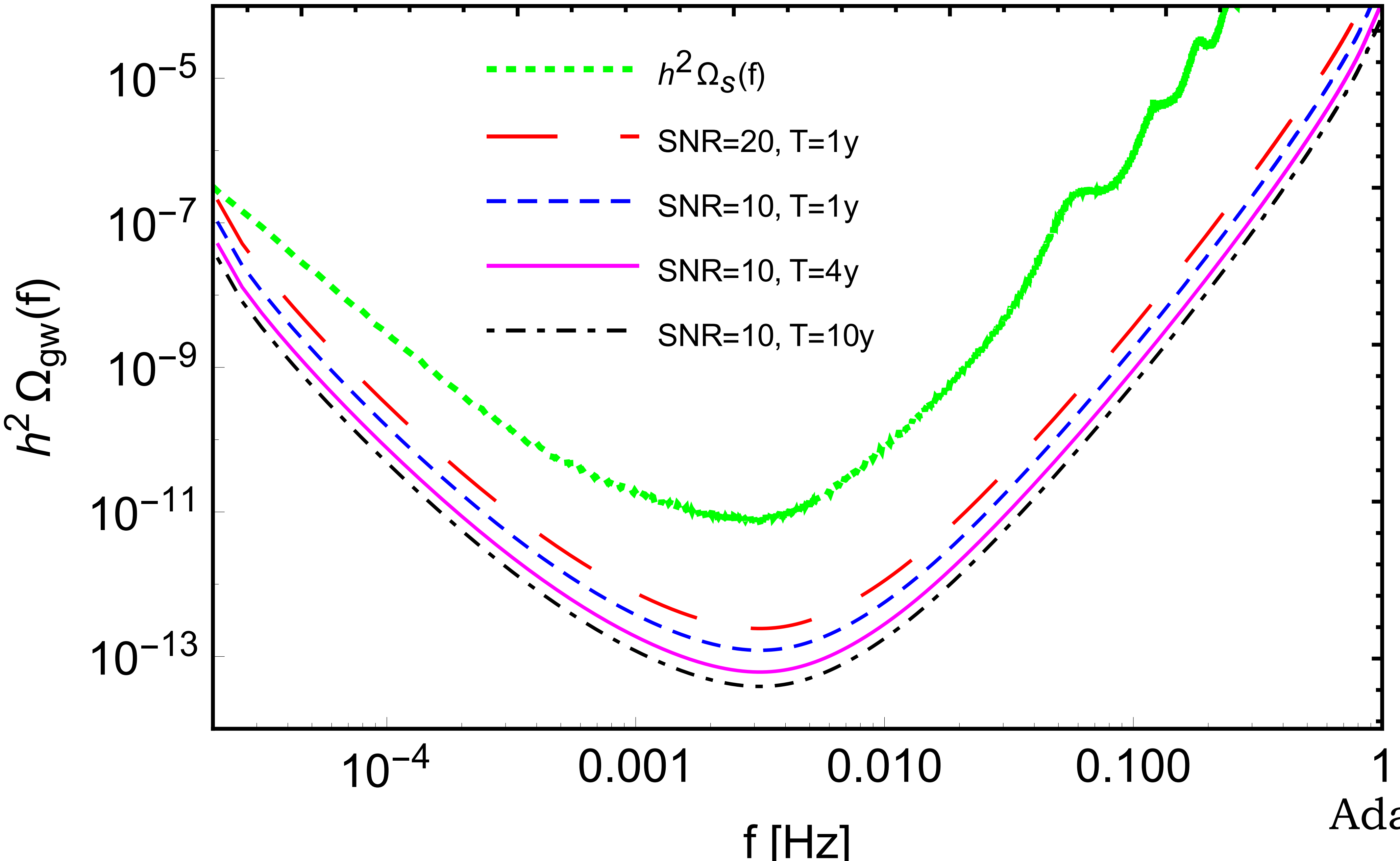
tensor to scalar ratio

tensor spectral index

Requirements for SGWB detection with LISA

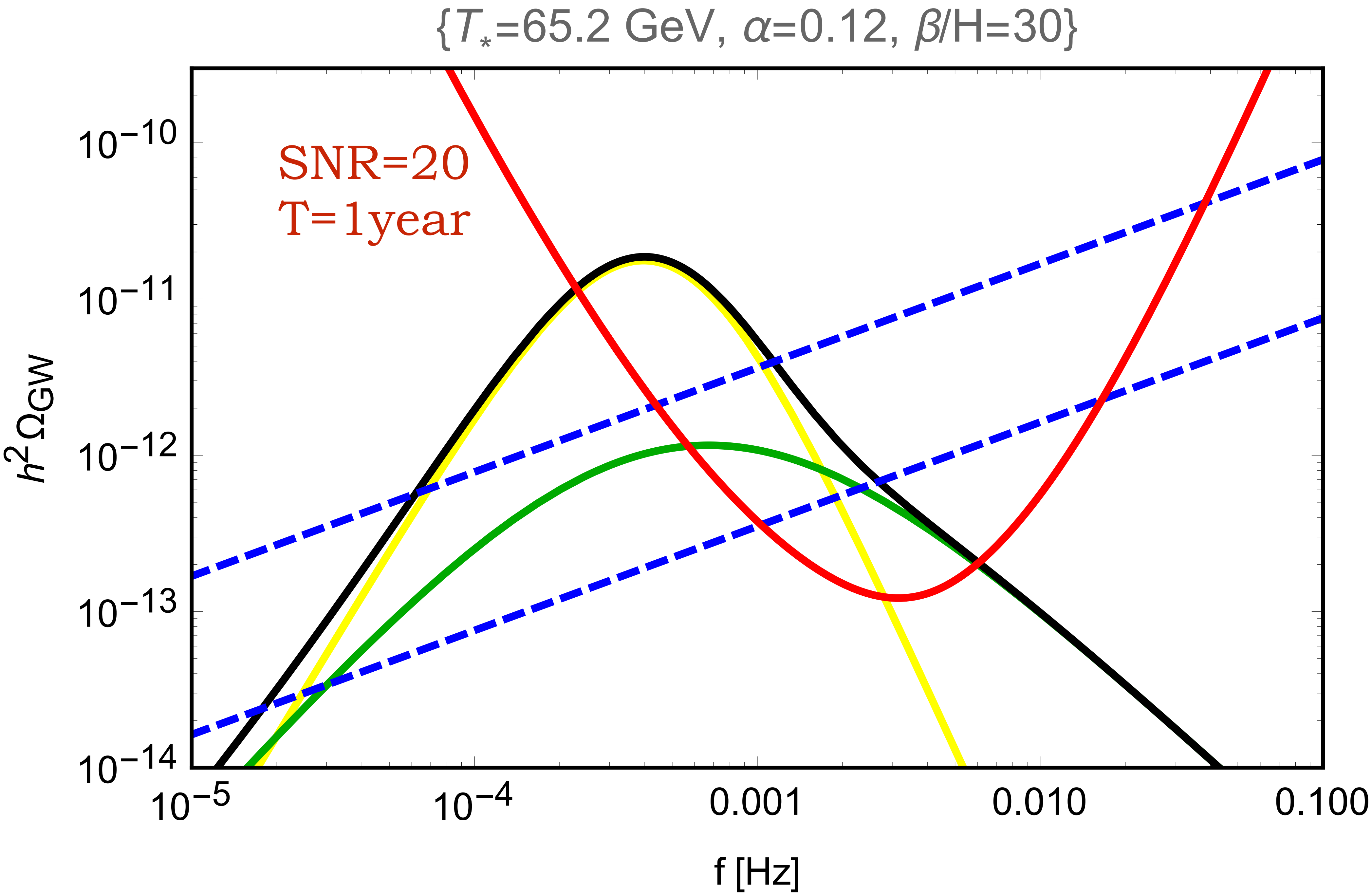
Thrane and Romano
arXiv:1310.5300

POWER LAW SENSITIVITY:
sensitivity to a <u>single power law</u> background
given the duration of the observation and a threshold SNR



Adams and Cornish
arXiv:1307.4116

Example of signal + foreground



GW150914-like BHB in the LISA band

Abbott et al, 1606.04856

$$\Omega_{\rm GW}(f) = 1.2^{+1.9}_{-0.9} \times 10^{-9} \left(\frac{f}{25\,{\rm Hz}}\right)^{2/3}$$

One power law is clearly not enough!

PLS in frequency bins
or adapting depending on the signal
(work in progress with G. Nardini and A. Petiteau)