Primordial GW in Modified Gravity & Cosmology

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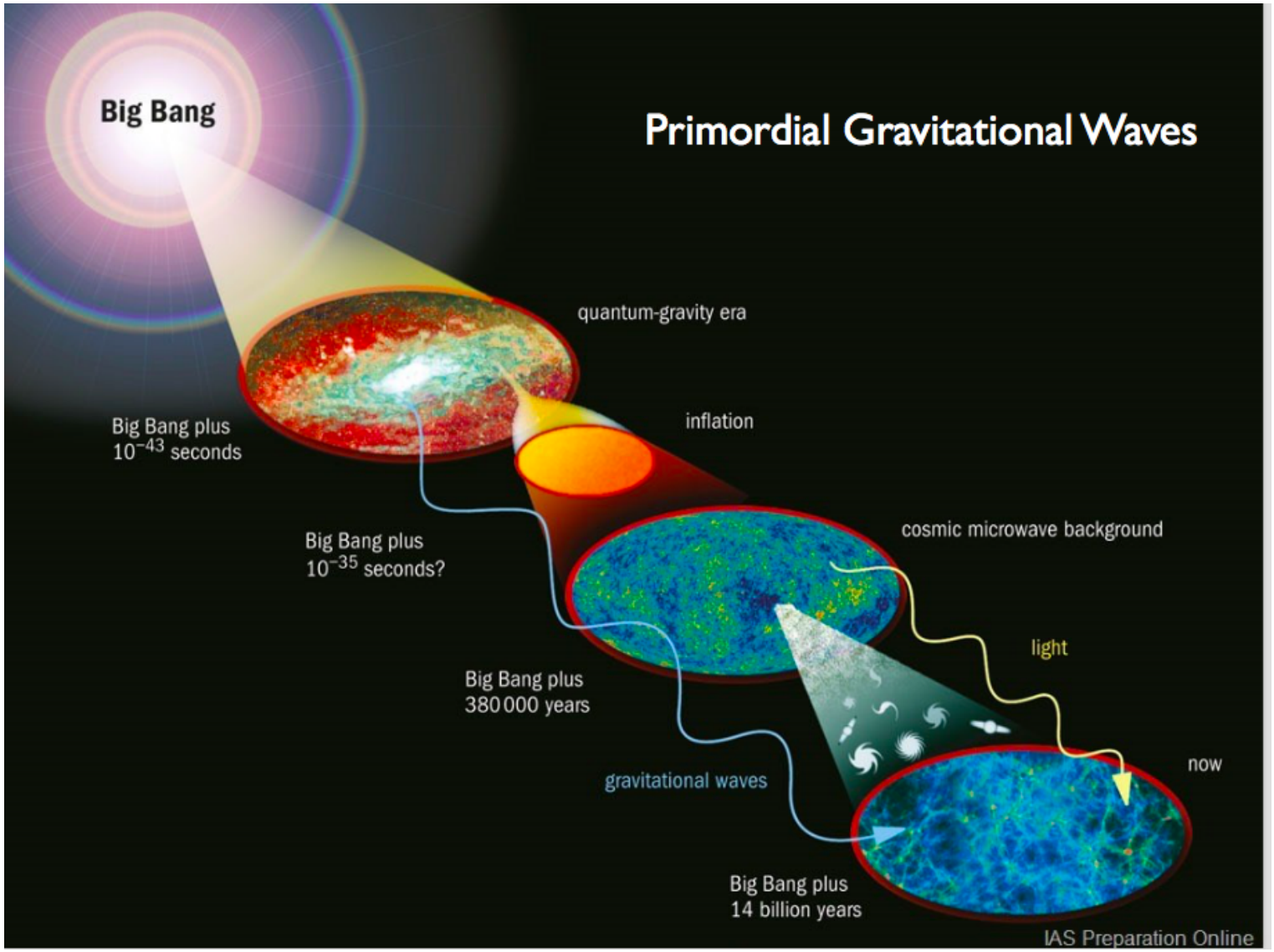
Based on -
arXiv: 1905.10410
arXiv: 1911.xxxxx

History of the Universe



The idea: Naively

Propagation of Primordial GW generated during Inflation:

$$\ddot{h}_{ij} + 3H\,\dot{h}_{ij} + \frac{k^2}{a^2} h_{ij} = 16\pi\, G\, \Pi_{ij}^{TT}\,, \tag{1}$$

Solution:

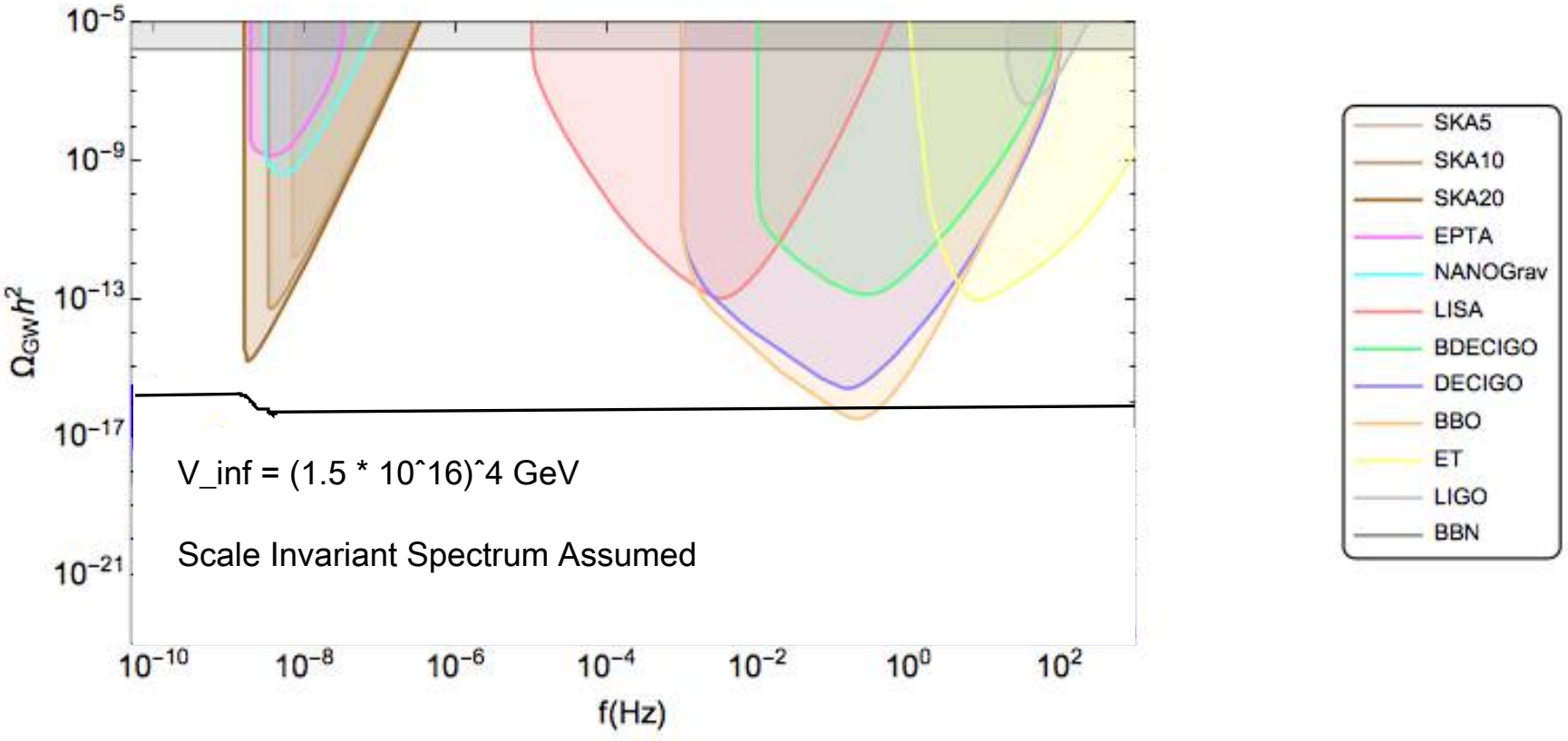
$$h_{ij}(t,\vec{x}) = \sum_P \int \frac{d^3k}{(2\pi)^3}\, h^P(t,\vec{k})\, \epsilon_{ij}^P(\vec{k})\, e^{i\,\vec{k}\cdot\vec{x}}, \tag{2}$$

$$h_{\vec{k}}^P = h_{\vec{k},\,0}^P\, U(t,k)\,, \tag{3}$$

$$\Pi_{ij} = \frac{T_{ij} - p\, g_{ij}}{a^2} \tag{4}$$

$$\Omega_{GW}(\eta,k) = \frac{1}{12\, a^2(\eta)\, H^2(\eta)} \mathcal{P}_T(k)\, \left[U'(\eta,\, k)\right]^2 \tag{5}$$

On the GW sensitivity Map



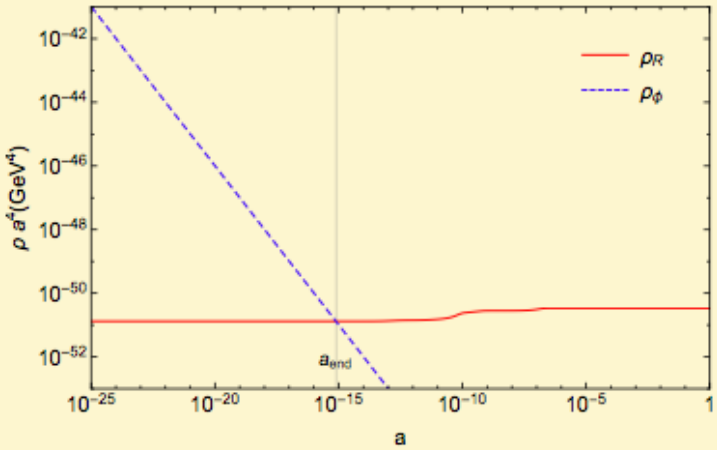
Non-standard Cosmology

- History of the Universe before BBN is unknown.
- Non-standard cosmology predicts scalar field ϕ and its energy density dominates in the Early Universe.
- Its Equation-of-state ω_ϕ.
- Modifies the Hubble expansion: $H^2 \propto \rho_\phi$.
- Parameter $\xi = \frac{\rho_\phi}{\rho_R}$.

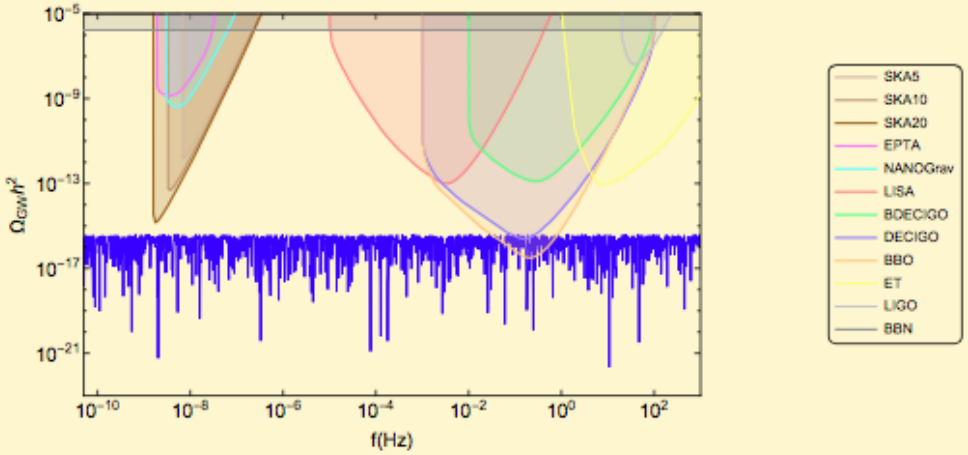
On the GW sensitivity Map

$$\omega_\phi = 1/3, \xi = 10^{25}$$

Radiation domination like scenario



$$T_{\rm dec} = 10\ MeV$$

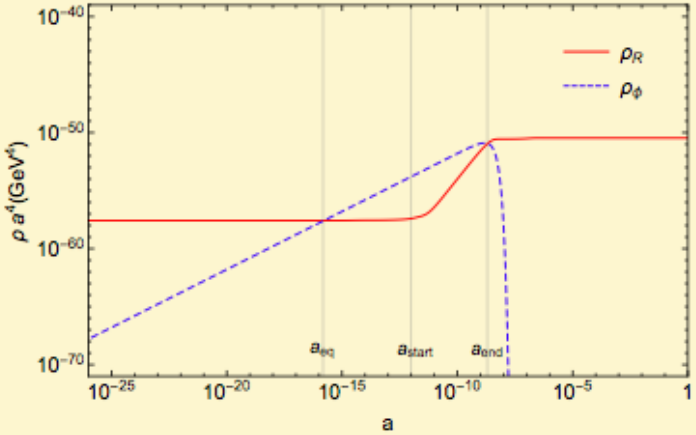


[Fazollah, GGI, Florence 2019]

On the GW sensitivity Map

$$\omega_\phi = 0, \xi = 10^{-11}$$

Modulus or matter domination like scenario



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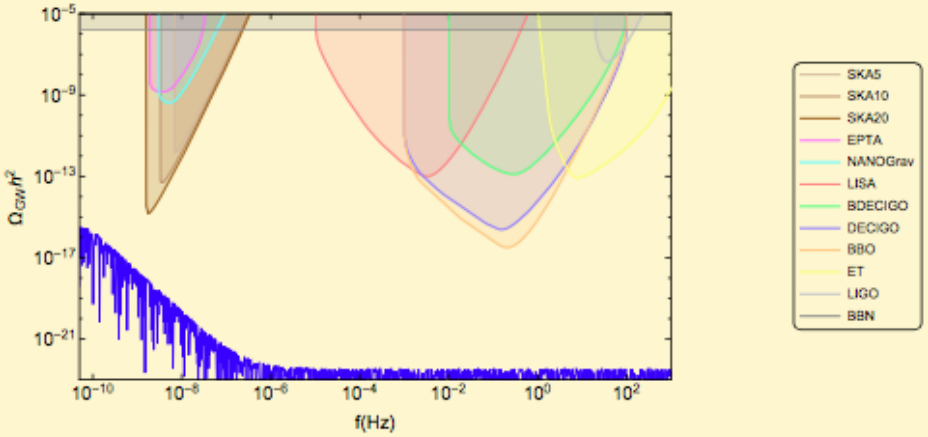
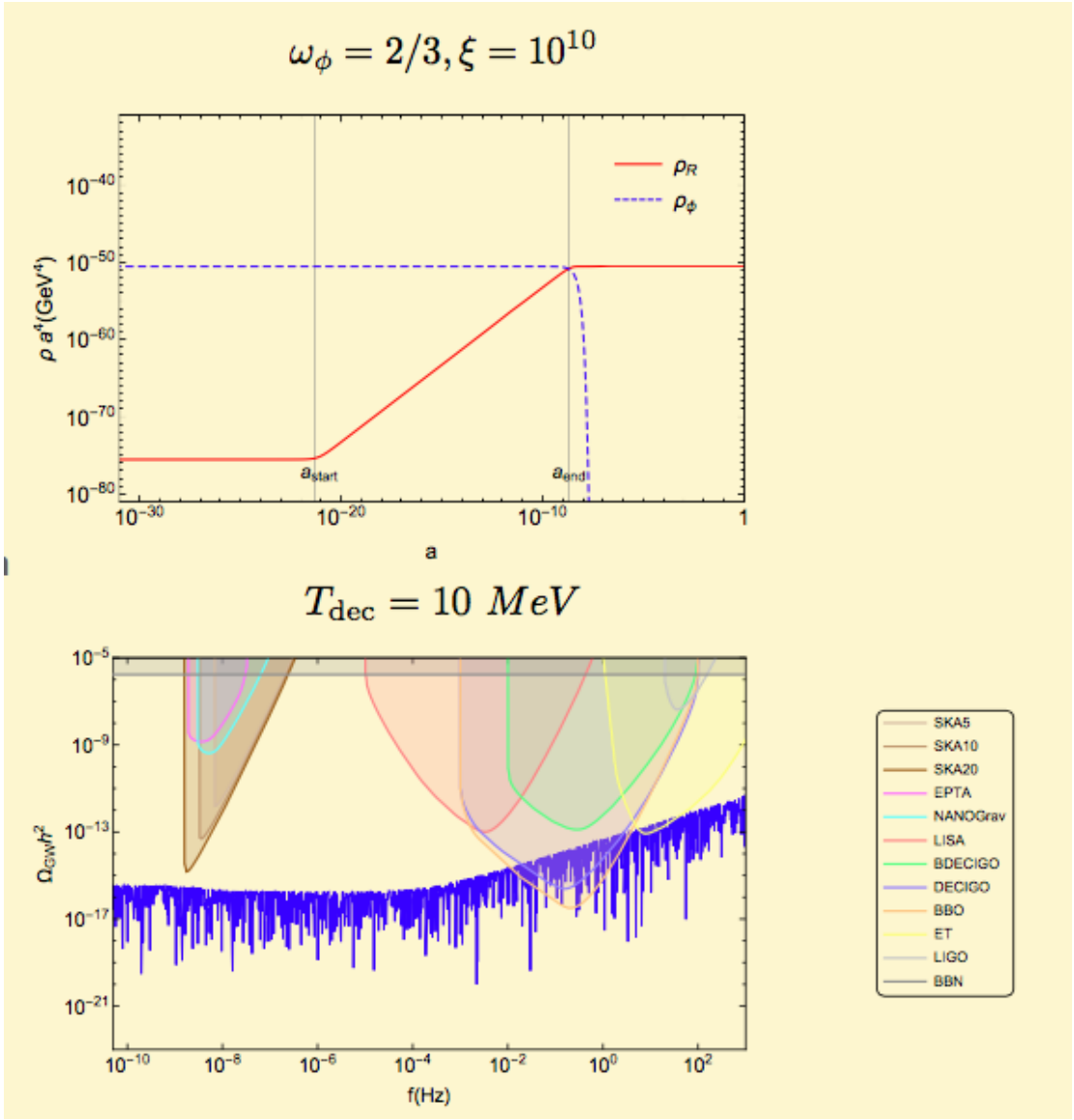


[Fazollah, GGI, Florence 2019]

On the GW sensitivity Map



[Fazollah, GGI, Florence 2019]

Modified Gravity

- Modify cosmological expansion (motivated from modified gravity theories)

$$H_{MC}(T) = A(T) H_{GR}(T)\,, \tag{6}$$

- Strategy:

$$A(T) = 1 + \eta \left(\frac{T}{T_*}\right)^{\nu}\,, \tag{7}$$

where T_* is a parameter with dimensions of the temperature, and $\{\eta, \nu\}$ are free parameters.

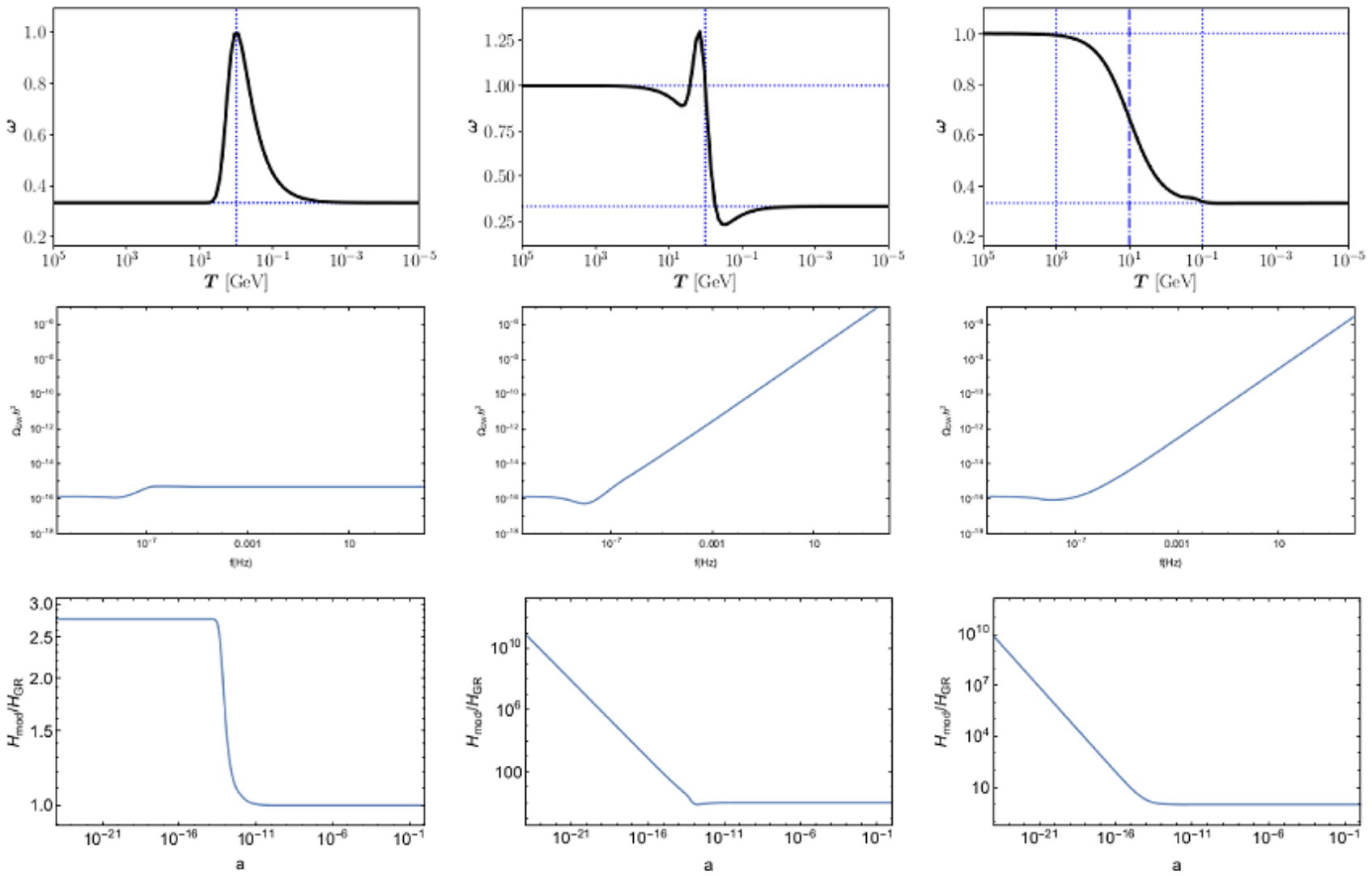
$$A(T) = \begin{cases} 1 + \eta \left(\frac{T}{T_*}\right)^{\nu} \tanh \frac{T - T_{re}}{T_{re}} & \text{for} \quad T > T_{BBN} \\ 1 & \text{for} \quad T \leq T_{BBN} \end{cases} \tag{8}$$

- ν labels cosmological models:
  1. $\nu = 2$ in Randall-Sundrum type II brane cosmology, $\nu = 1$ in kination models,
  2. $\nu = 0$ in cosmologies with an overall boost of the Hubble expansion rate like in the case of a large number of additional relativistic degrees of freedom in the thermal plasma
  3. $\nu = -1$ in scalar-tensor cosmology,
  4. $\nu = 2/n - 2$ in $f(x)$ cosmology, with $f(x) = x + \alpha x^n$, with $x = R, \mathcal{T}$ where R and $\mathcal{T}$ stand for the scalar curvature and the scalar torsion, respectively.

On the GW sensitivity Map

Some Preliminary results only -

η = 1, v = 0, T= 1 GeV η = 1,v = 1, T = 1 GeV η = 100, v = 1,T =1k GeV



CONCLUSION:

Probe of Modified Cosmological Expansion History in Early Universe !

On the GW sensitivity Map

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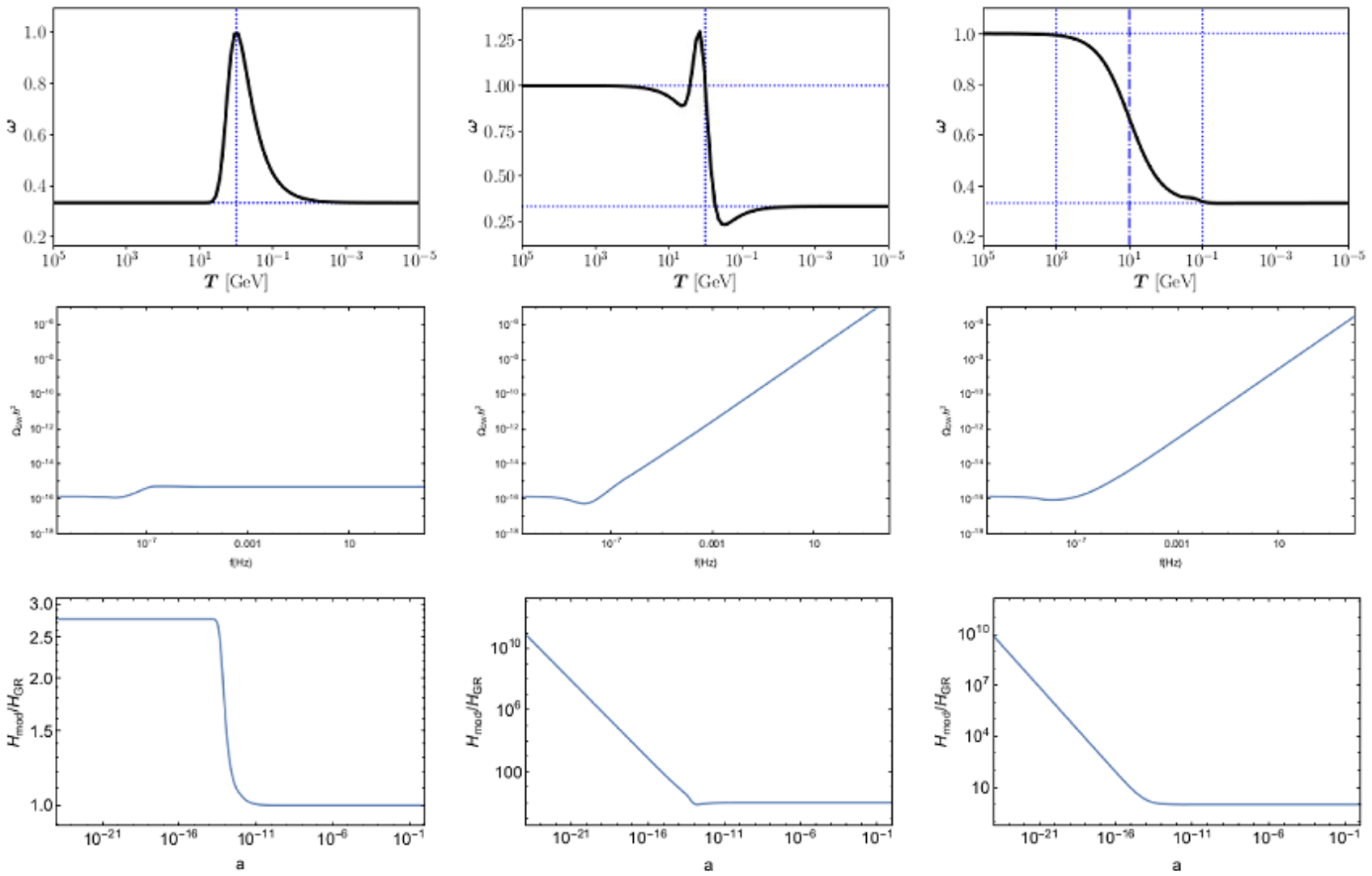

Thank You