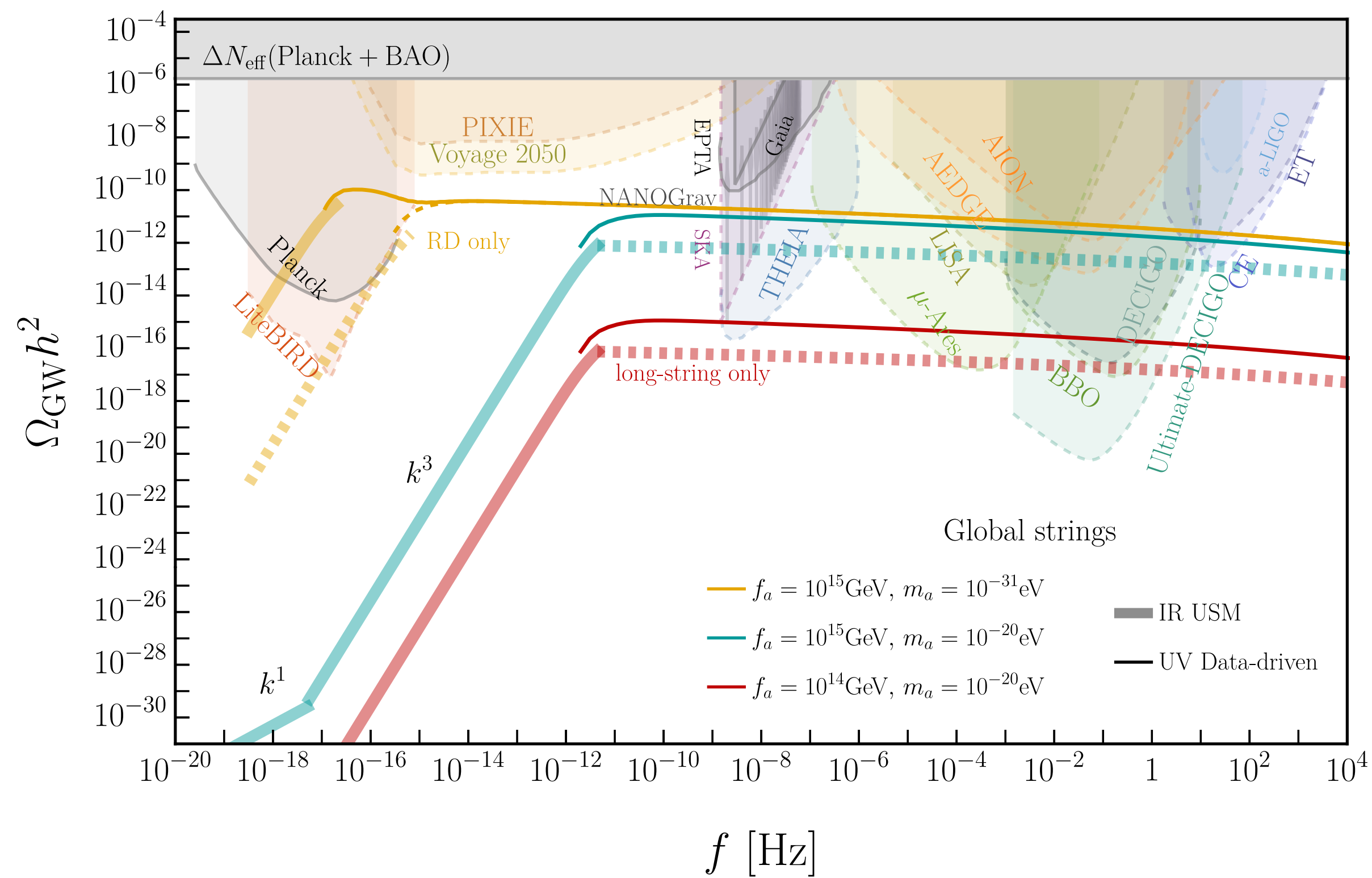


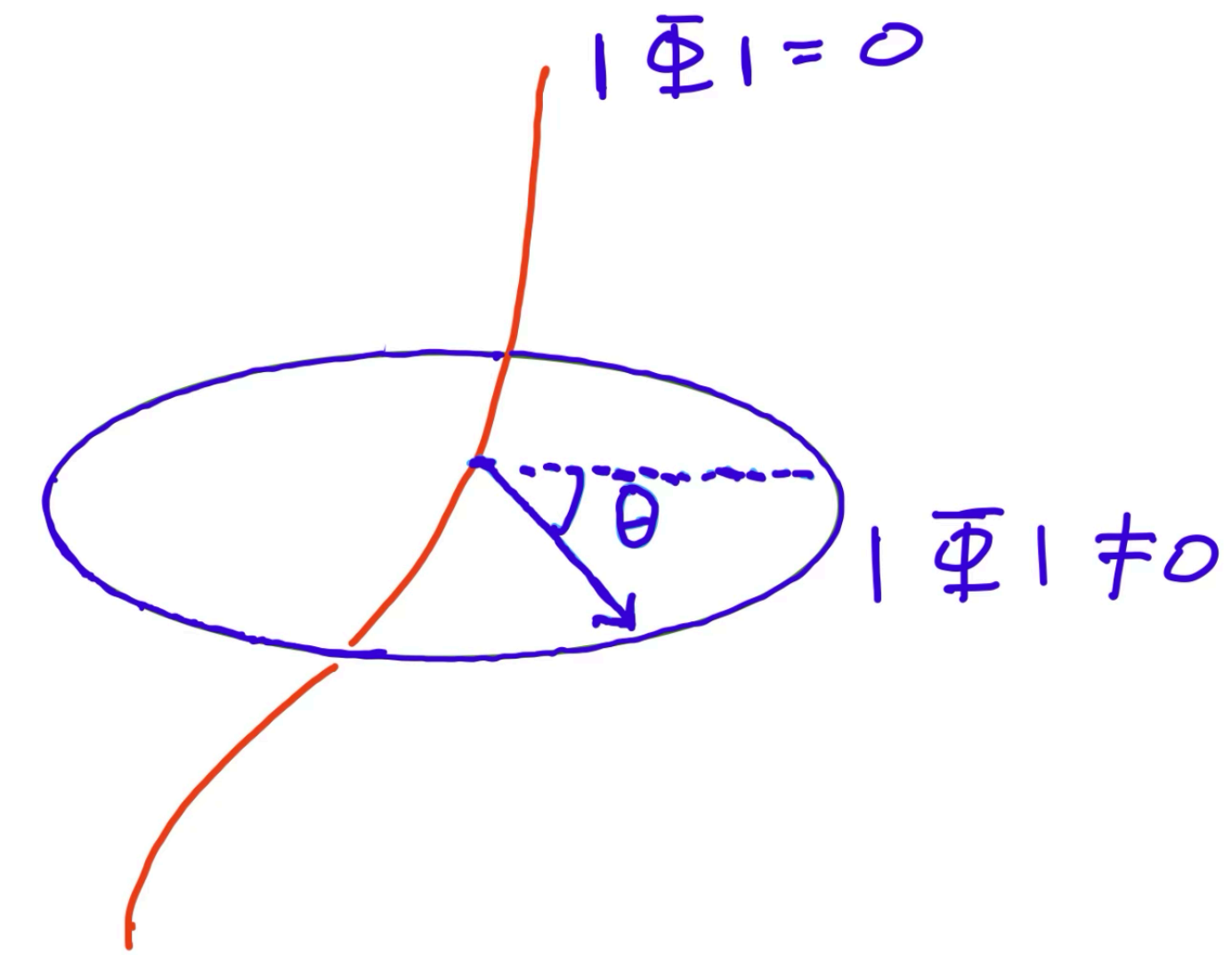
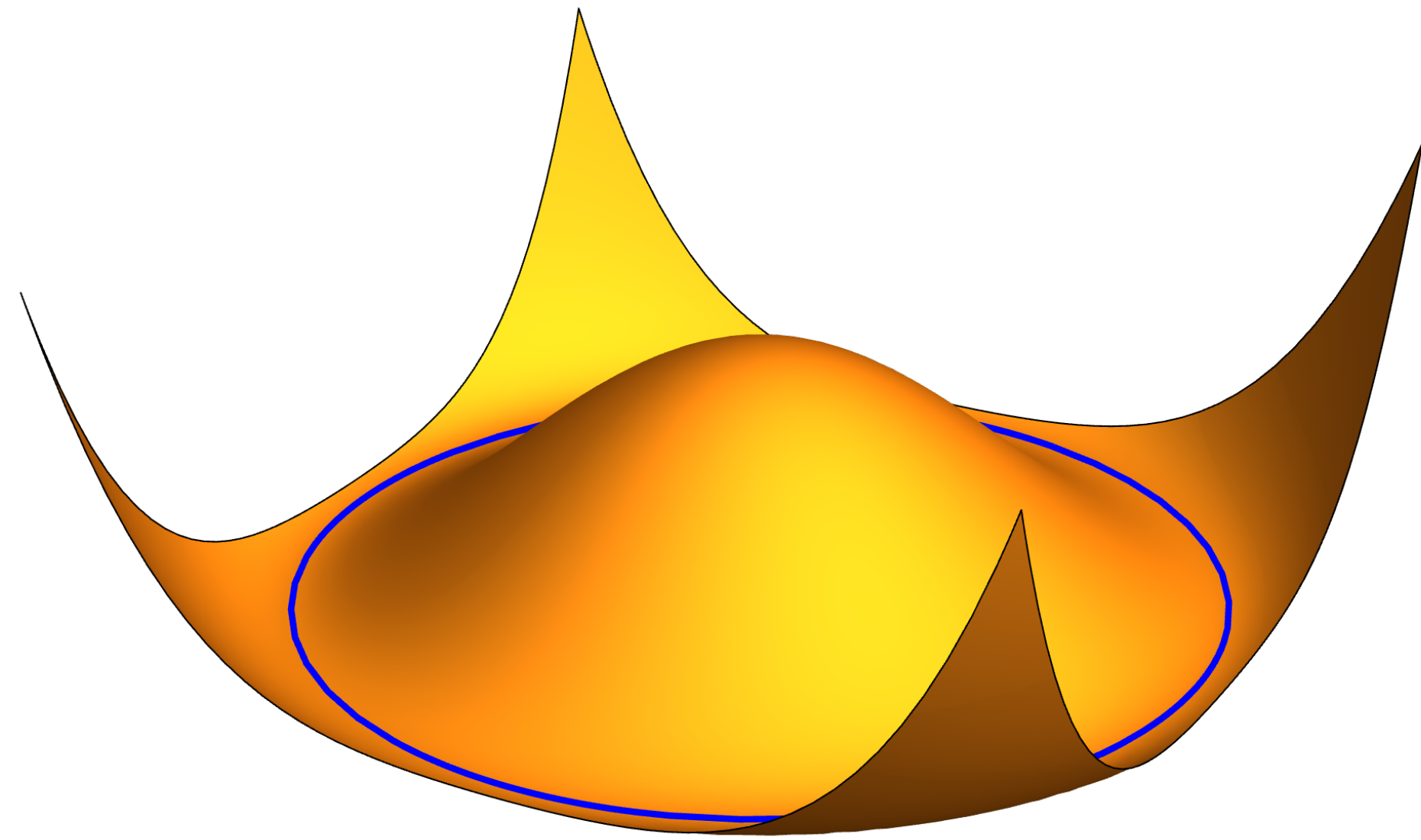
Gravitational Waves from Long Strings and Loops

Christos Litos

In collaboration with S. Verner, W. Xue, F. Yang



Cosmic Strings

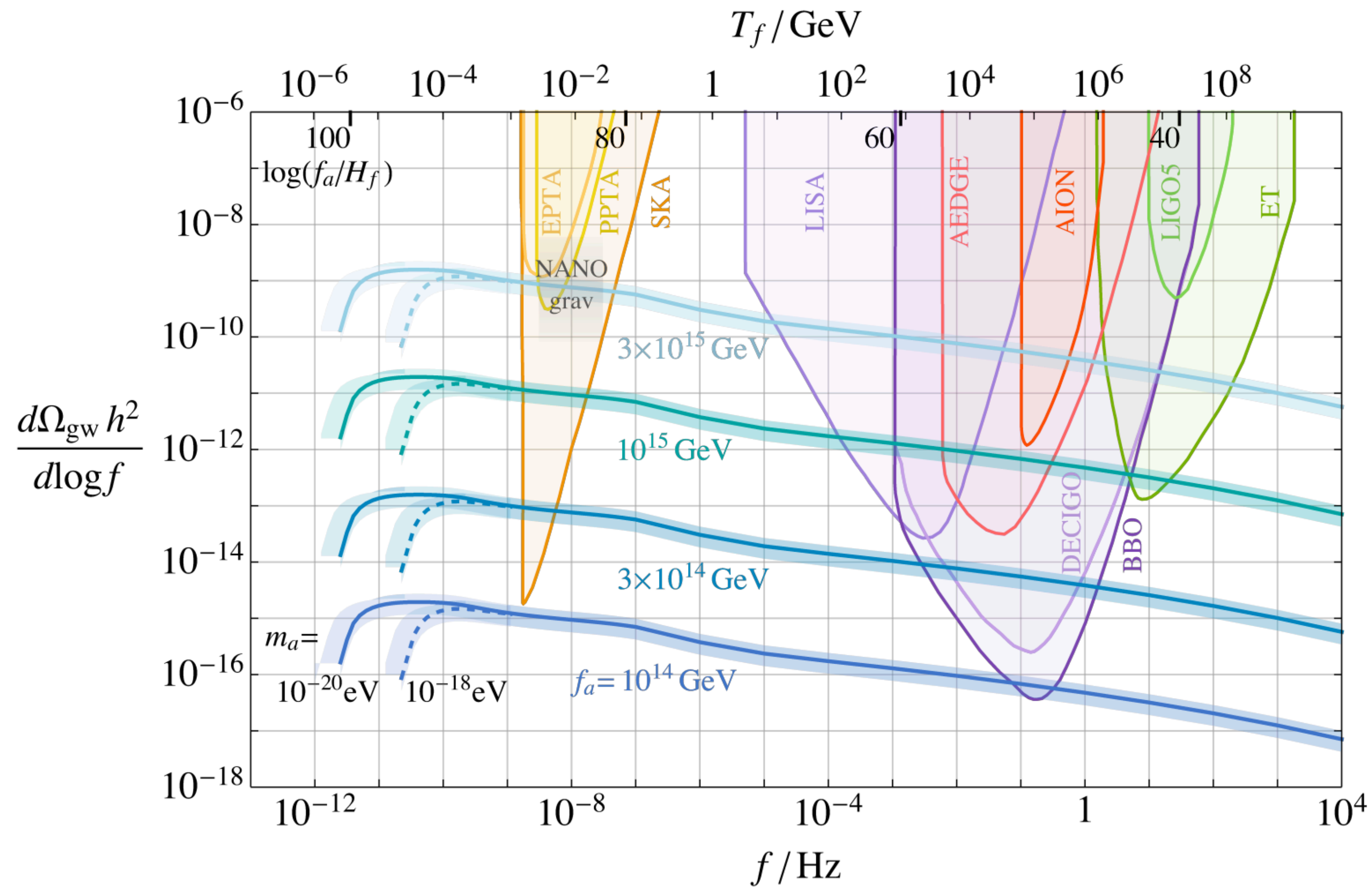


Gauged, which results in a network that **doesn't collapse**

The U(1) symmetry can either be:

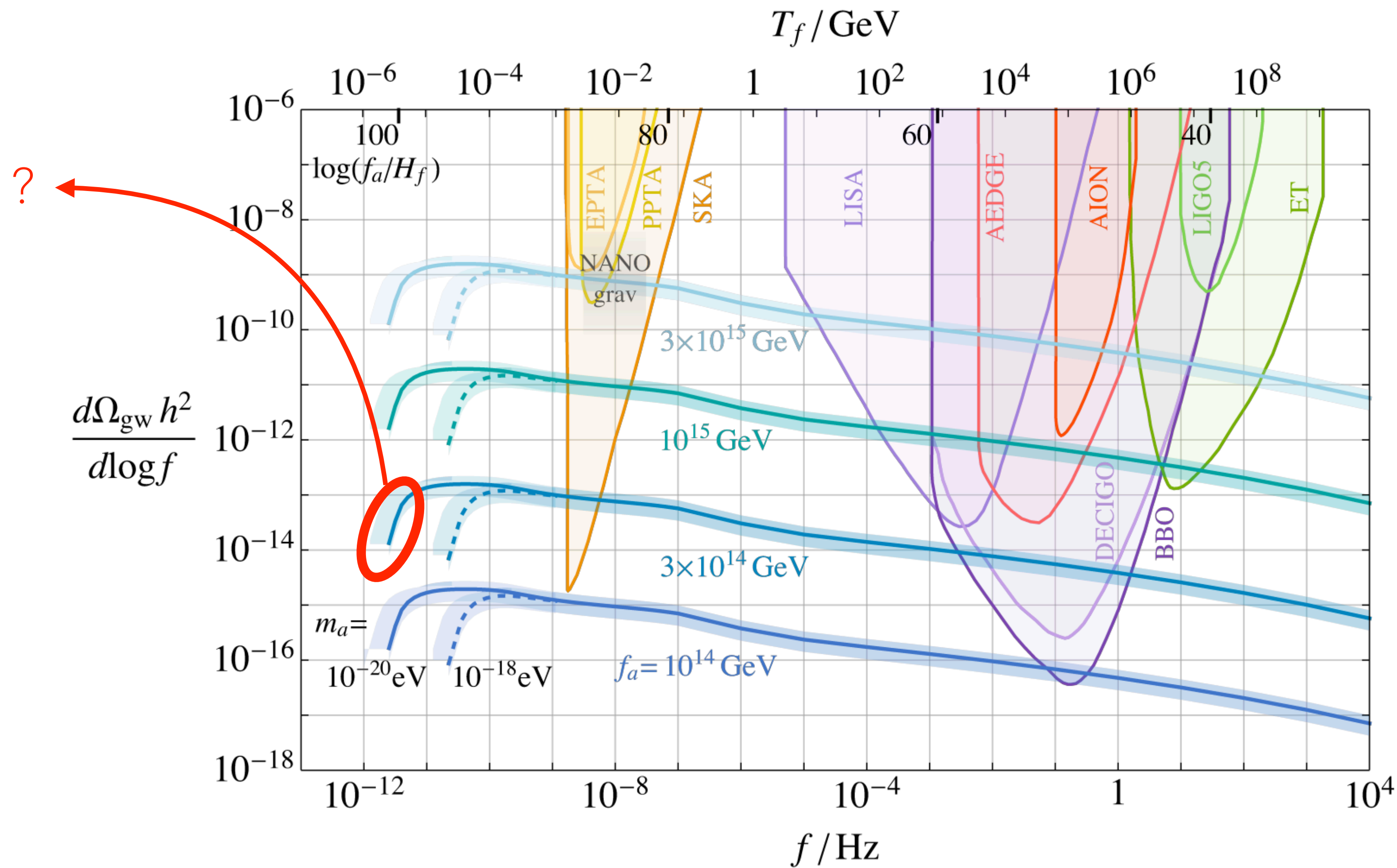
Global, which results in a network that eventually **collapses**

Cosmic String Networks



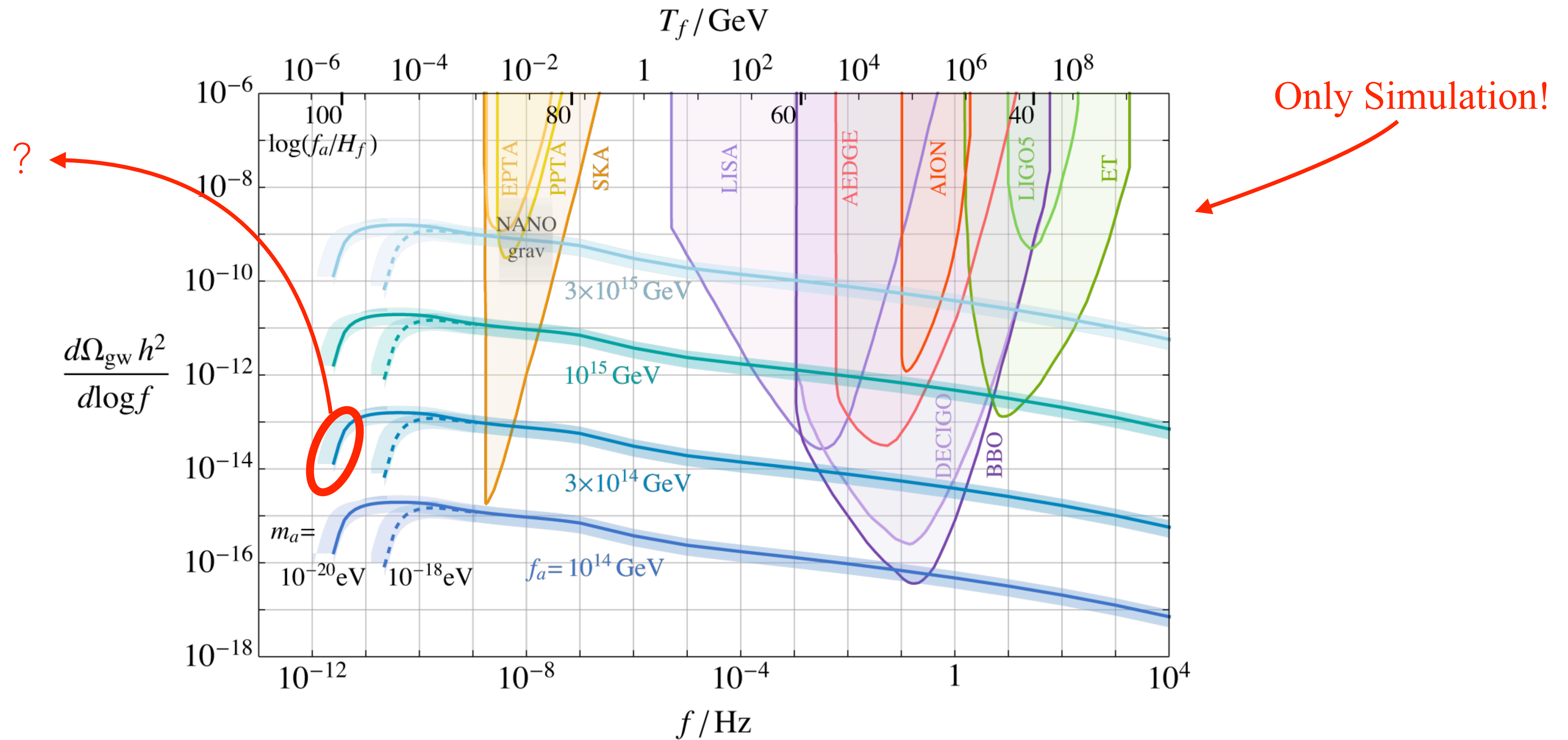
Retrieved from M. Gorghetto, E. Hardy, H. Nicolaescu (2021)

Cosmic String Networks



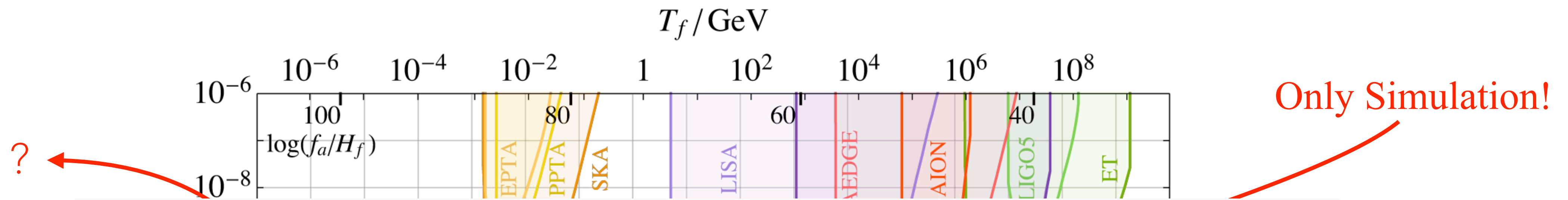
Retrieved from M. Gorghetto, E. Hardy, H. Nicolaescu (2021)

Cosmic String Networks

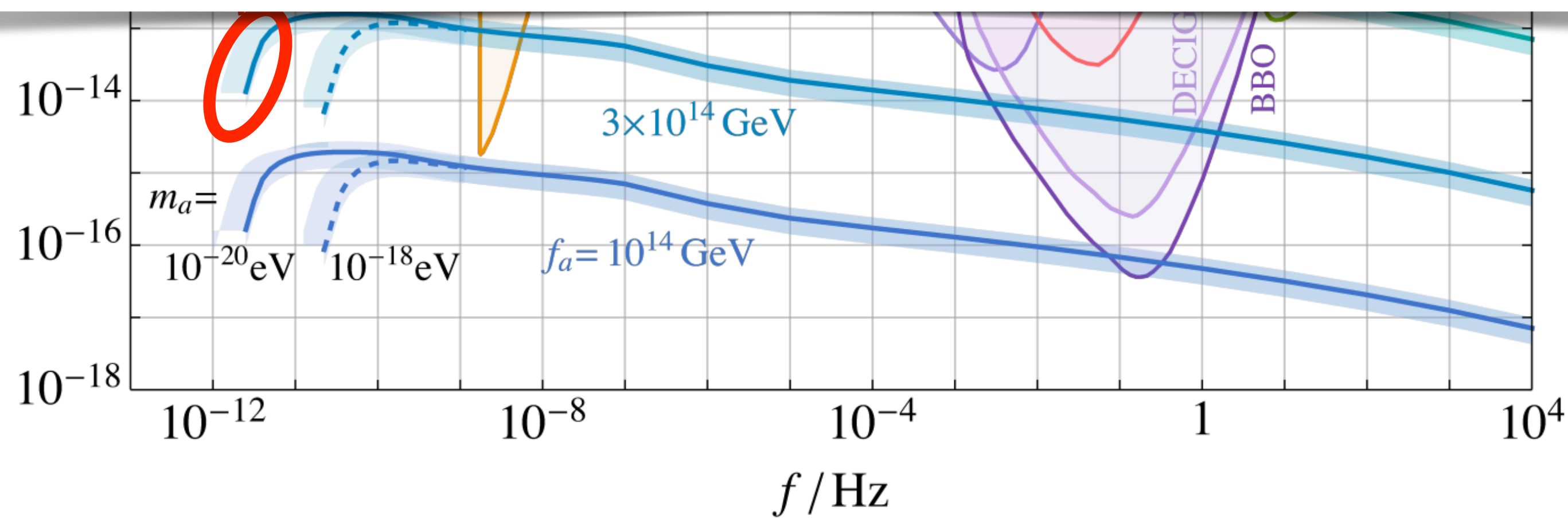


Retrieved from M. Gorghetto, E. Hardy, H. Nicolaescu (2021)

Cosmic String Networks



Can we obtain the GW signal of such networks (semi) analytically?



Retrieved from M. Gorghetto, E. Hardy, H. Nicolaescu (2021)

Gravitational Waves

Two Regimes:

IR

- Scales bigger than characteristic length of the string
- Small scale physics can be safely ignored

UV

- Scales smaller than characteristic length of the string
- Small scale physics become important

Gravitational Waves

IR



Gravitational Waves

IR



Smooth out
→



Gravitational Waves

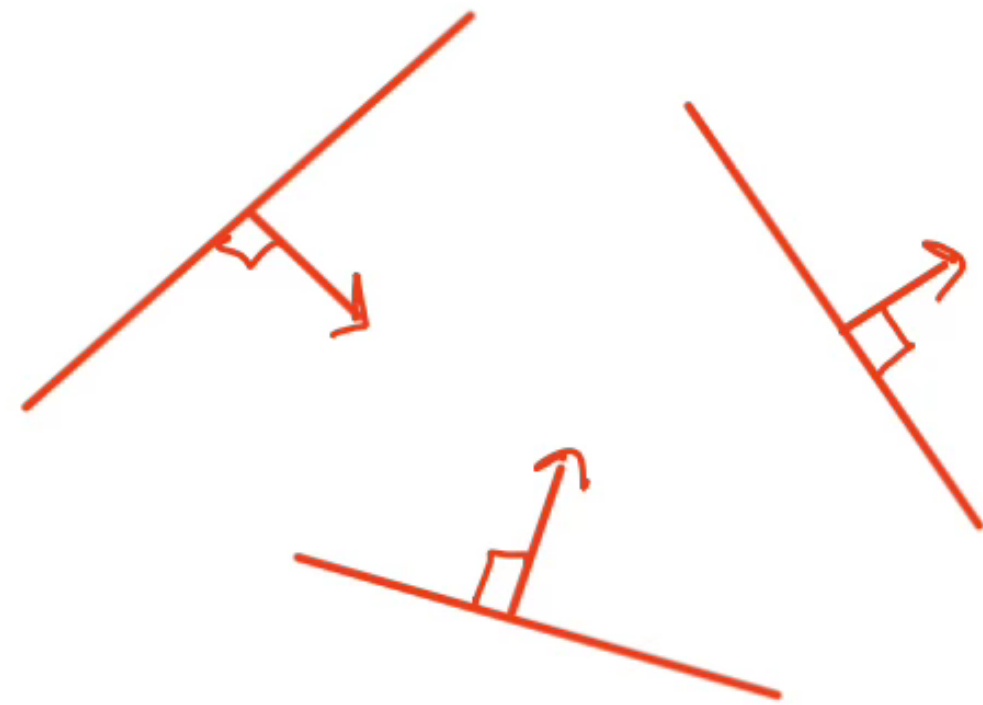
IR



Smooth out
→



Ensemble
→



Gravitational Waves

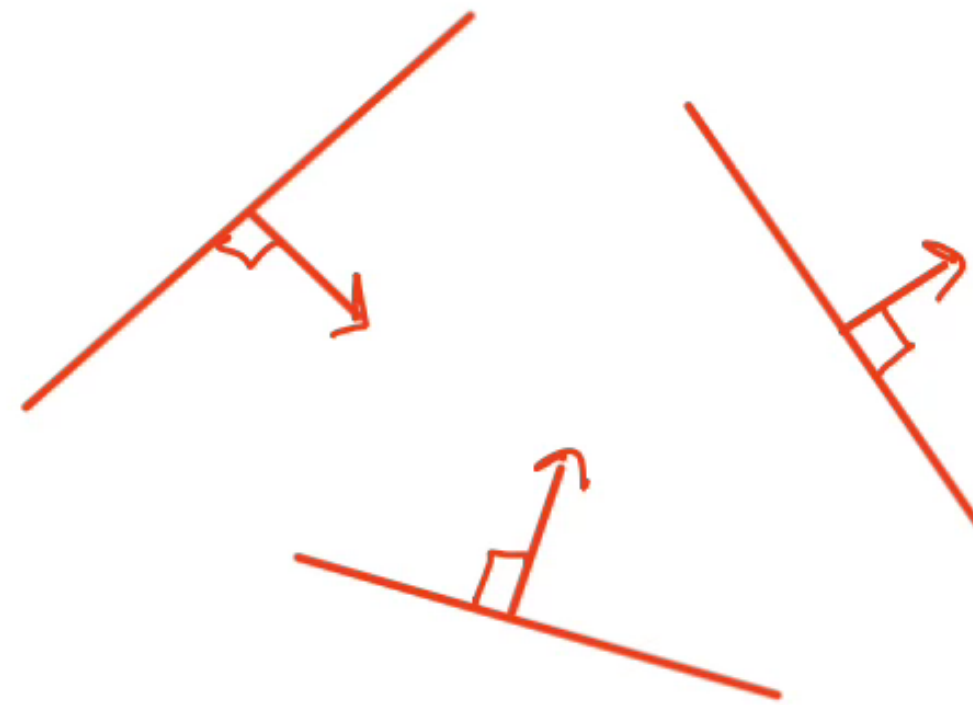
IR



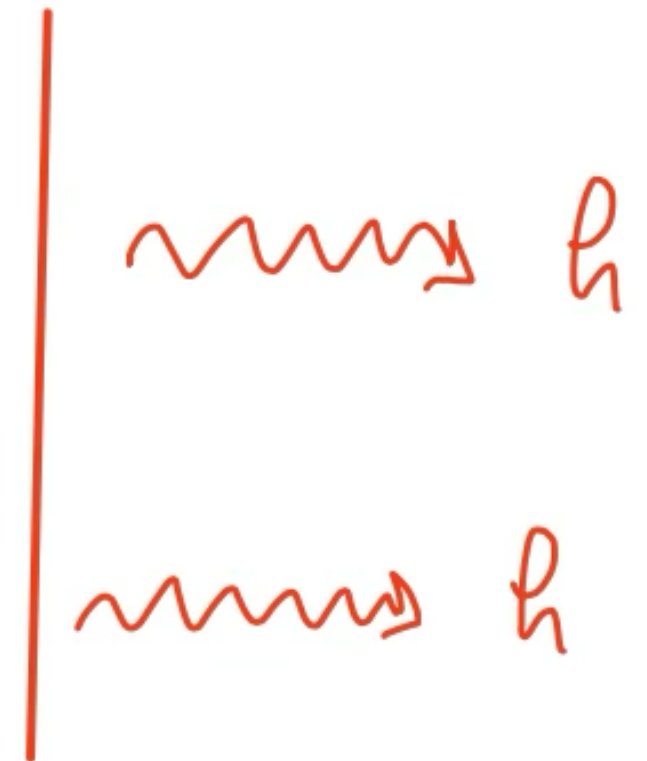
Smooth out
→



Ensemble
→



Radiation
→



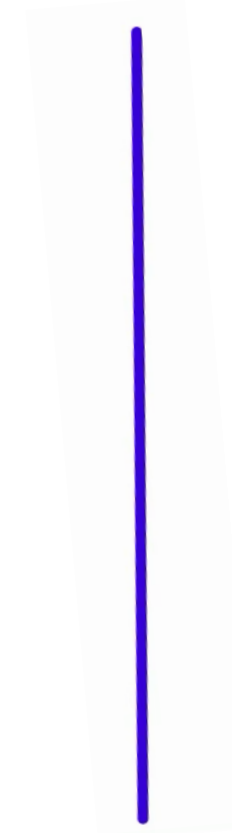
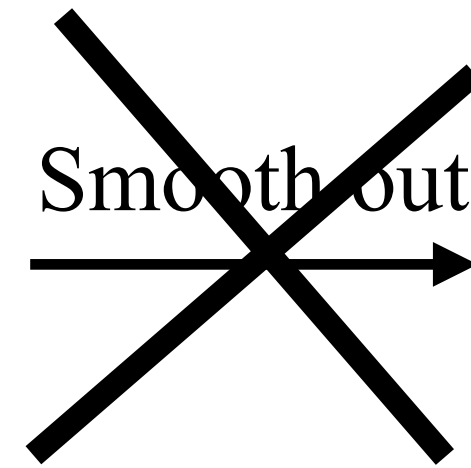
Gravitational Waves

UV



Gravitational Waves

UV



Gravitational Waves


UV

Do a data
driven method
instead


Gravitational Waves

UV

Do a data
driven method
instead



Obtain instantaneous
radiation spectrum
from simulations



Use analytical
transfer function
to evolve it

Gravitational Waves

$$\Omega_{GW,0}(k) = \frac{1}{12} \left(\frac{k}{a_0 H_0} \right)^2 \frac{k^3}{2\pi^2} \sum_{\lambda} \langle |h_{\lambda}(k, \eta_0)|^2 \rangle \sim k^5 |h|^2$$

IR:

Gravitational Waves

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IR:

Superhorizon

$h \sim \text{const}$, reenters the horizon during MD

$$h_0 \sim h_{\text{ini}} \frac{\cos(k\eta_0)}{(k\eta_0)^2} \sim k^{-2} h_{\text{ini}} \implies \Omega_{GW} \propto (G\mu)^2 \Omega_r \cdot k\eta_f$$

Gravitational Waves

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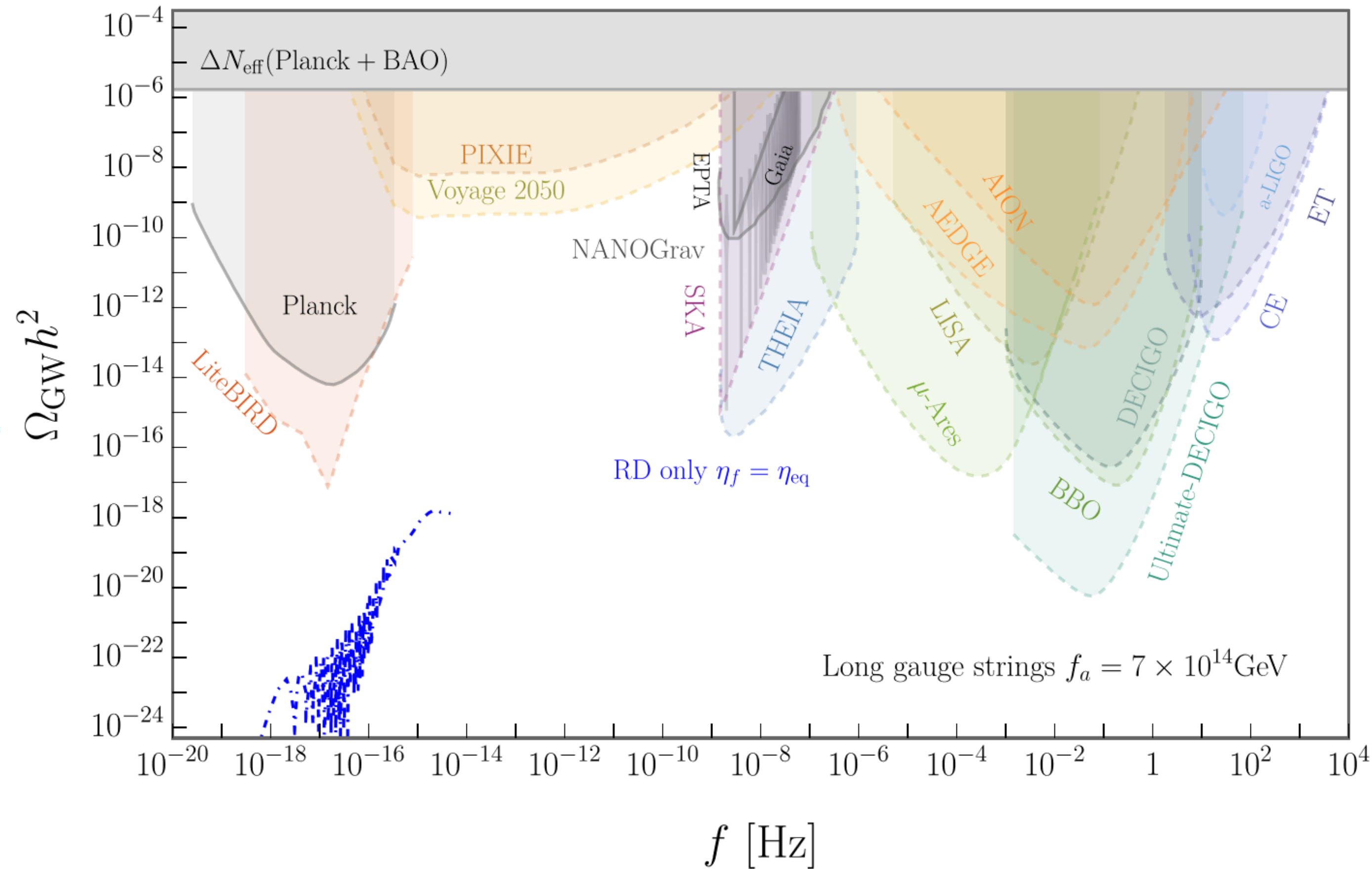
Subhorizon

Ensemble of independent, unresolved sources \rightarrow White Noise Spectrum

$$\Omega_{GW} \propto (G\mu)^2 \Omega_r \cdot (k\eta_f)^3$$

Gravitational Waves

Gauge Long Strings

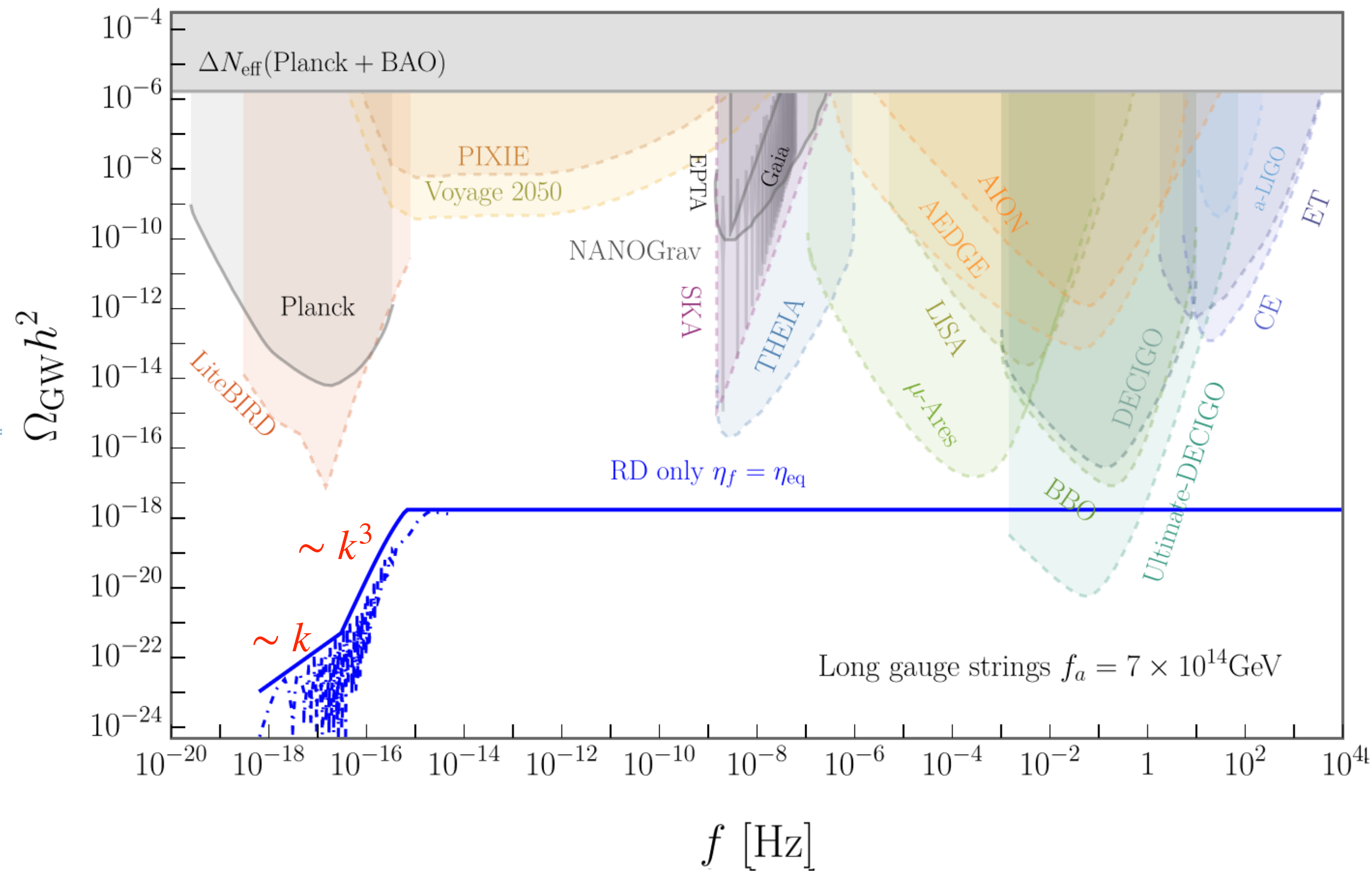


Legends

..... : Simulation (*D. Cunha, C. Ringeval and F. Bouchet, 2022*)

Gravitational Waves

Gauge Long Strings



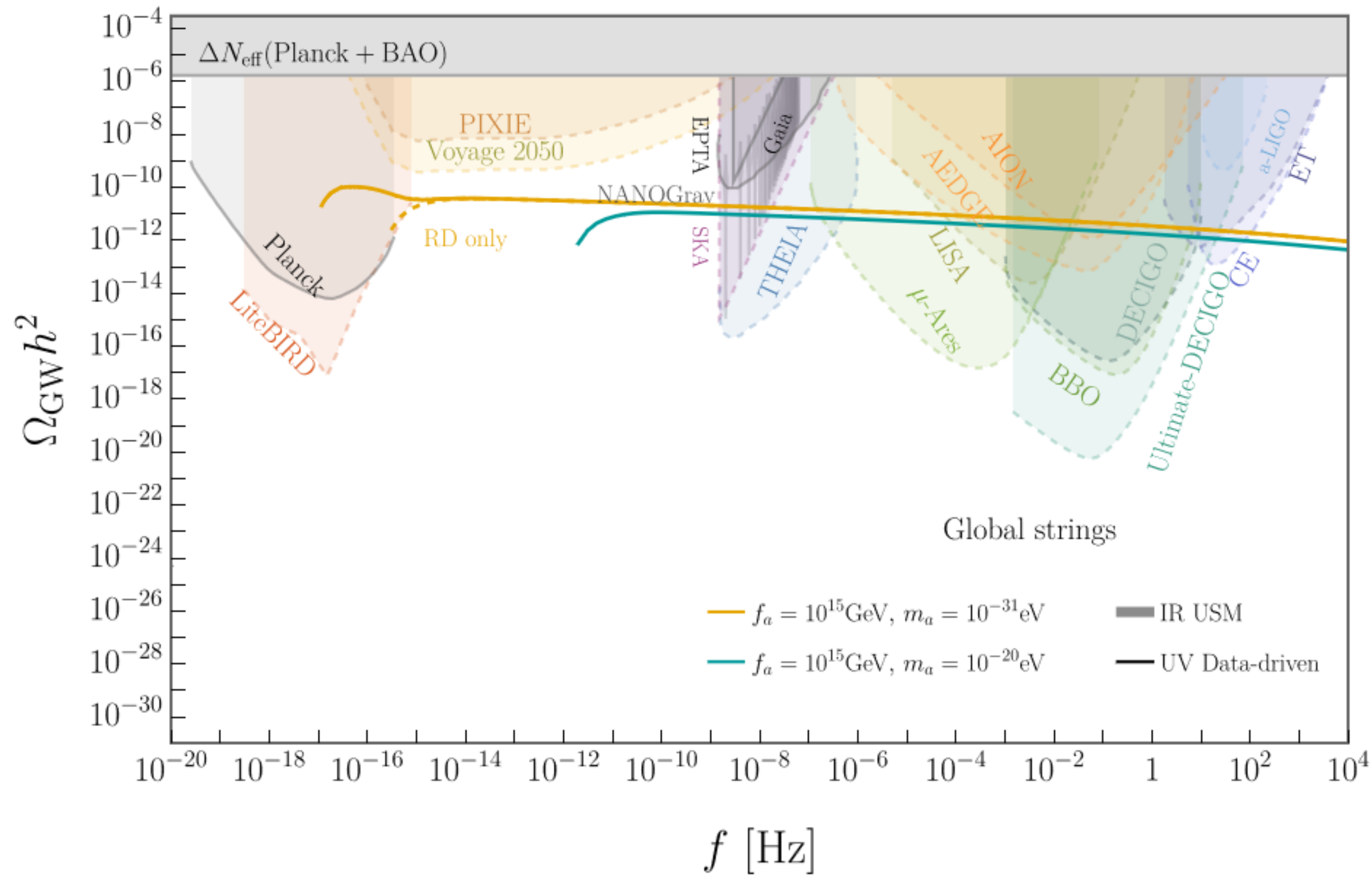
Legends

- : Simulation (*D. Cunha, C. Ringeval and F. Bouchet, 2022*)
- : Analytical

Impressive Agreement!

Results

Global Long Strings and Loops



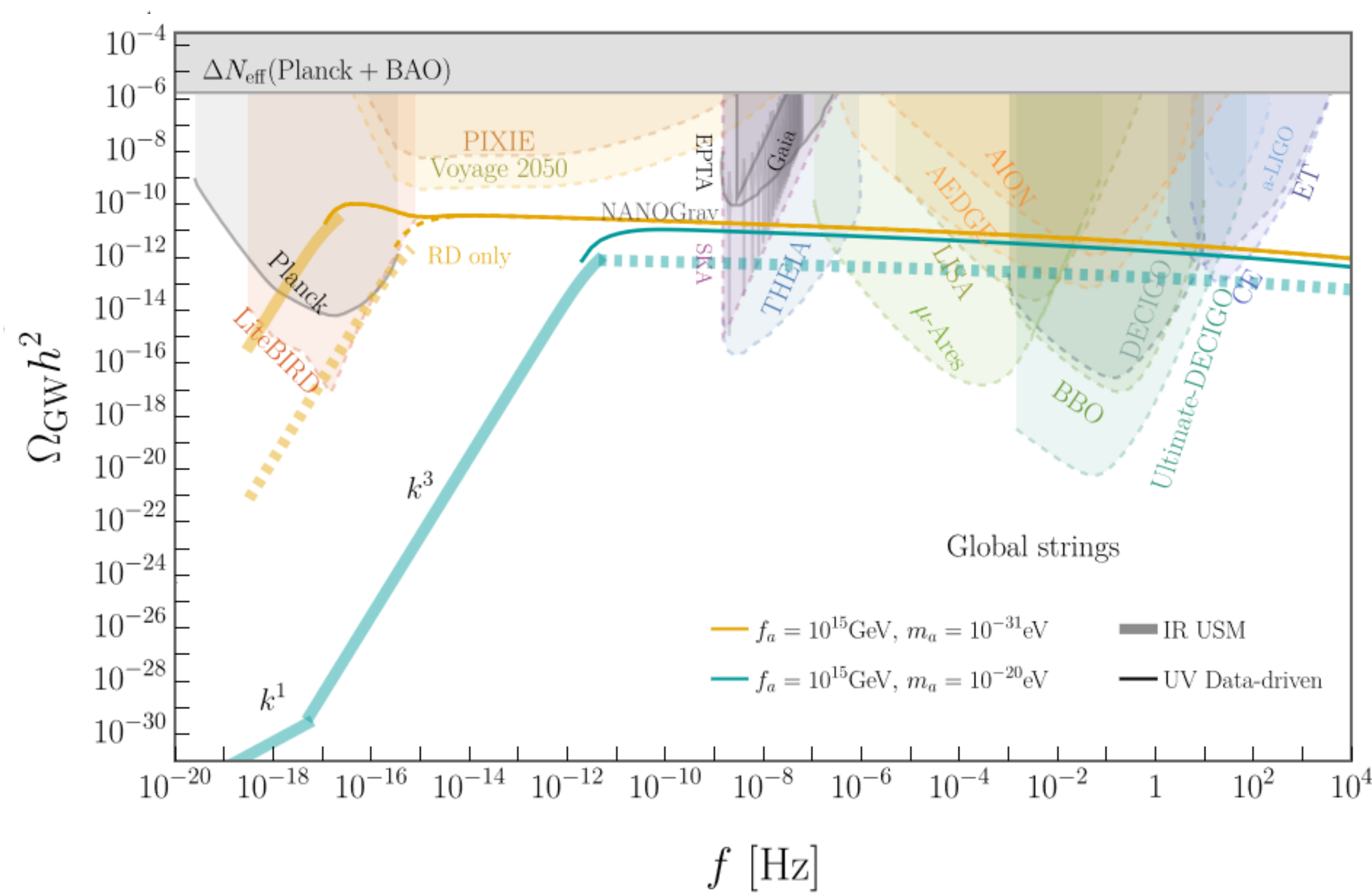
Legends



: UV part from simulation

Results

Global Long Strings and Loops



Legends

- : UV part from simulation
- : IR analytical contribution
- : IR contribution to UV with cutoff

Conclusions

- The constant creation and annihilation of strings produces a GW background
- We model for the first time analytically both long strings and loops* in the IR and match with simulations in the UV
- Impressive agreement with results done from simulations for Gauge Strings
- We leave to future work to see how what imprints they leave on LSS and the CMB

THANK YOU!