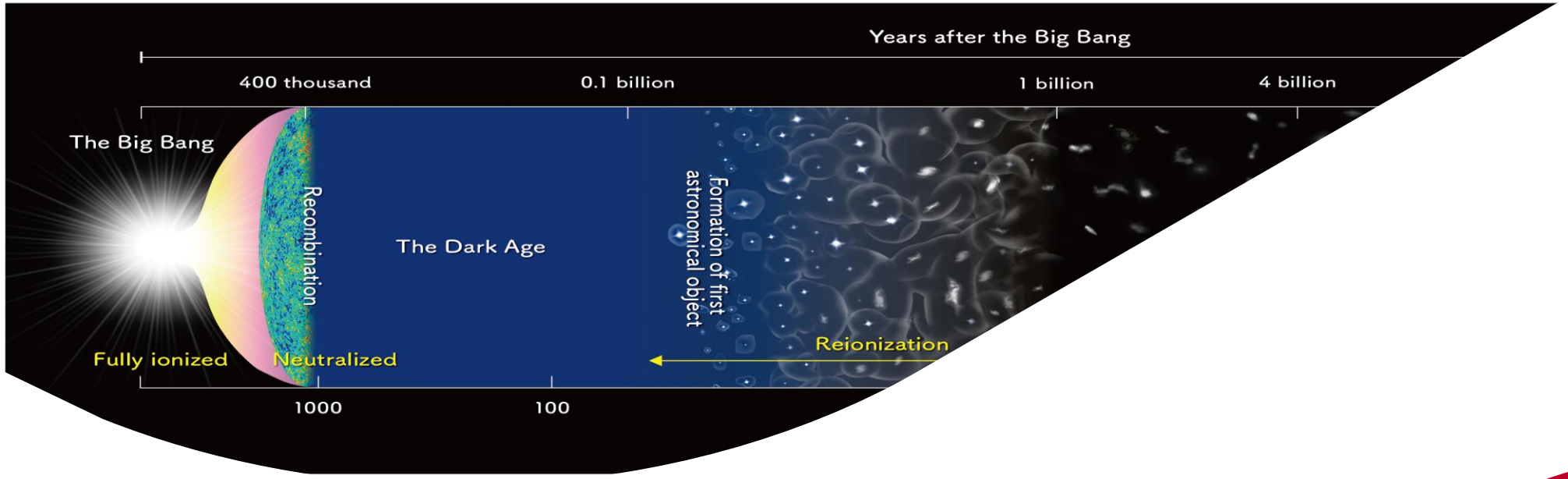
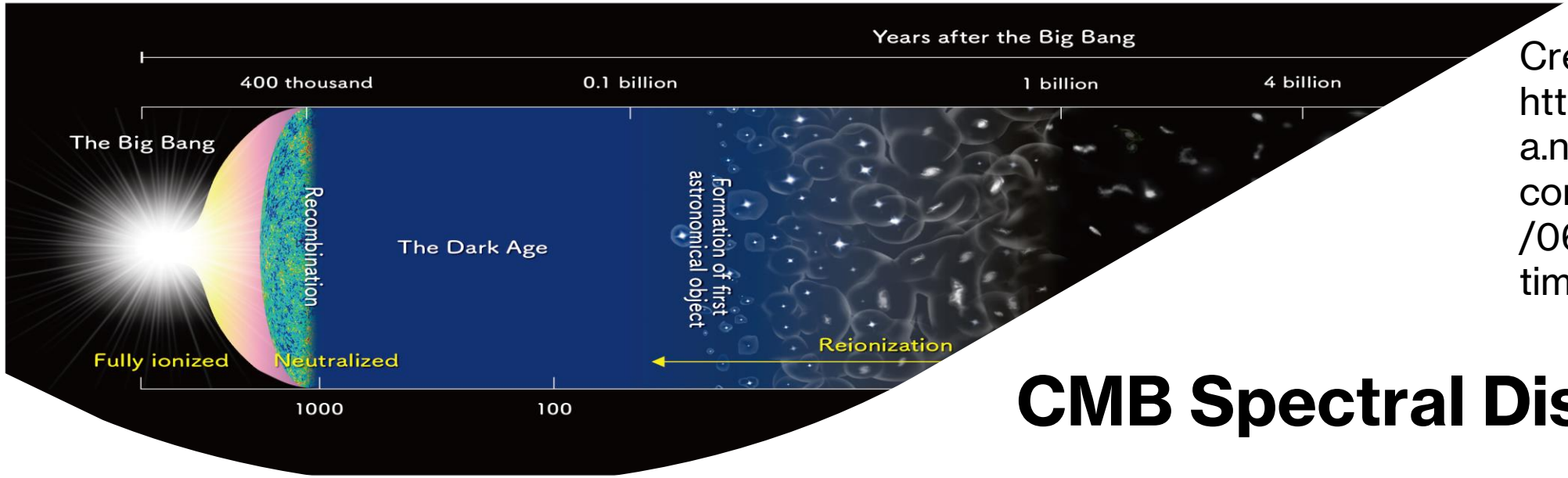


Distortions of the CMB through the Dark

Nicklas Ramberg,

In Collaboration with Wolfram Ratzinger (Weizmann), Pedro Schwaller.

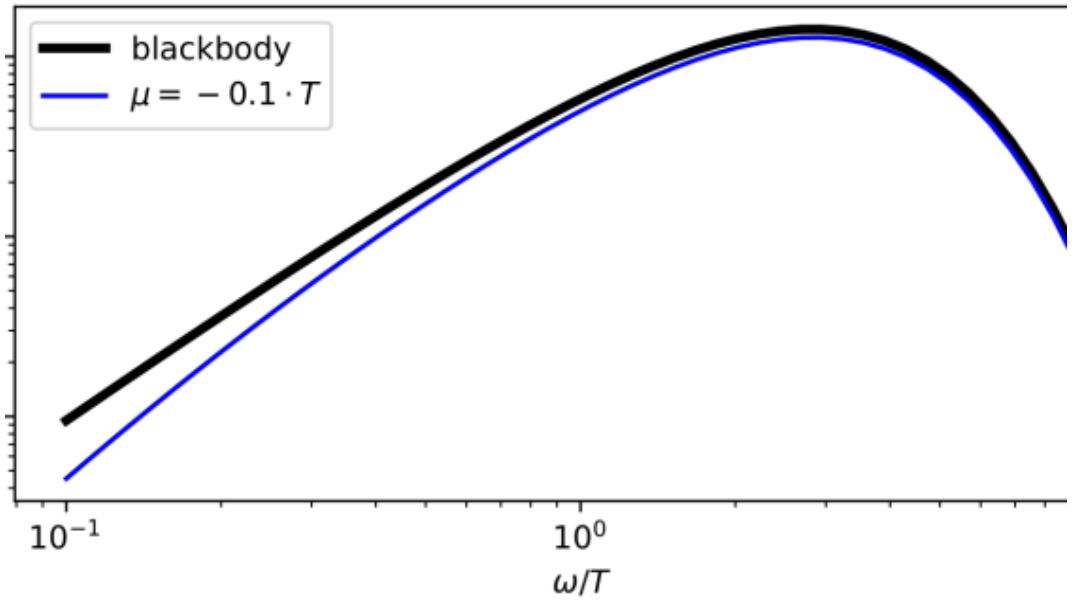
Arxiv:2209.14313



Credit: https://cdn.arstechnica.net/wp-content/uploads/2016/06/Reionization-timeline.jpg

CMB Spectral Distortion?

- CMB has a Blackbody spectrum with T ~ 2.73K.
- Photon-Baryon fluid out of thermal equilibrium
- Spectral Distortion? Deviation from the Black-Body spectrum.
- μ –distortion: chemical potential in CMB BB spectrum $10^1 eV \leq T_\gamma \simeq 10^3 eV$.



Energy Injection: Dark Sector Density Fluctuations

Dark Sector Properties:

Dark Sector Energy Density

$$\Omega_d = \frac{\rho_d}{\rho_\gamma} \ll 1$$

Generation of Fluctuations

$$\tau_* \rightarrow a_*, H_*$$

Characteristic Length Scale

$$L_* \sim \frac{1}{k_*} < \frac{1}{a_* H_*}$$

Amplitude of Fluctuations

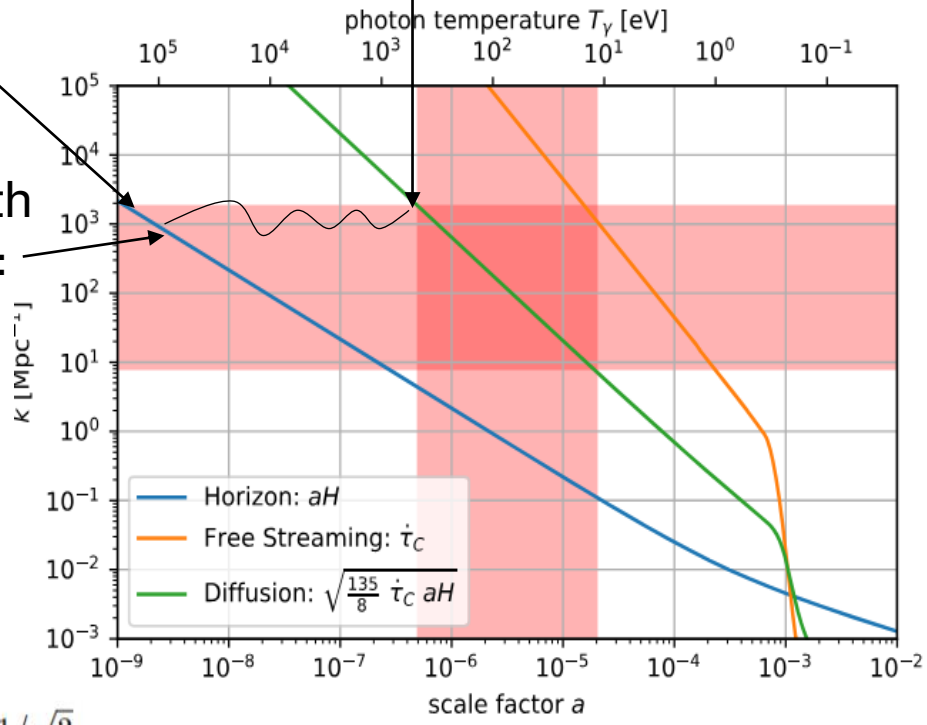
$$\langle \delta_d^2 \rangle = A_{\delta_d}$$

Sound Wave sourced through gravitational interaction.

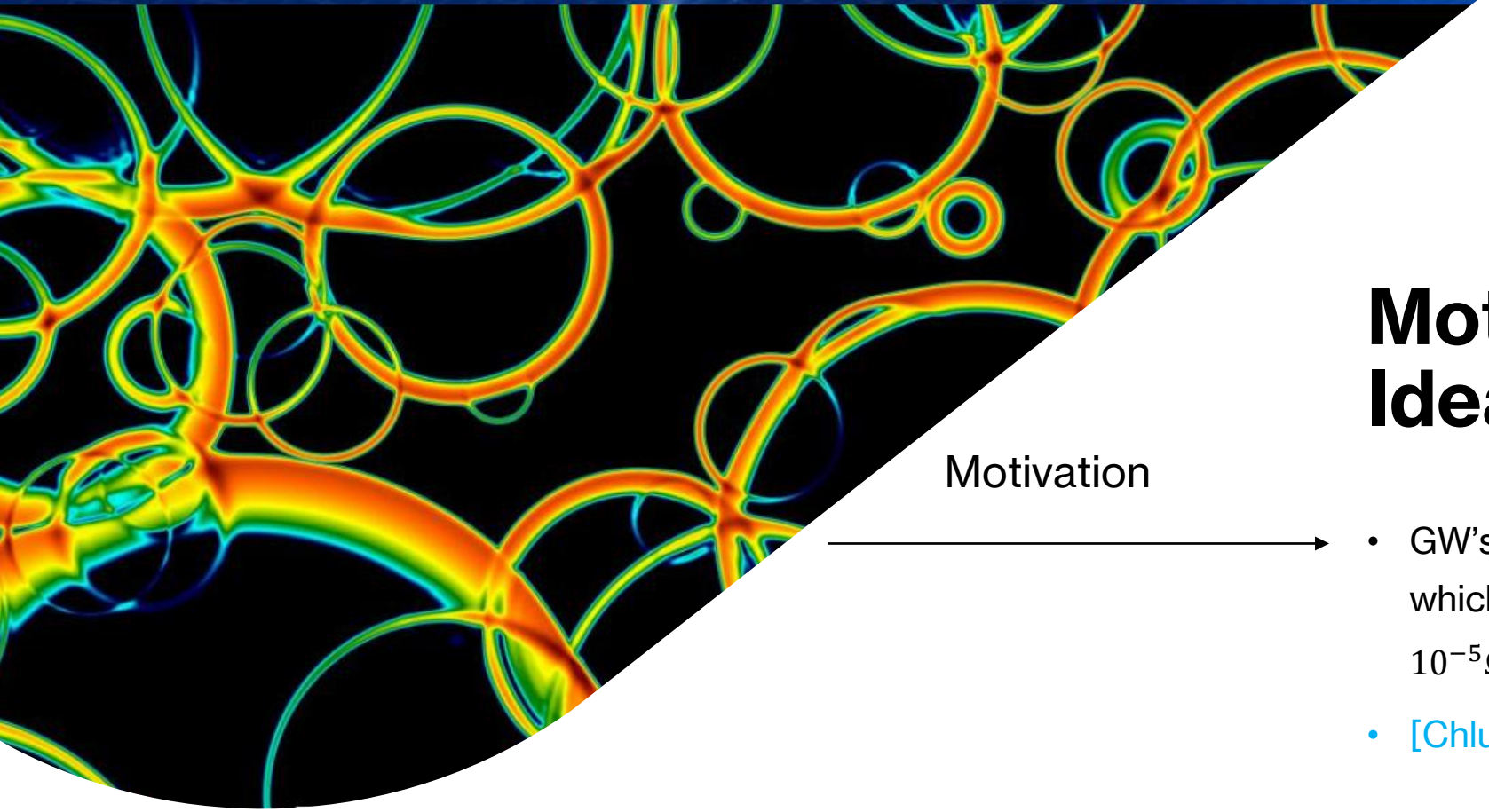
S.W is damped by Diffusion (Silk Damping)

S.W propagates with constant amplitude:

$$\epsilon_{ac,d} = \frac{\rho_{ac}}{\rho_\gamma}.$$



$$\epsilon_{ac}(k) \approx \Omega_{d,*}^2 \, A_{\delta_d} \left(\frac{k}{k_*}\right)^3 \exp\left(-\frac{k^2}{2k_*^2}\right) \left(\frac{a_* H_*}{k}\right)^n \quad \text{with} \quad \begin{cases} n=2 & \text{resonant } c_d = 1/\sqrt{3} \\ n=4 & \text{off resonant } c_D \neq 1/\sqrt{3} \\ n=3 & \text{stochastic} \end{cases}$$



Credit: Weir, et al. , https://ieeexplore.ieee.org/document/4376157.

Motivation

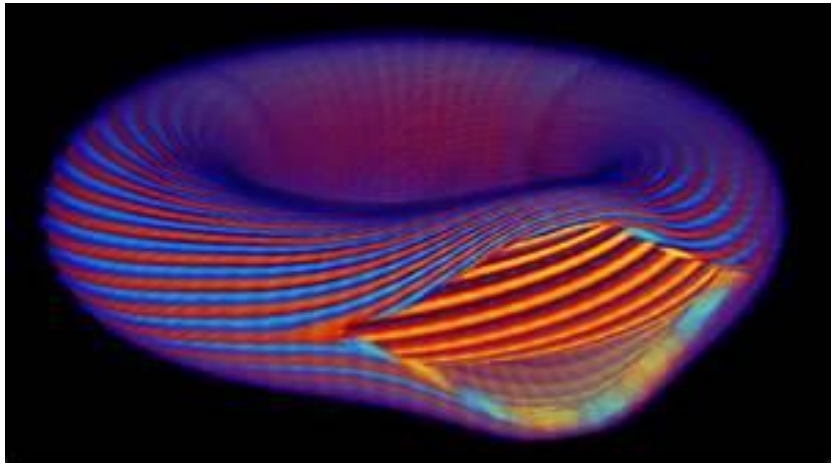
Motivation & Main Idea?

- GW's cause deformation of Plasma which cause it to heat up. $\mu \sim \frac{\rho_{in}}{\rho_\gamma} \simeq 10^{-5}\Omega_{GW}$
- [Chluba, Patil ,et al: 2010.00040]

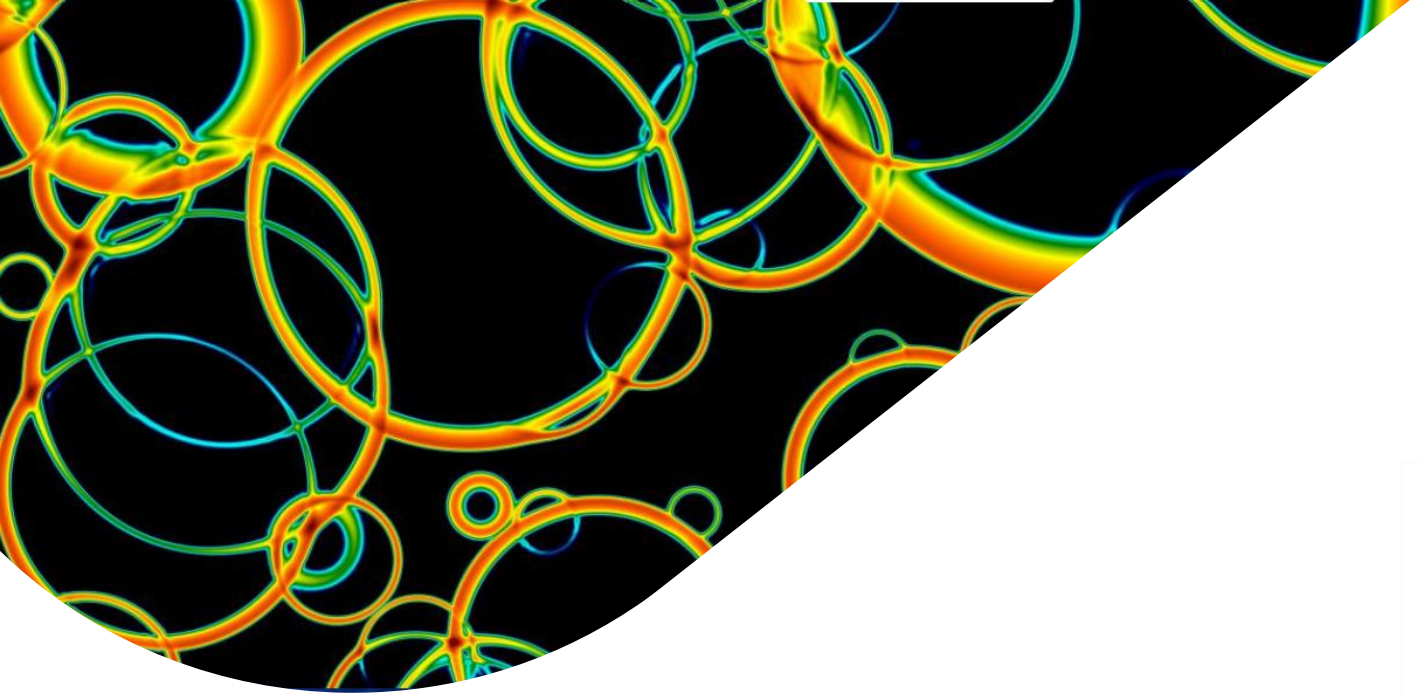
Idea!

S.W in Photon Baryon Fluid $\mu \sim \frac{\rho_{in}}{\rho_\gamma} = \frac{\rho_{ac}}{\rho_\gamma}$. Causes additional Heating!!

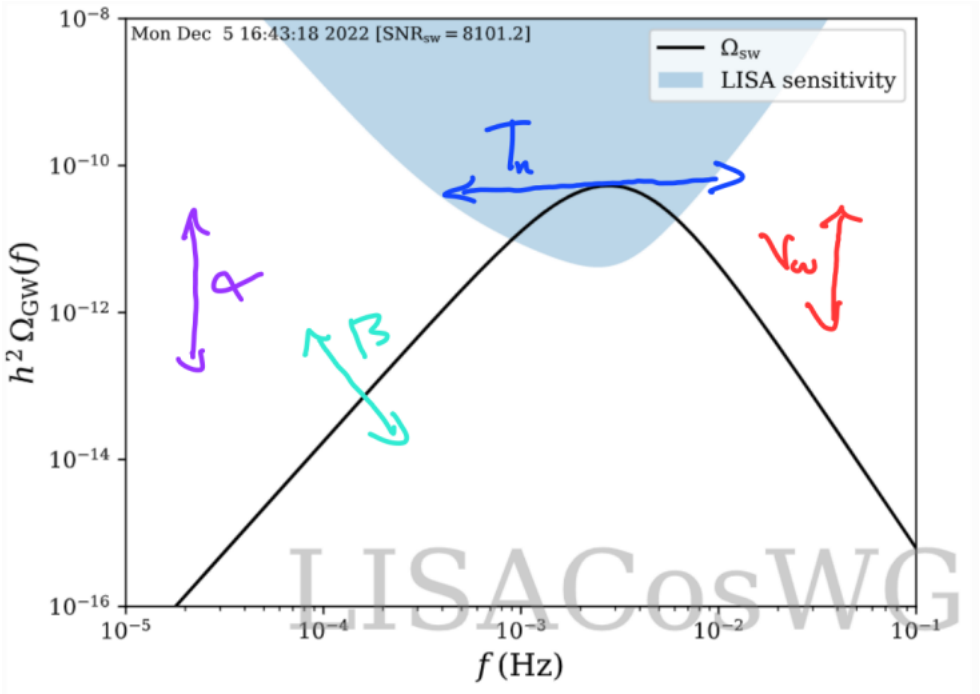
Sources with large density fluctuations prone to emit GWs!



First Order Phase Transition in the Dark Sector

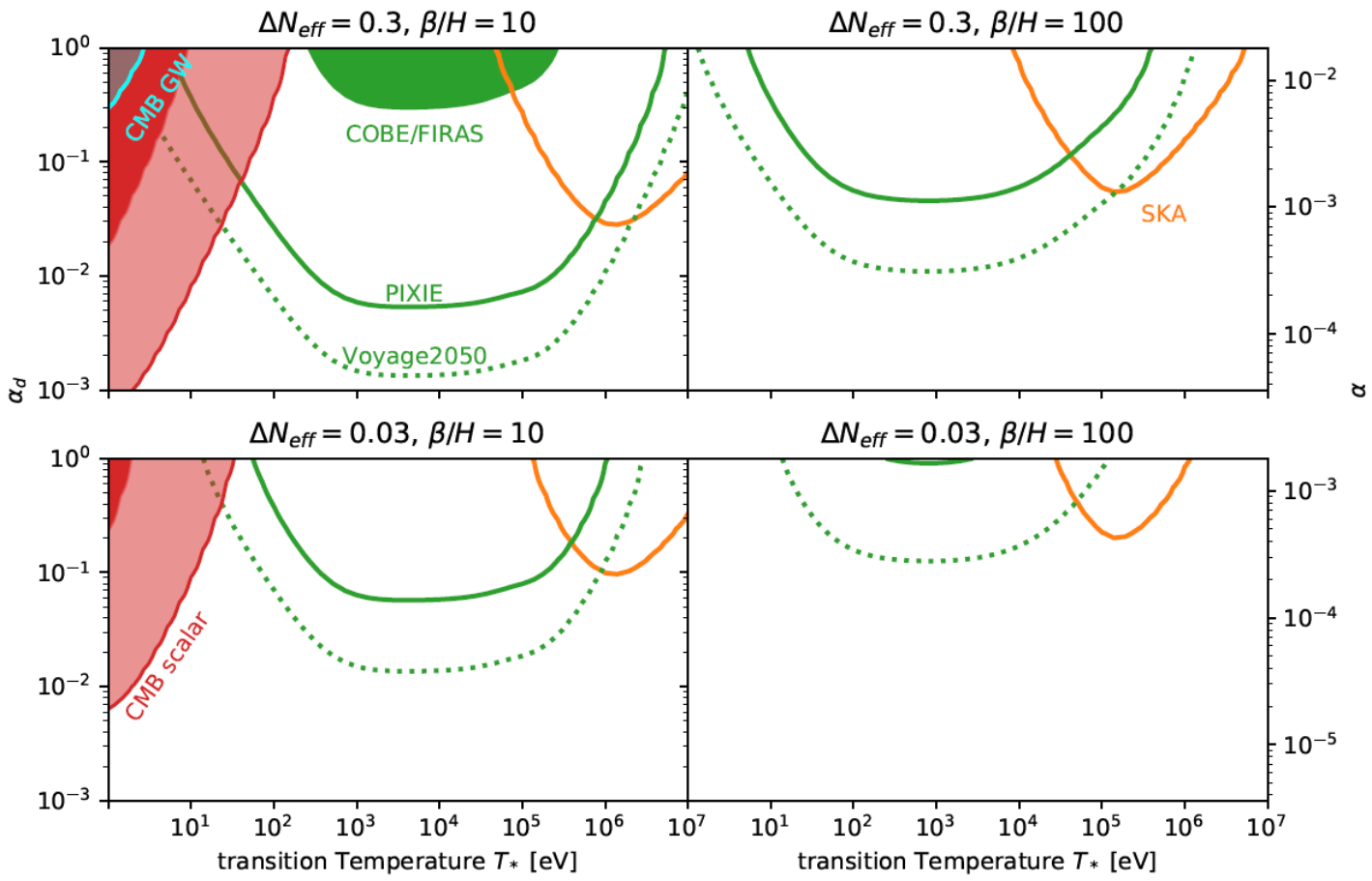


An FOPT in a Dark Sector Fluid is characterized by $(\Omega_D, \alpha_D, T_*, \frac{\beta}{H_*}, v_w)$



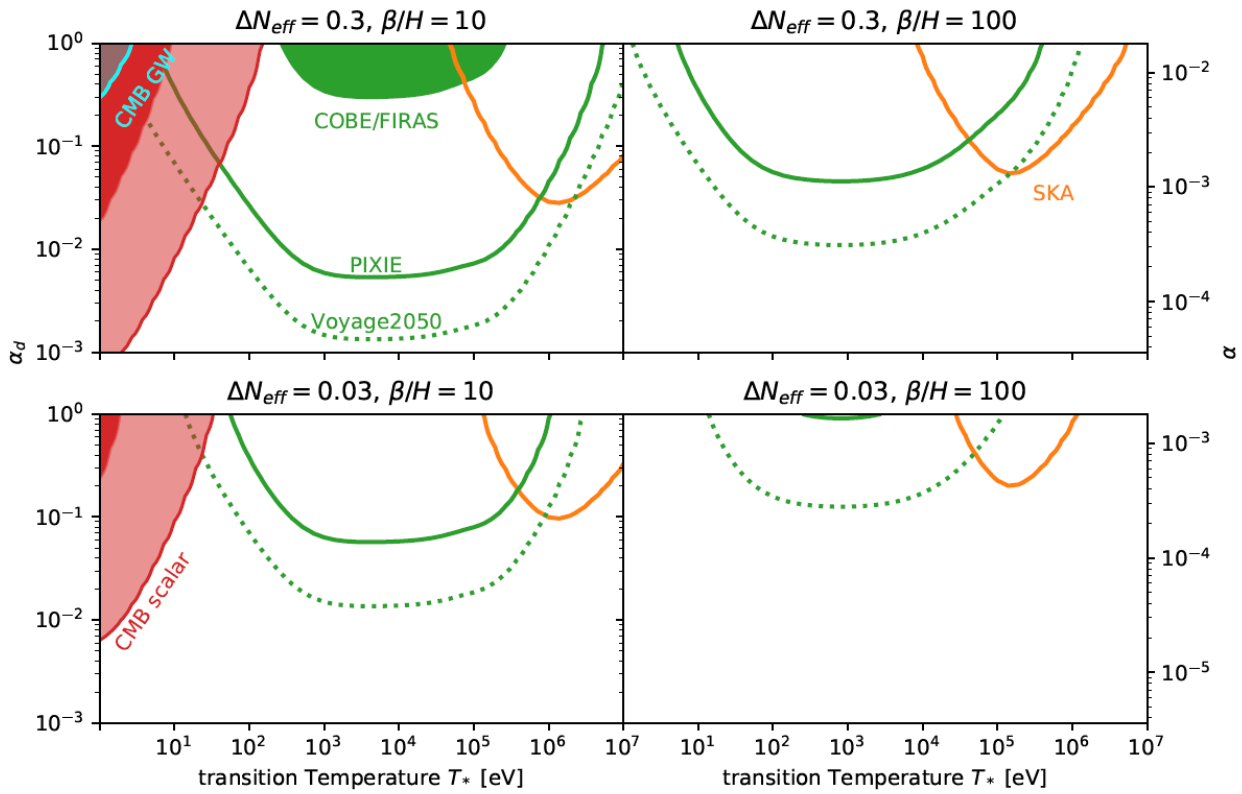
We only consider the Sound Wave contribution of the fluctuations.

First Order Phase Transition in the Dark Sector



Message 1:
Strong bounds
from Distortions!!

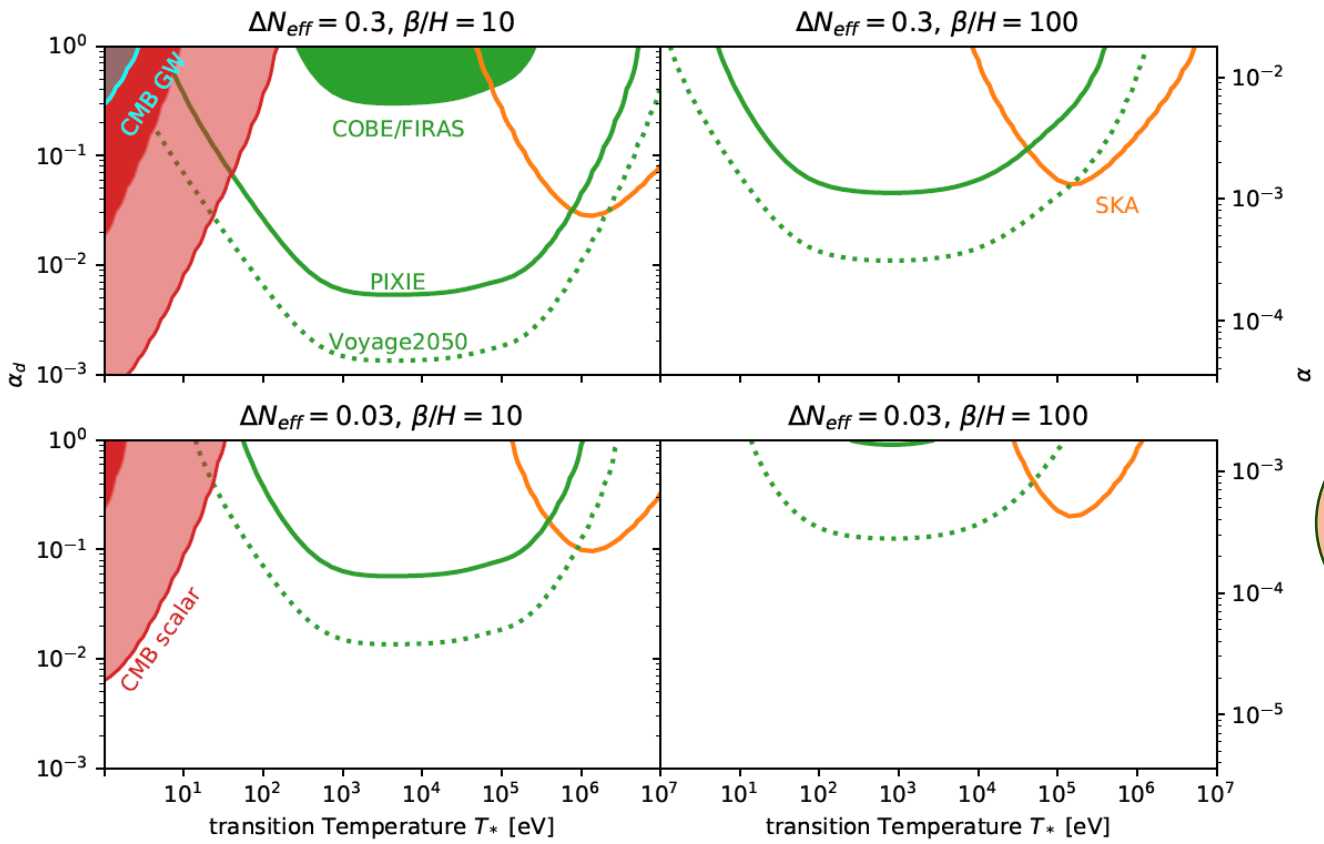
First Order Phase Transition in the Dark Sector



Message 1:
Strong bounds
from Distortions!!

Message 2:
Distortions bridge
the gap between
CMB and PTAs.

First Order Phase Transition in the Dark Sector

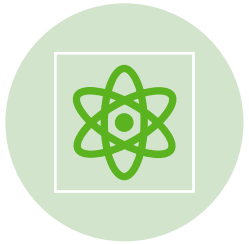


Message 1:
Strong bounds from Distortions!!

Message 2:
Distortions bridge the gap between CMB and PTAs.

Message 3:
Complementarity among distortions and PTAs.

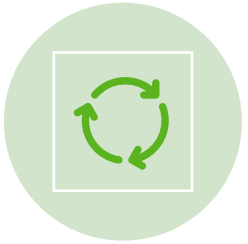
Summary



Powerful new probe for gravitationally coupled sectors!

Multimessenger probe with Gravitational Waves searches PTAs!

Bridges the gap between CMB and PTAs!



We also studied Meta-stable topological defect (DWs/Strings), Tachyonic instability, and reheating dynamics

Thank you for your Attention!!