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Leptogenesis in the presence of density perturbations

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1 Motivation

- In the next 10—20 years, we will have the opportunity to test dynamical processes in the high-energy early universe (e.g. gravitational waves)
- **We need to reconsider processes of particle theory** in such a situation

2 Temperature perturbations

Ref. Baumann, '22

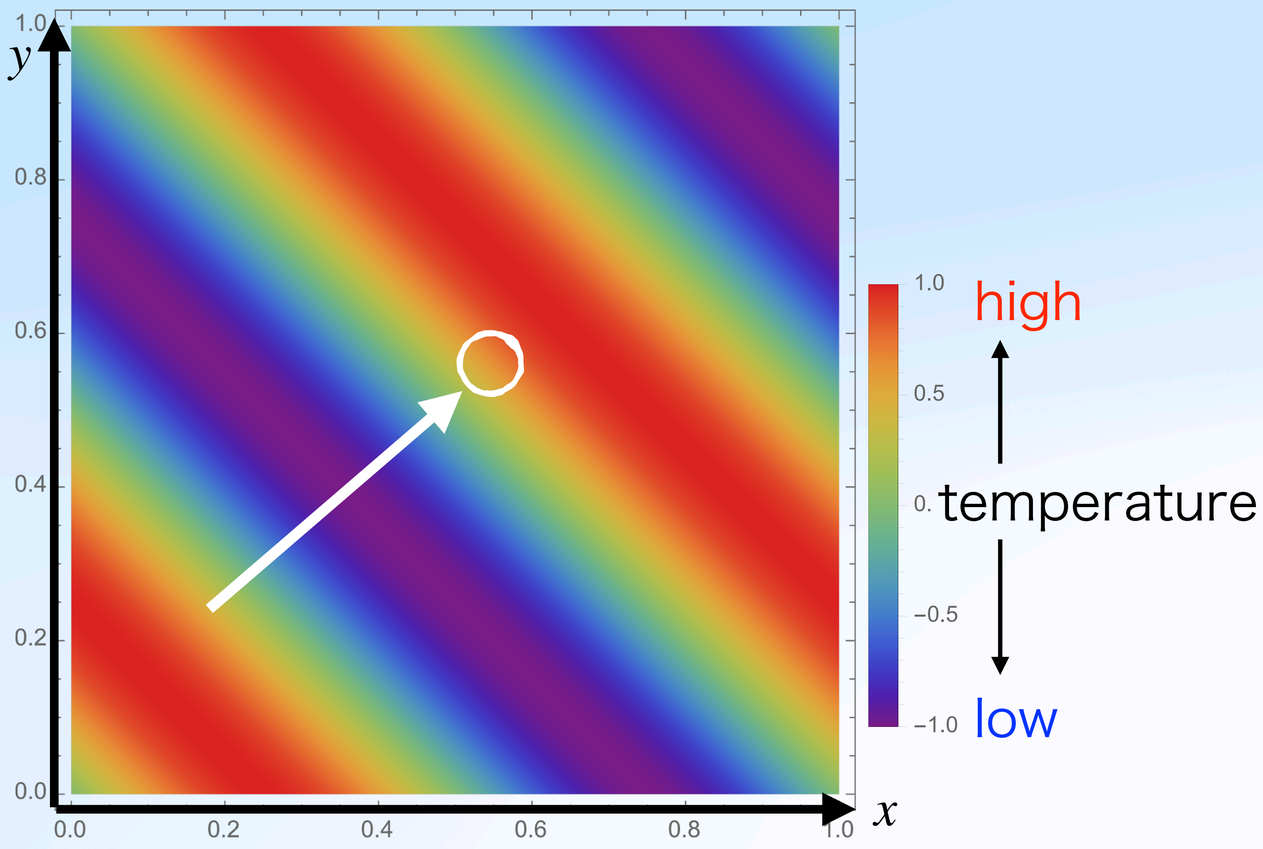
- Temperature perturbations are given by

$$\delta_T = 2\,|\mathcal{R}_i|\cos\delta\,\frac{\sin\varphi-\varphi\cos\varphi-\varphi^2\sin\varphi+\frac{1}{2}\varphi^3\cos\varphi}{\varphi^3}$$

- $|\mathcal{R}_i|$ is the absolute value of primordial curvature perturbation
- φ is the time variable $\varphi=\frac{k\eta}{\sqrt{3}}$, and k is the wavenumber
- In this study, waves are approximated as monochromatic
- δ is the initial phase of temperature perturbations:

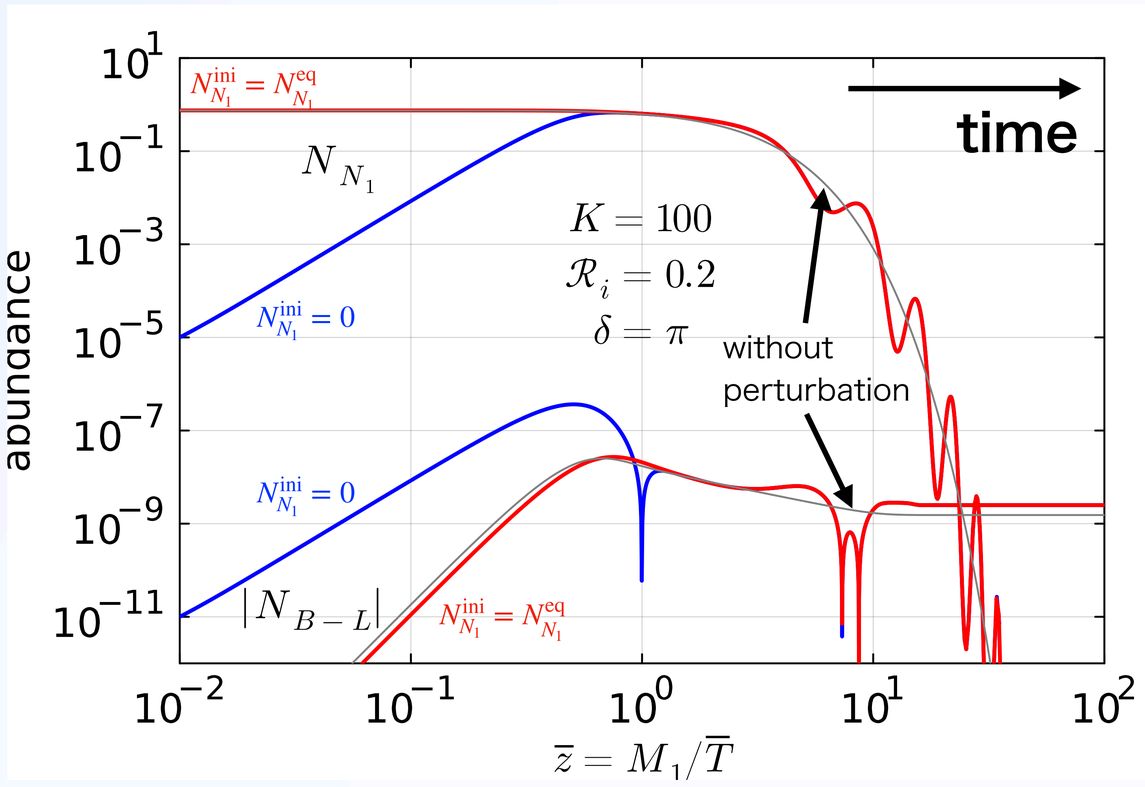
$$\delta=\vec{k}_{\text{sound wave}}\cdot\vec{x}$$

3 Physical meaning of initial phases δ



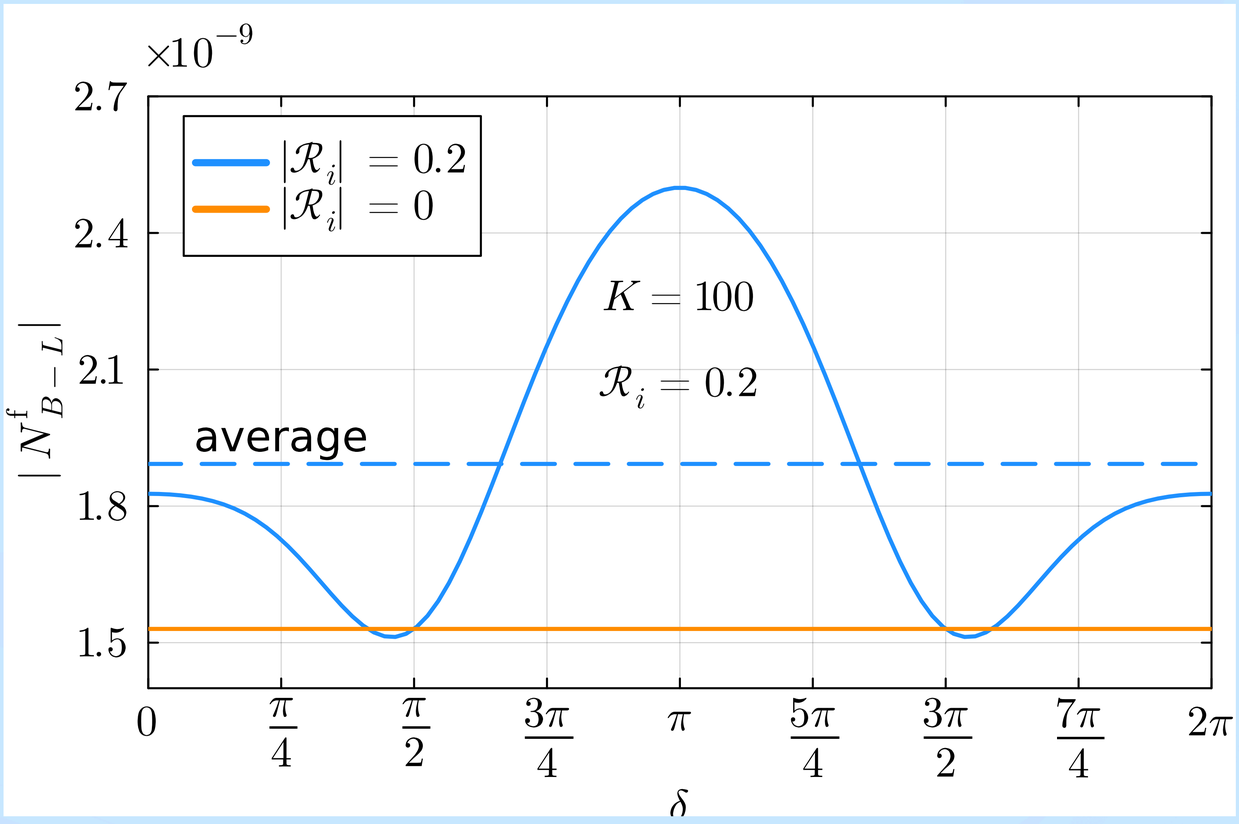
- Each spatial point has a different value at the initial time
- This determines the spatial pattern of high-temperature regions (red) and low-temperature regions (blue)

4 Evolution of RHN N_1 and $B-L$



5 Spatially averaged lepton asymmetry enhancement

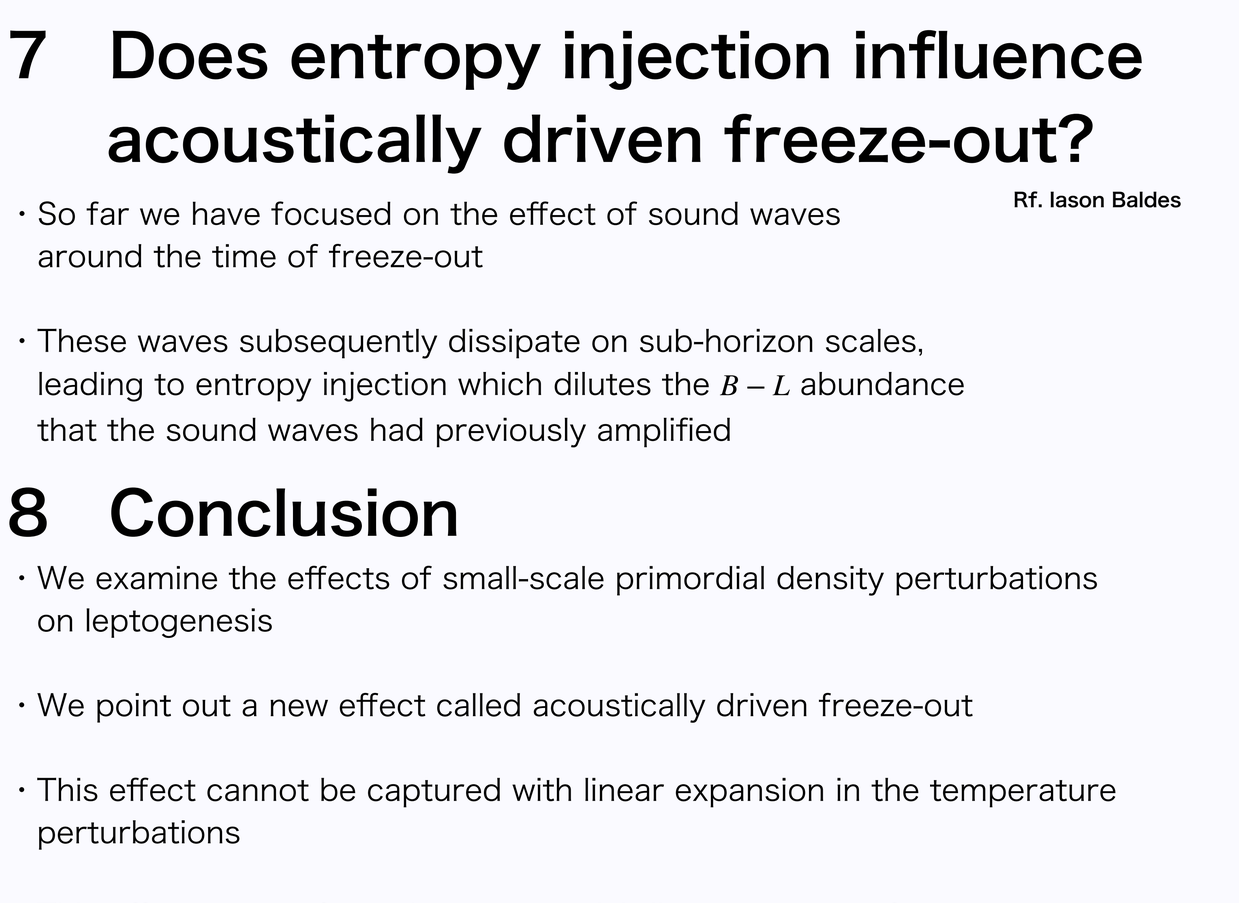
Cf. Iason Baldes arXiv: 2503.02936
(Similar analysis in type-II, III seesaw)



- An increase in the spatially averaged lepton number implies this effect is beyond-linear with respect to perturbations δ_T
- This is called **acoustically driven freeze-out**

6 Mass window: allowed areas of M_1

Ref. Buchmuller, Bari, Plumacher, '03, PDG '22



- With perturbations, allowed areas of RHN mass become broad

7 Does entropy injection influence acoustically driven freeze-out?

Rf. Iason Baldes

- So far we have focused on the effect of sound waves around the time of freeze-out
- These waves subsequently dissipate on sub-horizon scales, leading to entropy injection which dilutes the $B-L$ abundance that the sound waves had previously amplified

8 Conclusion

- We examine the effects of small-scale primordial density perturbations on leptogenesis
- We point out a new effect called acoustically driven freeze-out
- This effect cannot be captured with linear expansion in the temperature perturbations
- This effect comes from the exponential disappearance of RHN from the thermal bath, and **we found that it enhances the final lepton (and thus the final baryon) asymmetry**