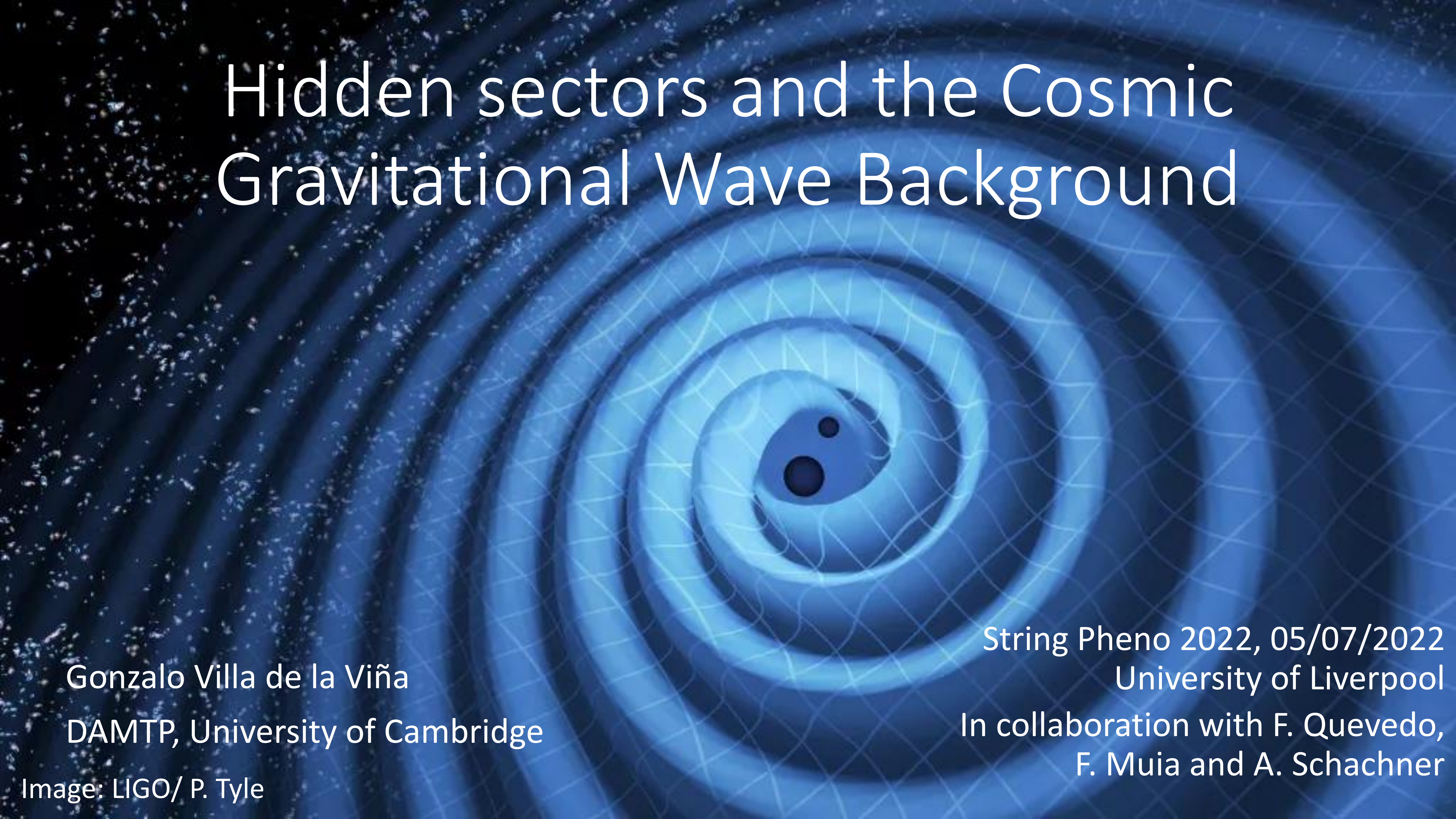


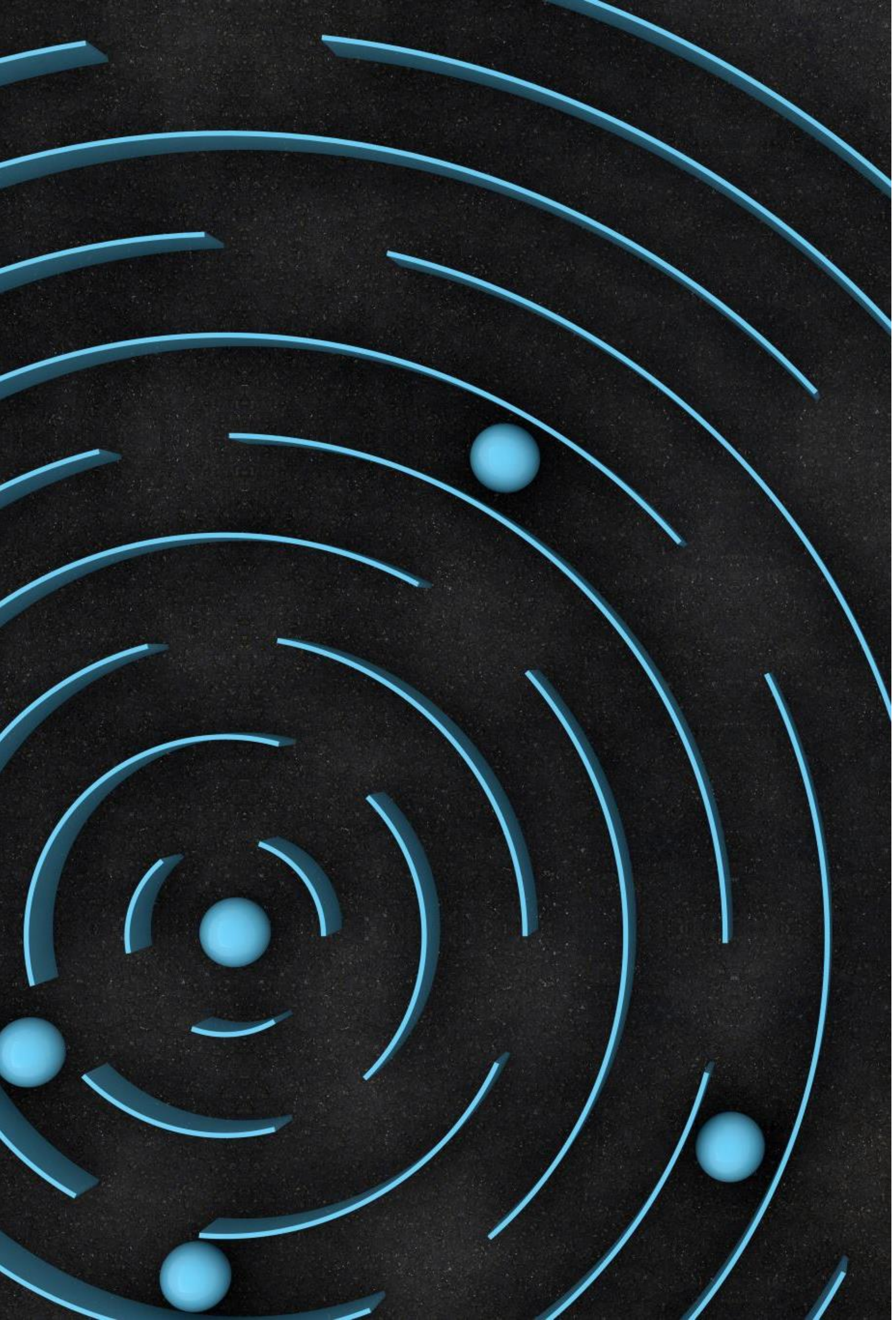
Hidden sectors and the Cosmic Gravitational Wave Background

String Pheno 2022, 05/07/2022
University of Liverpool

Gonzalo Villa de la Viña
DAMTP, University of Cambridge

In collaboration with F. Quevedo, F. Muia and A. Schachner

Image: LIGO/ P. Tyle



Outline

- GW vs EM astronomy
- Stochastic GW backgrounds
- The Cosmic GW Background
- New Physics

GW vs EM astronomy

- Newborns are <u>noisy</u>
- Teenagers emit <u>EM signals</u>
- The Universe is similar!

Stochastic backgrounds

Caprini, Figueroa '18

- A stochastic background of GWs consists in a superposition of uncorrelated signals.
- It is characterized by the fractional energy density:

$$\Omega = \frac{1}{\rho_c}\frac{d\rho}{d\log k}$$

$$\rho = \frac{M_p^2}{4}\langle \dot{h}_{ij}\dot{h}_{ij}\rangle$$

Cosmological GW backgrounds are always stochastic!

The Physics of the CGWB

- The Early Universe plasma is known to have emitted GWs. How?
- Consider again the EM analogy:

Ghiglieri, Laine '18

EM:

$$\frac{\mathrm{d}\Gamma_\gamma(\mathbf{k})}{\mathrm{d}^3\mathbf{k}} = \frac{1}{(2\pi)^3 2k} \sum_\lambda \epsilon^{(\lambda)}_{\mu,\mathbf{k}} \epsilon^{(\lambda)*}_{\nu,\mathbf{k}} \int_{\mathcal{X}} e^{i\mathcal{K}\cdot\mathcal{X}} \langle J^\mu_{\mathrm{em}}(0) J^\nu_{\mathrm{em}}(\mathcal{X}) \rangle$$

Gravity:

$$\frac{\mathrm{d}\rho_{\mathrm{GW}}}{\mathrm{d}t\, \mathrm{d}^3\mathbf{k}} = \frac{4\pi G}{(2\pi)^3} \sum_\lambda \epsilon^{\mathrm{TT}(\lambda)}_{ij,\mathbf{k}} \epsilon^{\mathrm{TT}(\lambda)*}_{mn,\mathbf{k}} \int_{\mathcal{X}} e^{i\mathcal{K}\cdot\mathcal{X}} \langle T^{ij}(0)\, T^{mn}(\mathcal{X}) \rangle$$

GW production

Ghiglieri *et al* ´20
Ringwald *et al* ‘21

- The leading contribution is:

$$\eta \sim \mathcal{N}\hat{m}^2 \frac{\hat{k}}{e^{\hat{k}}-1} \log\left(1+\frac{4\hat{k}^2}{\hat{m}^2}\right)$$

- Where the variables involved are approximately constant:

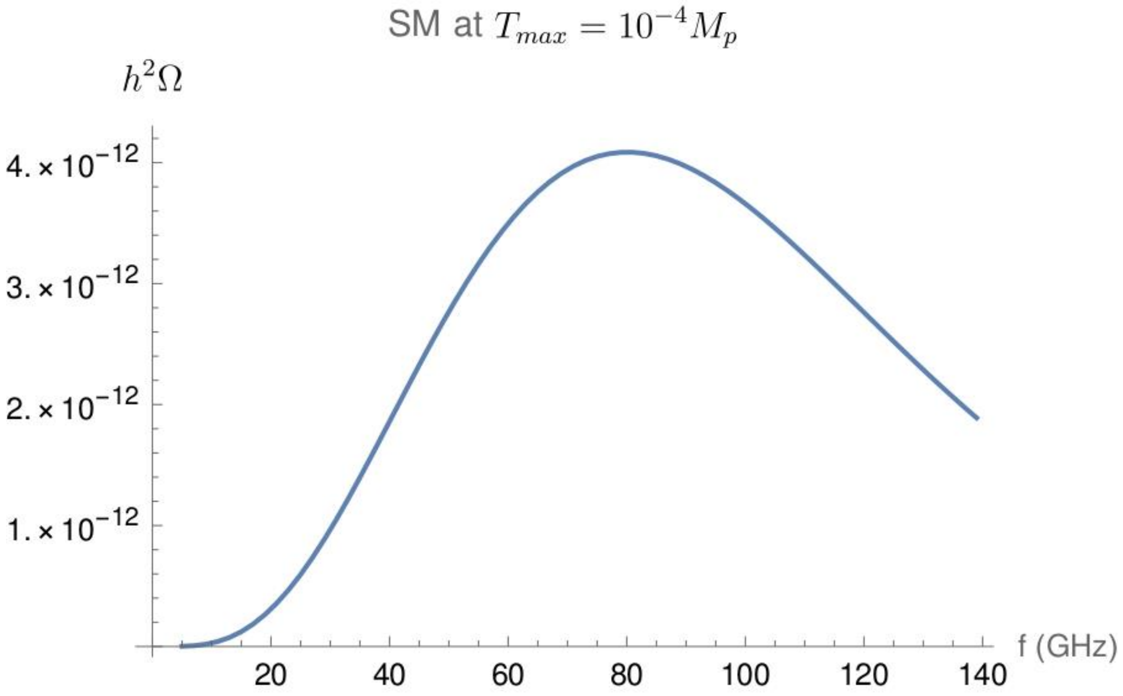
$$\hat{k} = \frac{k}{T} \qquad \hat{m}^2 \sim g^2 \times (\text{field content})$$

- The temperature at a given time fixes the frequency!

Why is the CGWB hiding?

- Its existence does not require new physics, it must be there!
- The amplitude peaks at ultra high frequencies (GHz)

Aggarwal *et al* '21



New Physics in the CGWB

- Hidden sectors are QFTs that only interact gravitationally with the SM. In a Minkowski frame:

$$T_{\mu\nu} = T_{\mu\nu}^{SM} + T_{\mu\nu}^{hidden}$$

↑

Well motivated from IR and UV

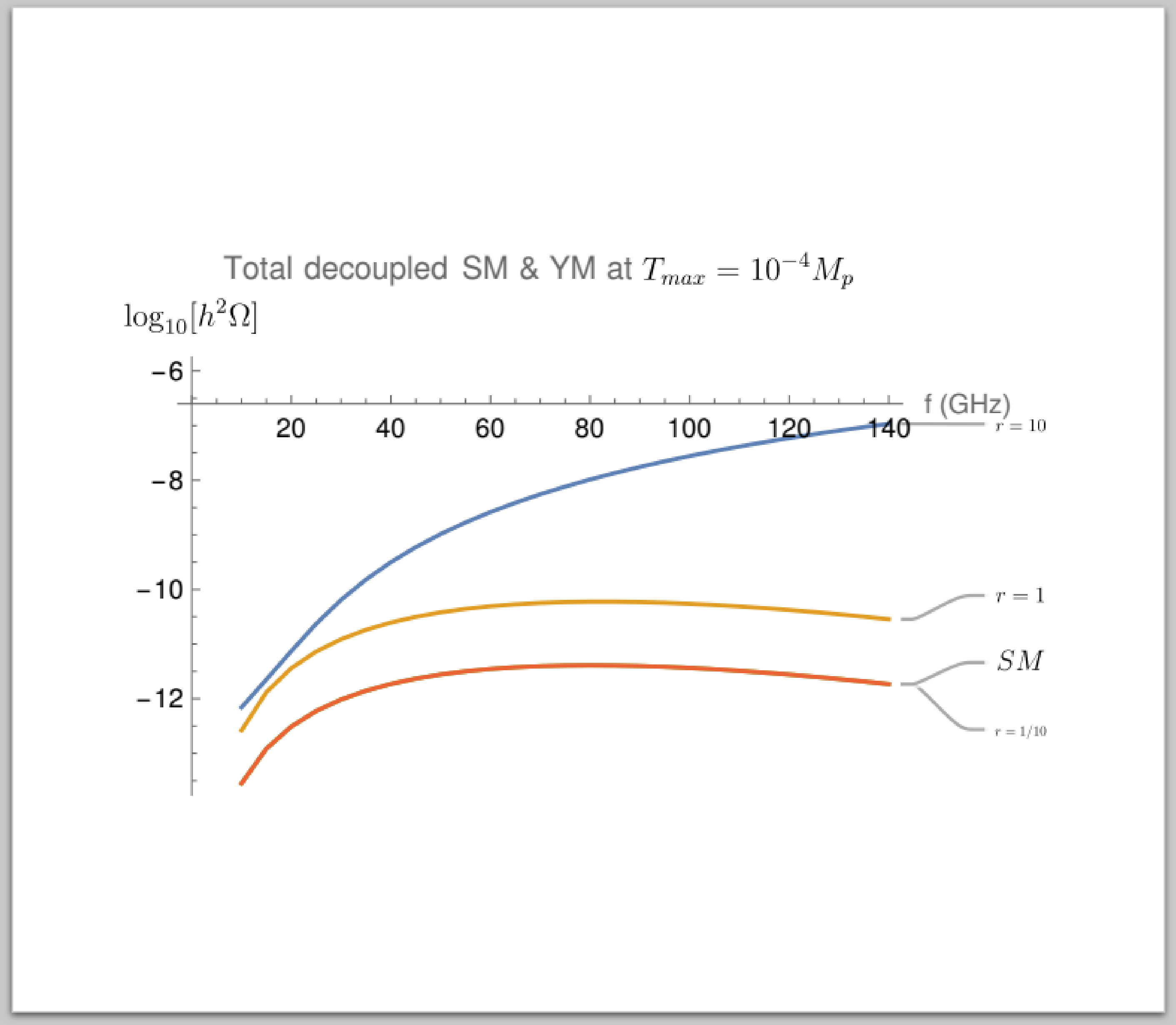
→ Their pressence alters the shape of the CGWB! $\Omega = \Omega_{SM} + \Omega_{hidden}$

Example: different temperatures

- Hidden sectors do not reach thermal equilibrium with the SM.
- They can be at different temperatures.
- Strong dependence on temperature ratio r:

$$f_{peak} \sim r f_{SM,peak}$$

$$\frac{\Omega_{hidden}}{\Omega_{SM}} \sim \frac{r^7}{\sqrt{g_i r^4 + g_{SM}}}$$



The elephant in the room

- Hot hidden sectors are severely constrained by BBN.

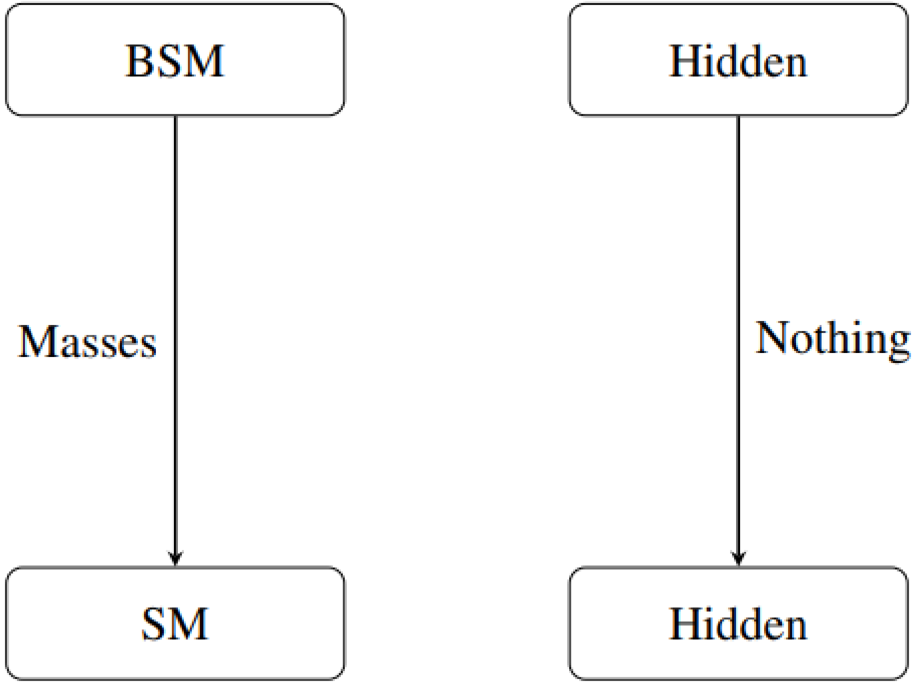
$$\rho = \frac{\pi^2}{30}\left(g_{SM} + r^4 g_h\right) T_{SM}^4$$

- The SM sector must be the hottest <u>at this time</u>.

Remember the baby?

$$T_{SM} = \frac{T_h}{r}$$

$$T_{SM} = \left(\frac{g_{BSM}}{g_{SM}}\right)^{1/3} \frac{T_h}{r}$$



Conclusions

GW astronomy can probe energies larger than telescopes/colliders.

Cosmological backgrounds peak at high frequencies.

The CGWB is ensured to be there.

Measuring a deviance from the SM prediction is a signal of BSM Physics.