Gravitational waves from cosmic strings with friction

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Plan

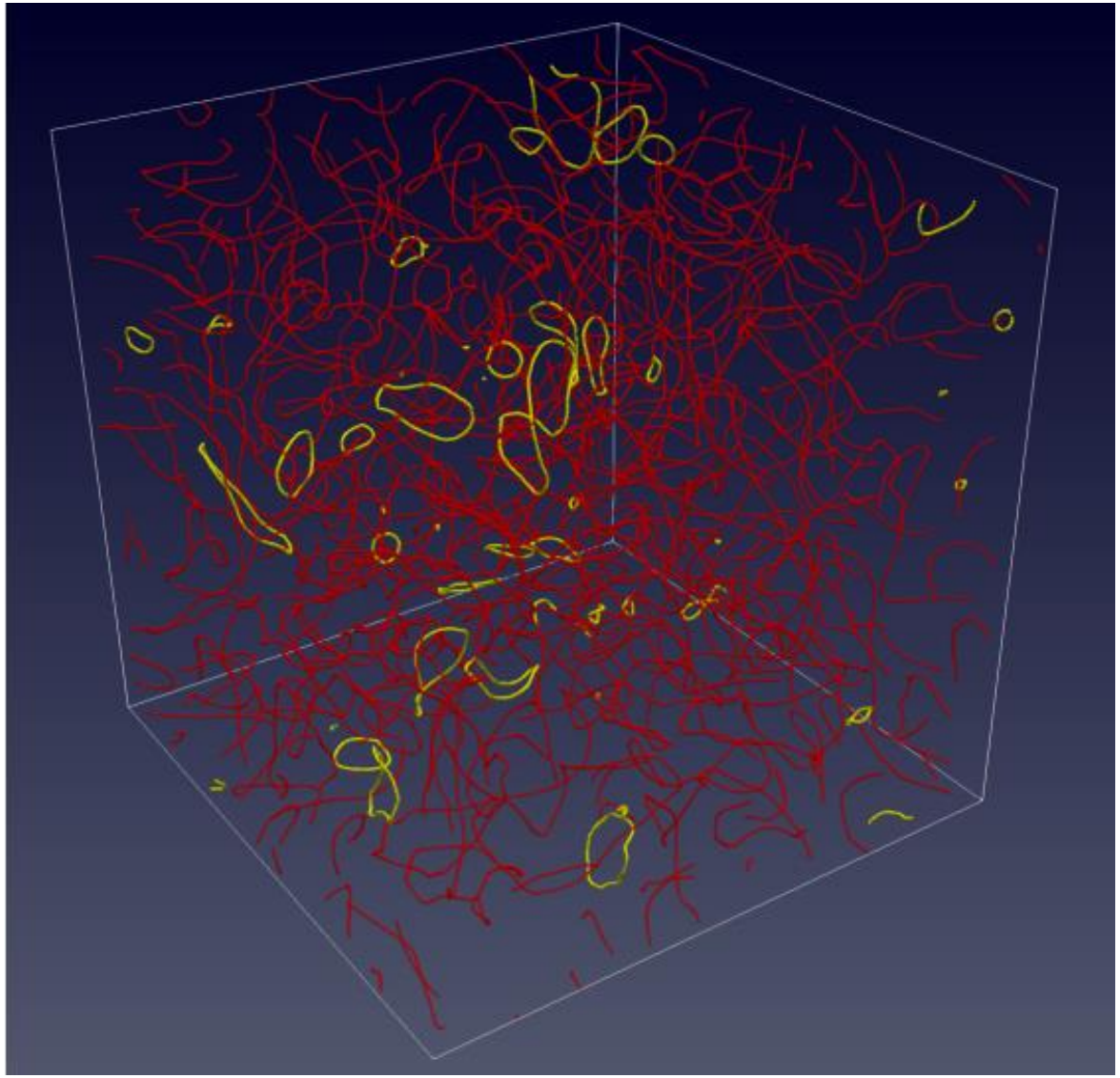
1. Production of cosmic strings
2. Evolution of a cosmic string network
3. Cosmic string loops
4. Stochastic Gravitational Wave Background (SGWB) calculation
5. SGWB with friction
6. Detectability

Production of a cosmic string network

During phase transitions as a result of spontaneous symmetry breaking

- GUT strings
- Electroweak strings
- Axion strings
- …

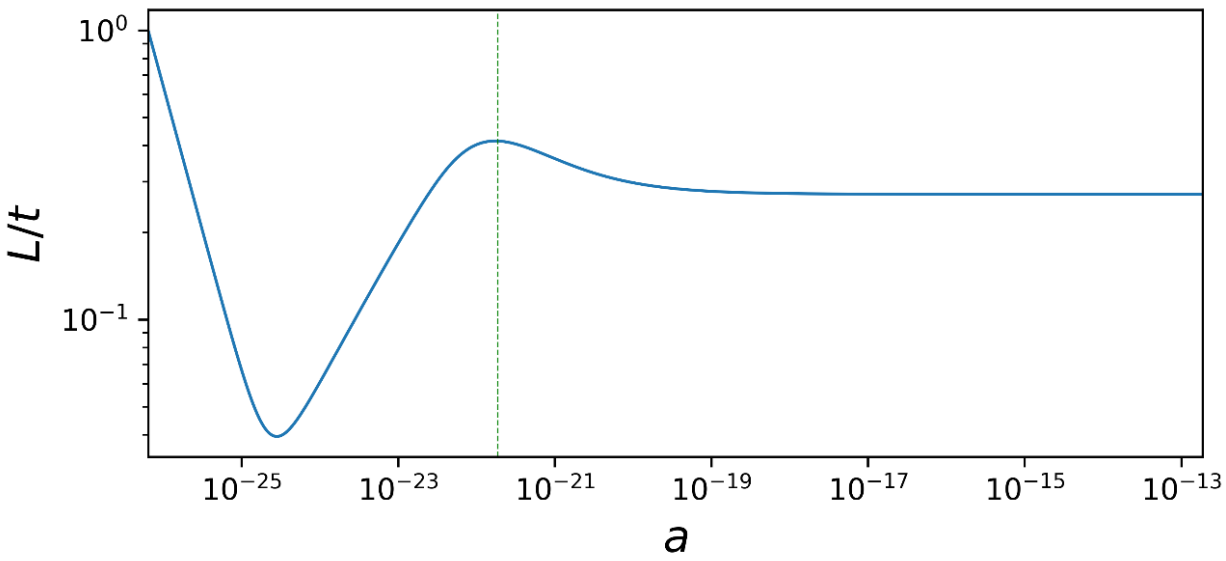
Cosmic superstrings



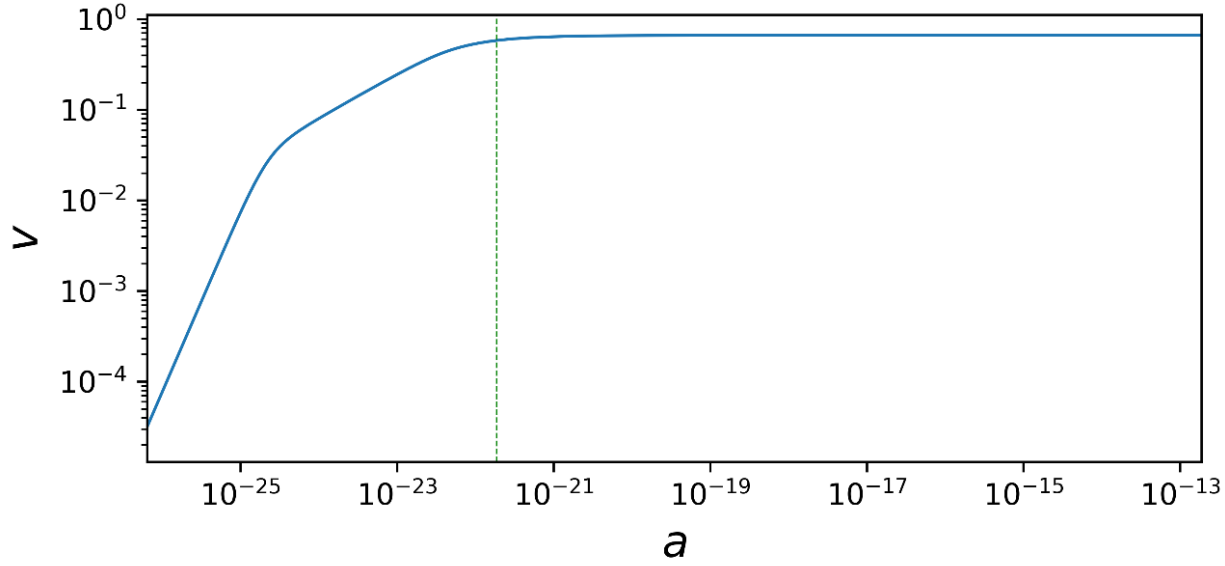
Naoya Kitajima, Kazunori Nakayama; 2212.13573

The evolution of cosmic string networks
Scaling regimes

L - the characteristic lengthscale



$\bar{v}$ - the Root-Mean-Squared (RMS) velocity



Stretching

$$L = L_c \left(\frac{t}{t_c}\right)^{1/2}, \quad \bar{v} = \bar{v}_c \left(\frac{t}{t_c}\right)$$

Kibble

$$\frac{L}{t_c} \sim \left(\frac{t}{t_c}\right)^{5/4}, \quad \bar{v} \sim \left(\frac{t}{t_c}\right)^{1/4}$$

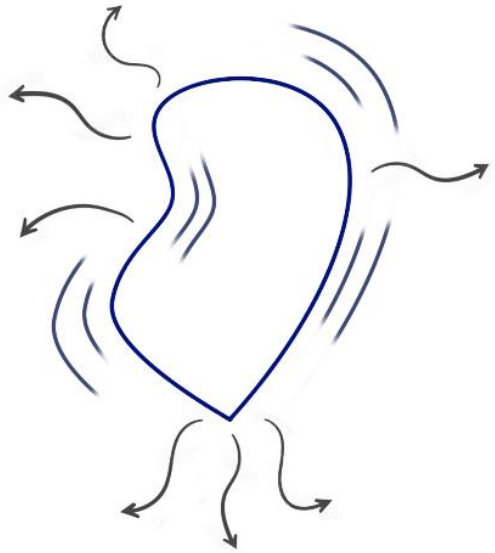
Linear

$$L \sim t, \quad \bar{v} = const$$

Cosmic string loops

String-string collisions

Self-intersections



The stochastic gravitational wave background (SGWB)

The SGWB. Calculation

1) Calculate the evolution of the network: $L(t)\ \bar{v}(t)$

⇨

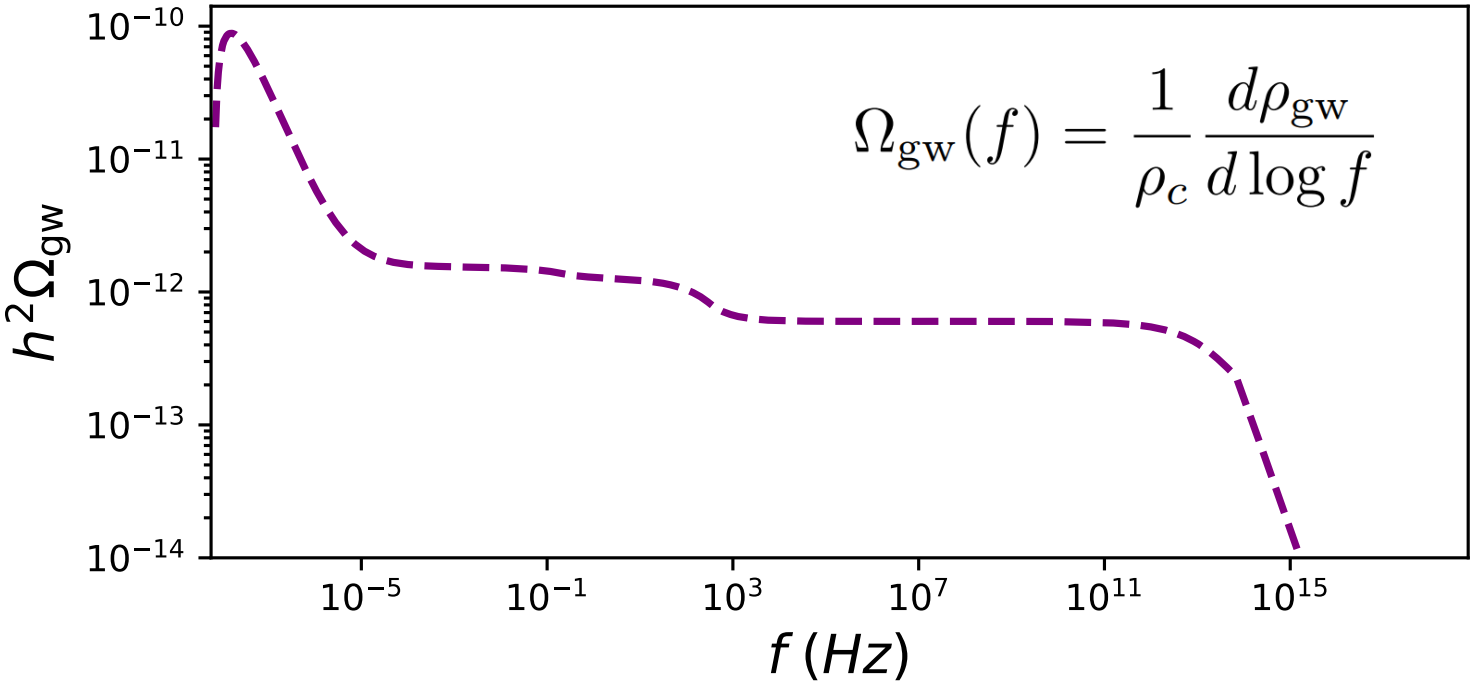
Find the loop production function:

$f(l,t)dl =$ the number density of loops with length between l and $l + dl$ produced per unit time.

2) Evolution of the cosmic string loop:

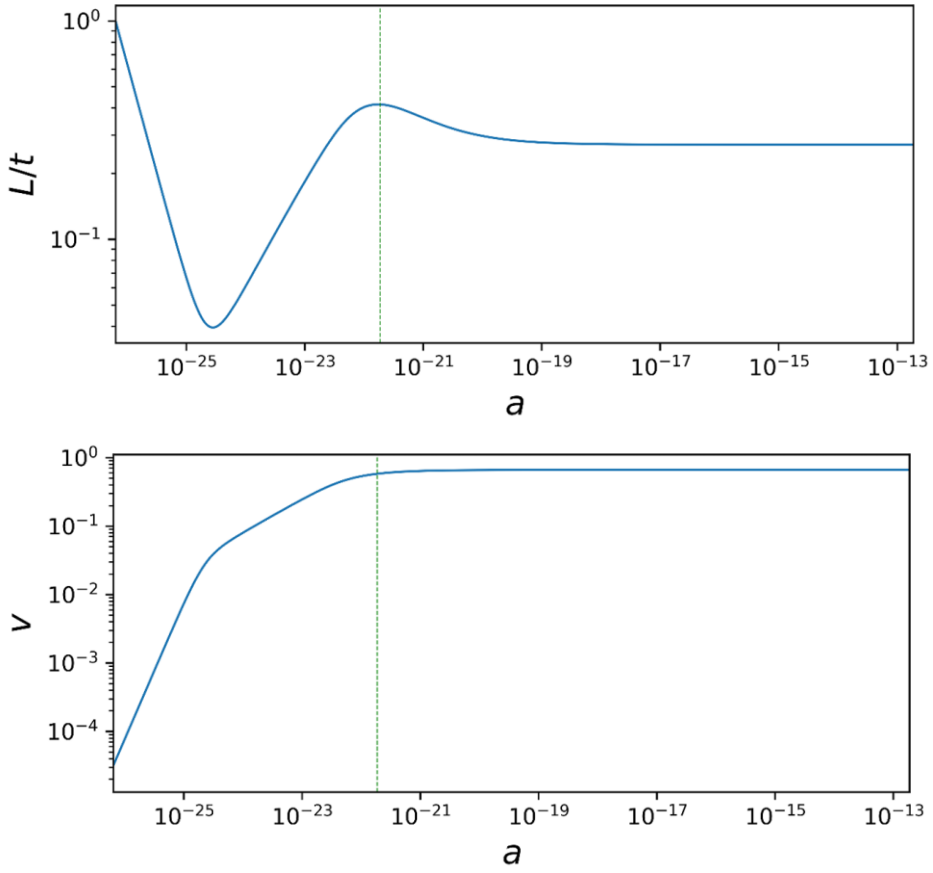
$$\ell = \ell_b - \Gamma G\mu\,(t - t_b)$$

$$\ell_b = \alpha L(t_b)$$



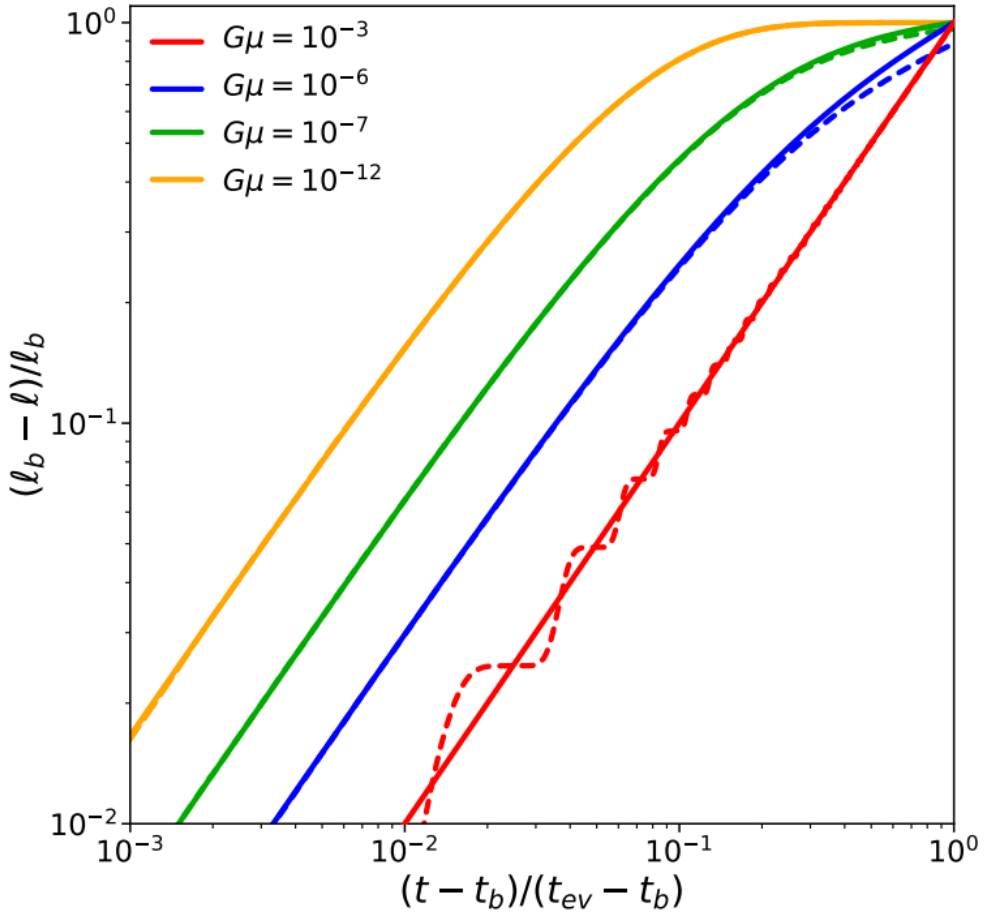
The SGWB with friction. Calculation

Evolution of the cosmic string network:



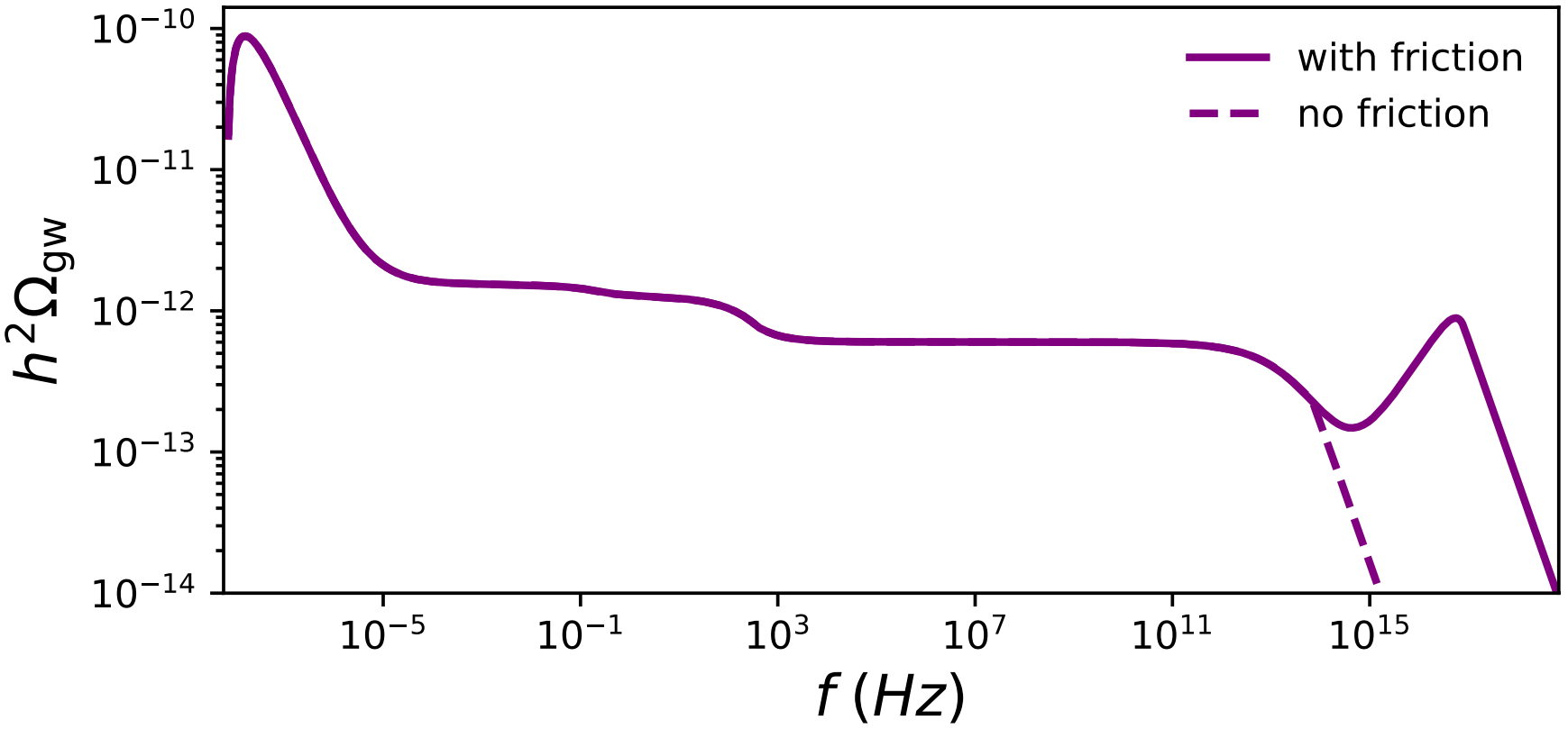
Evolution of the cosmic string loop:

$$\ell = \ell_b exp\left[t_f^{1/2}\left(t^{-1/2} - t_b^{-1/2}\right)\right] - \Gamma G\mu\,(t - t_b),\; t_f = \frac{t_{pl}}{\chi^3}\left(\frac{\beta}{G\mu}\right)^2$$



The SGWB with friction. Full spectrum.

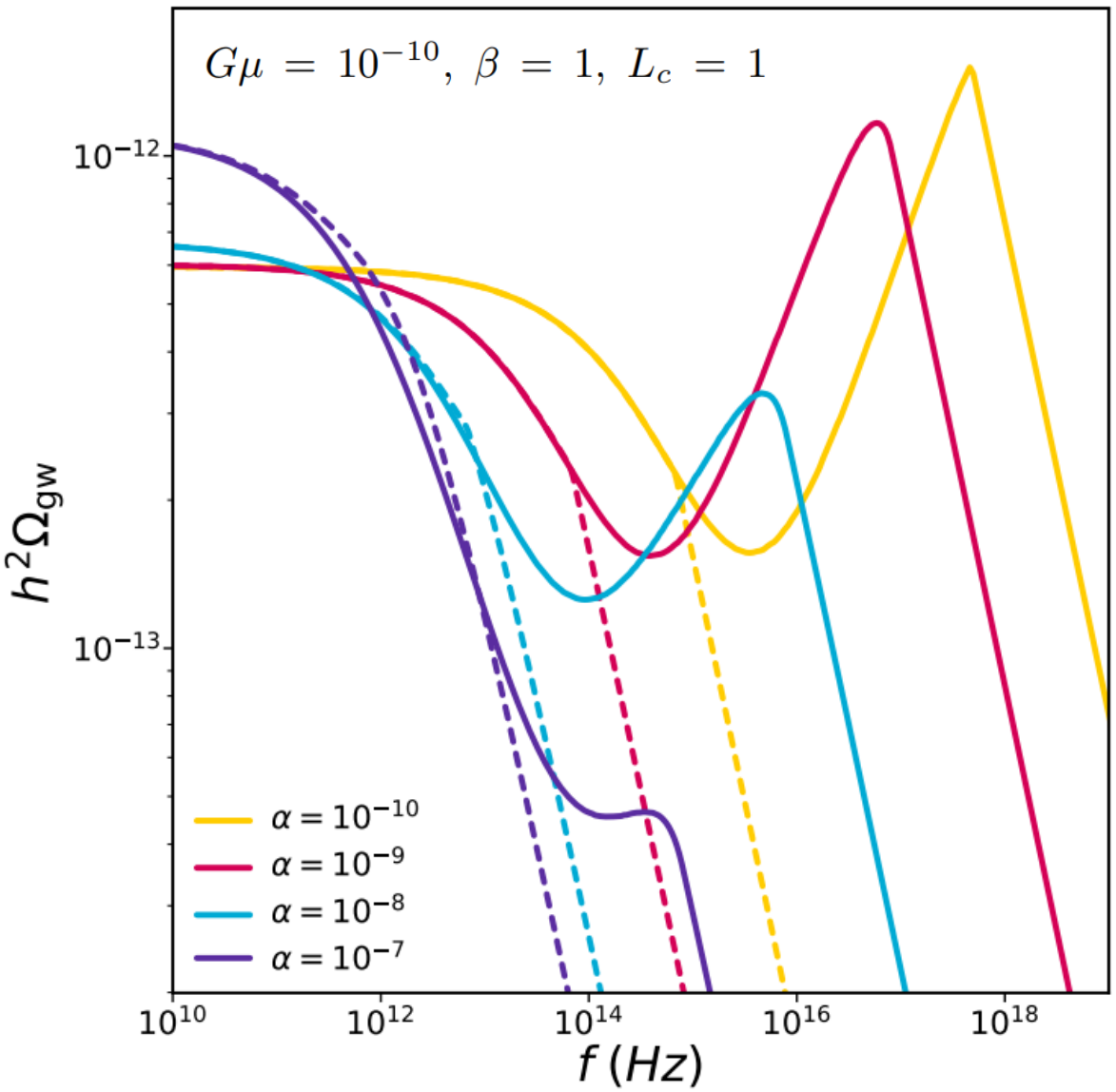
$$G\mu = 10^{-10},\ \alpha = 10^{-9},\ \beta = 1,\ L_c = t_c$$

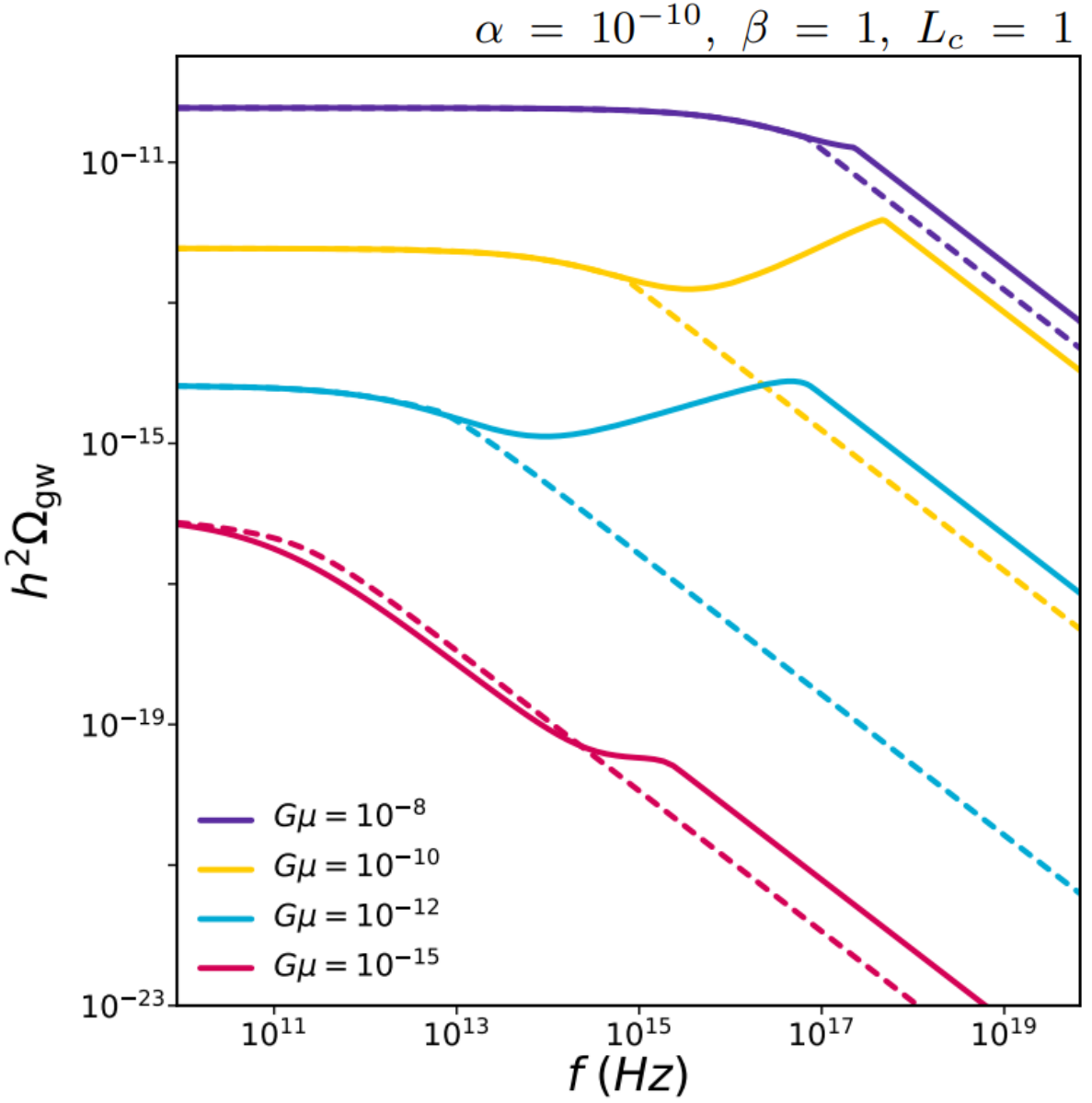


Cut-offs on the size scales

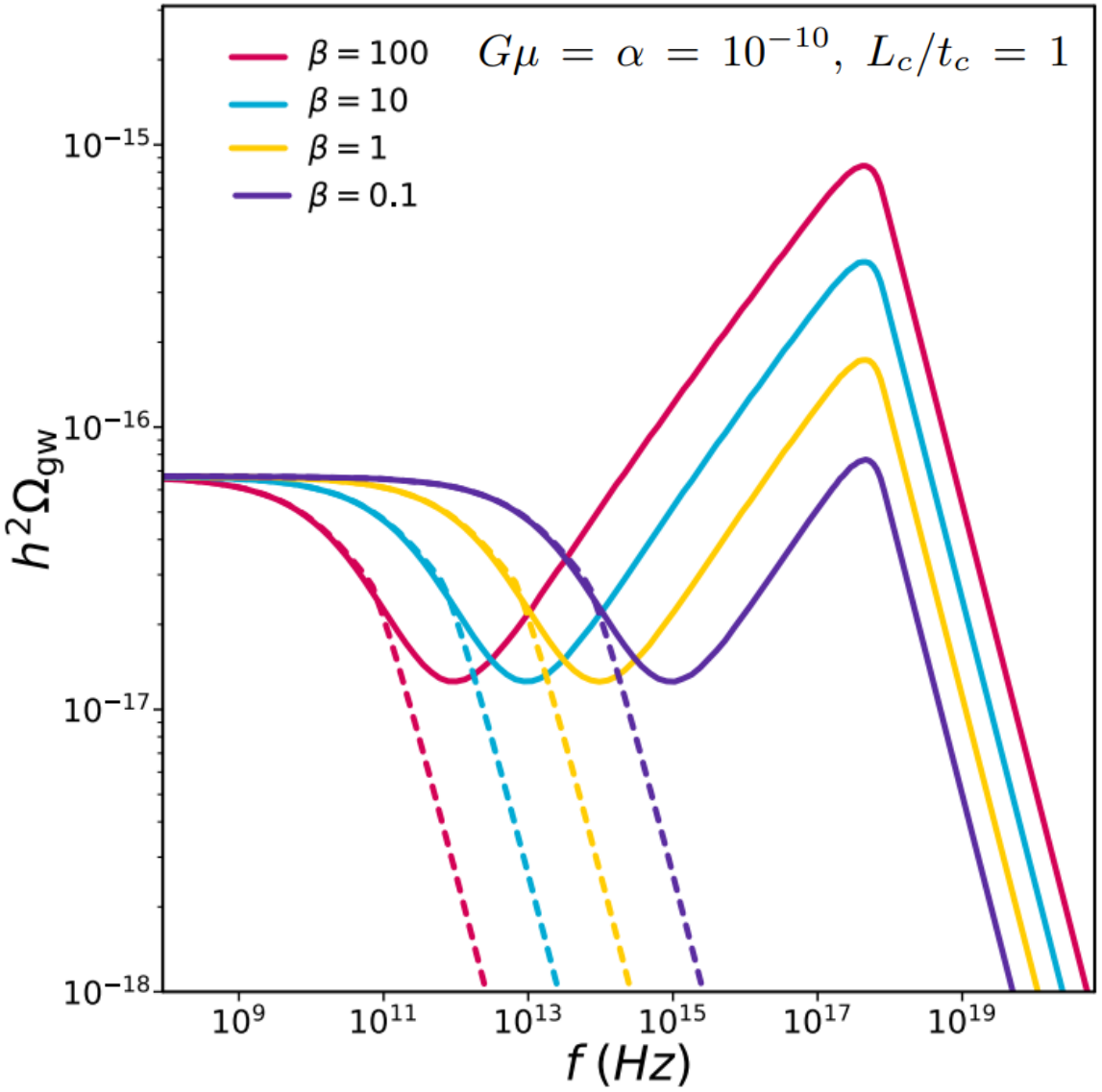
Length of loops	$> l_{pl}$
Gravitational backreaction scale	$> l_{pl}$

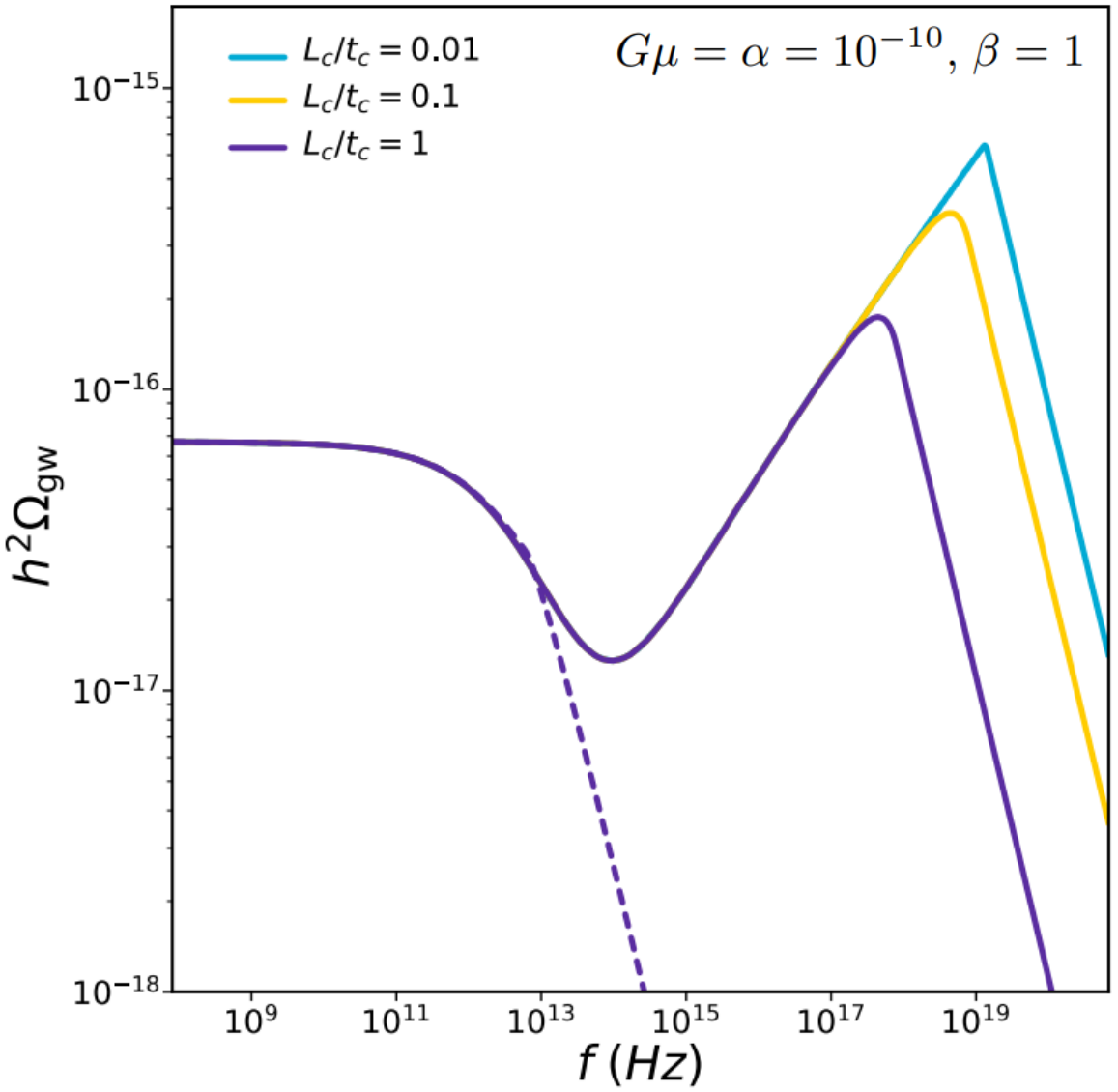
The SGWB with friction. Parameters variation.



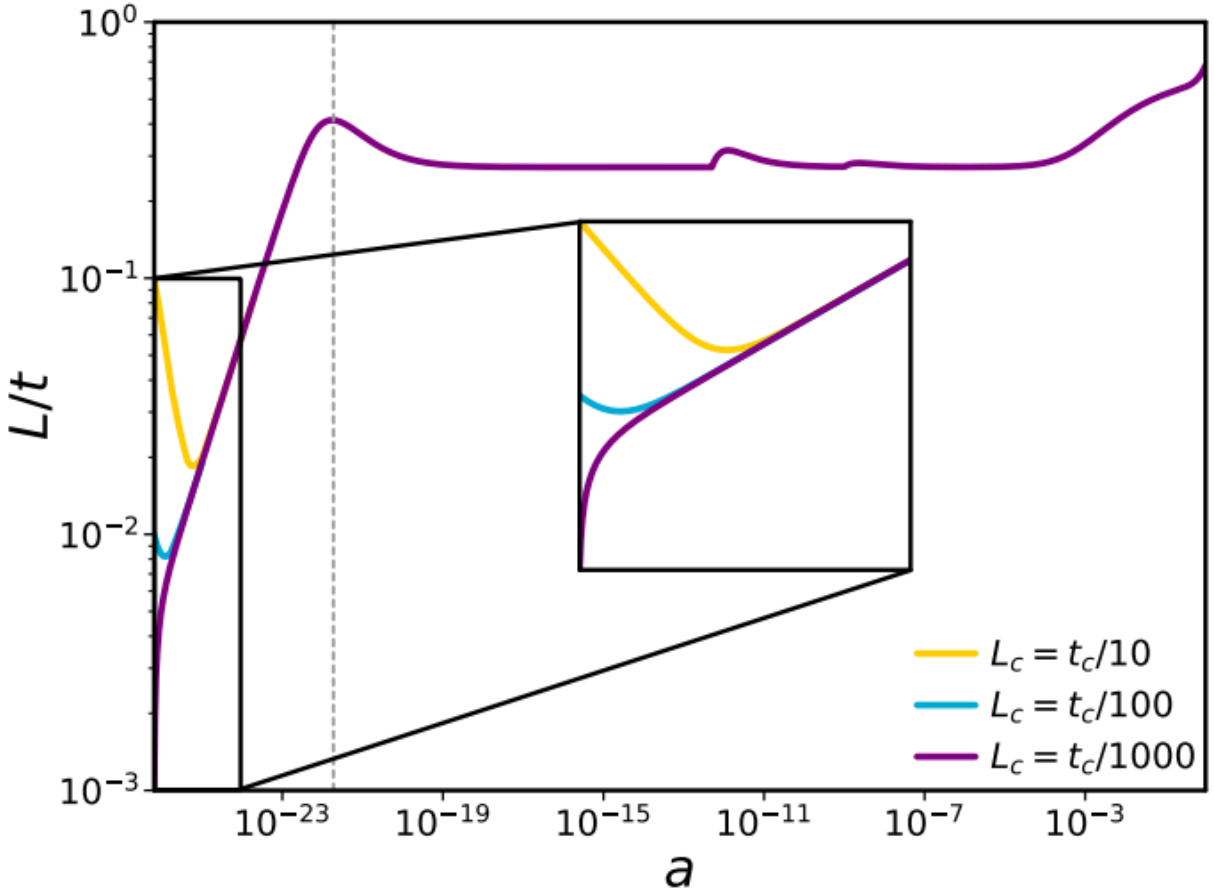


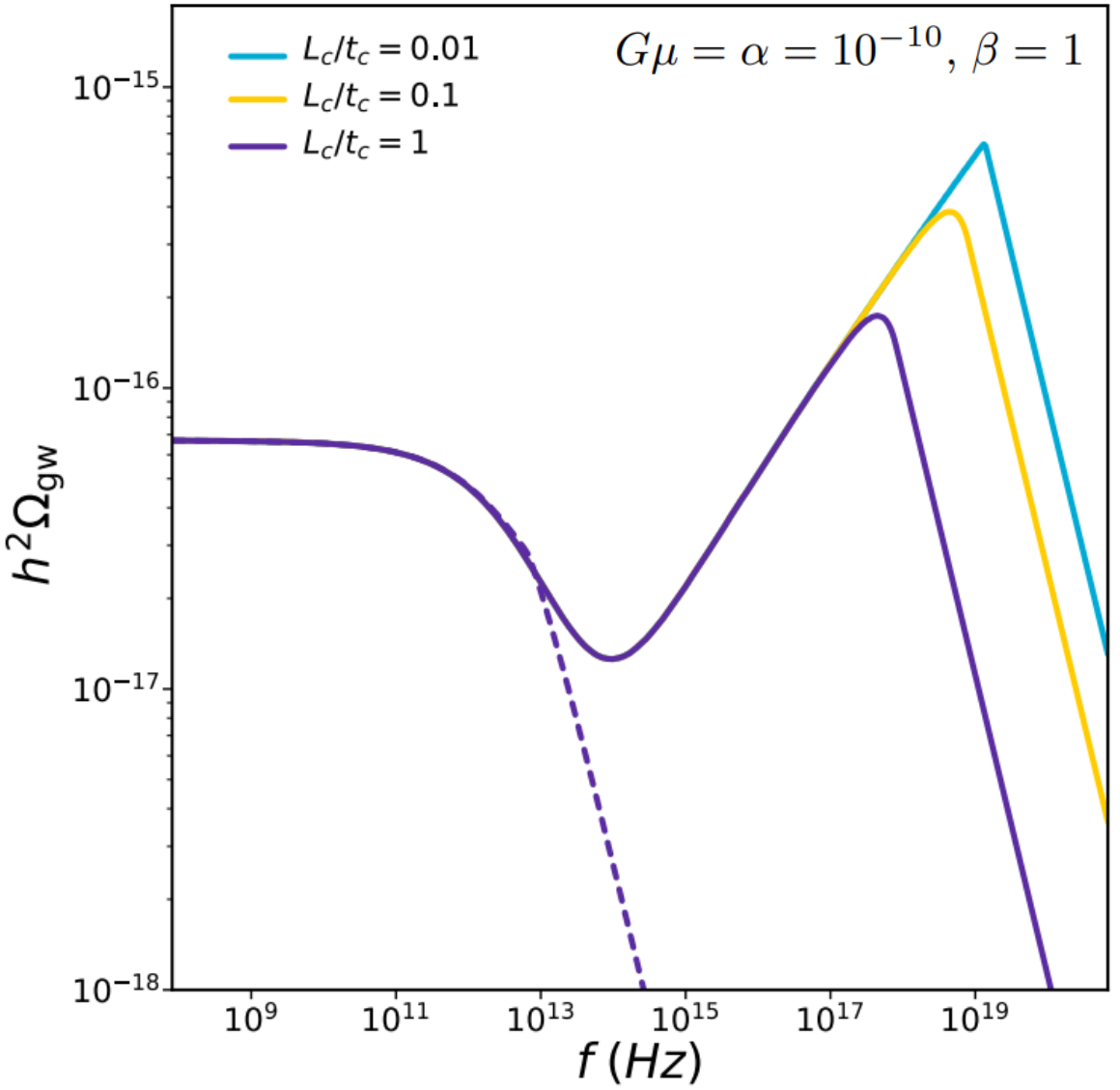
The SGWB with friction. Parameters variation.





The SGWB with friction. Parameters variation.





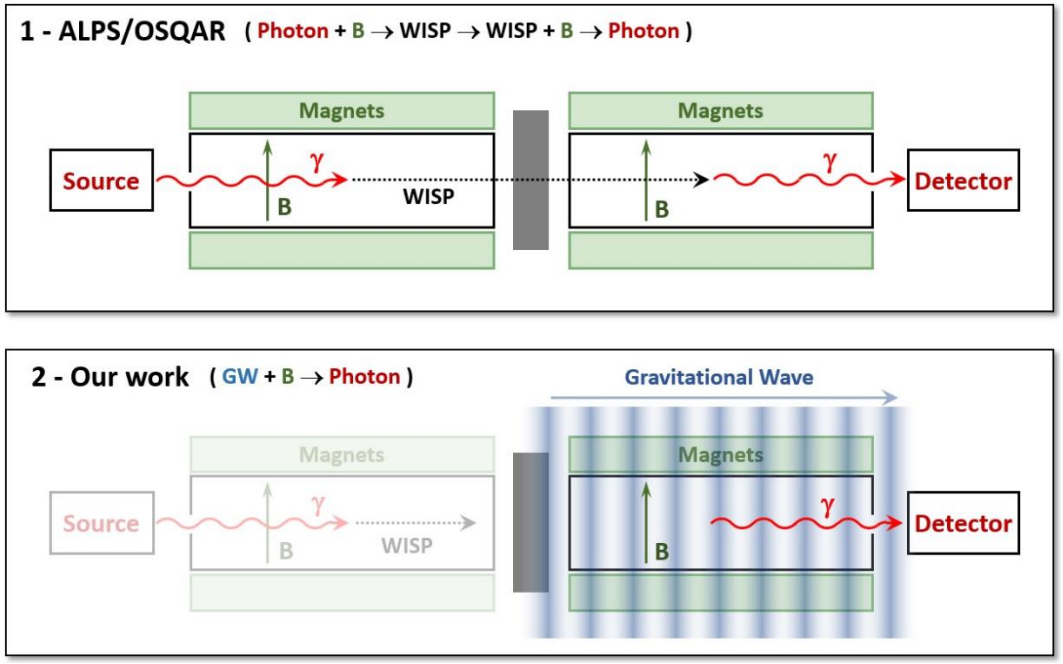
Detectability

HF GWs technical concepts:

- Laser interferometers
- Optically levitated sensors
- Magnetic conversion
- Resonant polarization rotation
- Microwave cavities
- Graviton-magnon resonance

Recent review arXiv:2011.12414

Magnetic conversion



A. Ejlli et al.; 1908.00232

Magnetic fields of pulsars, planetary magnetospheres, galaxy clusters, artificial magnetic fields

Conclusions

- There is a signature of friction in the UHF range of the spectrum
- It is strongly dependent on the particular particle physics theory of the early universe
- It’s detection is challenging. There is a strong interest of the scientific community in this range of the spectrum.

The signature of friction opens a wider window for probing the physics of the very early universe, inaccessible by considering just frictionless period of evolution.