Leptogenesis

Primordial Black Holes – Low Scale – Higgs decay – Gauge Boson Scattering

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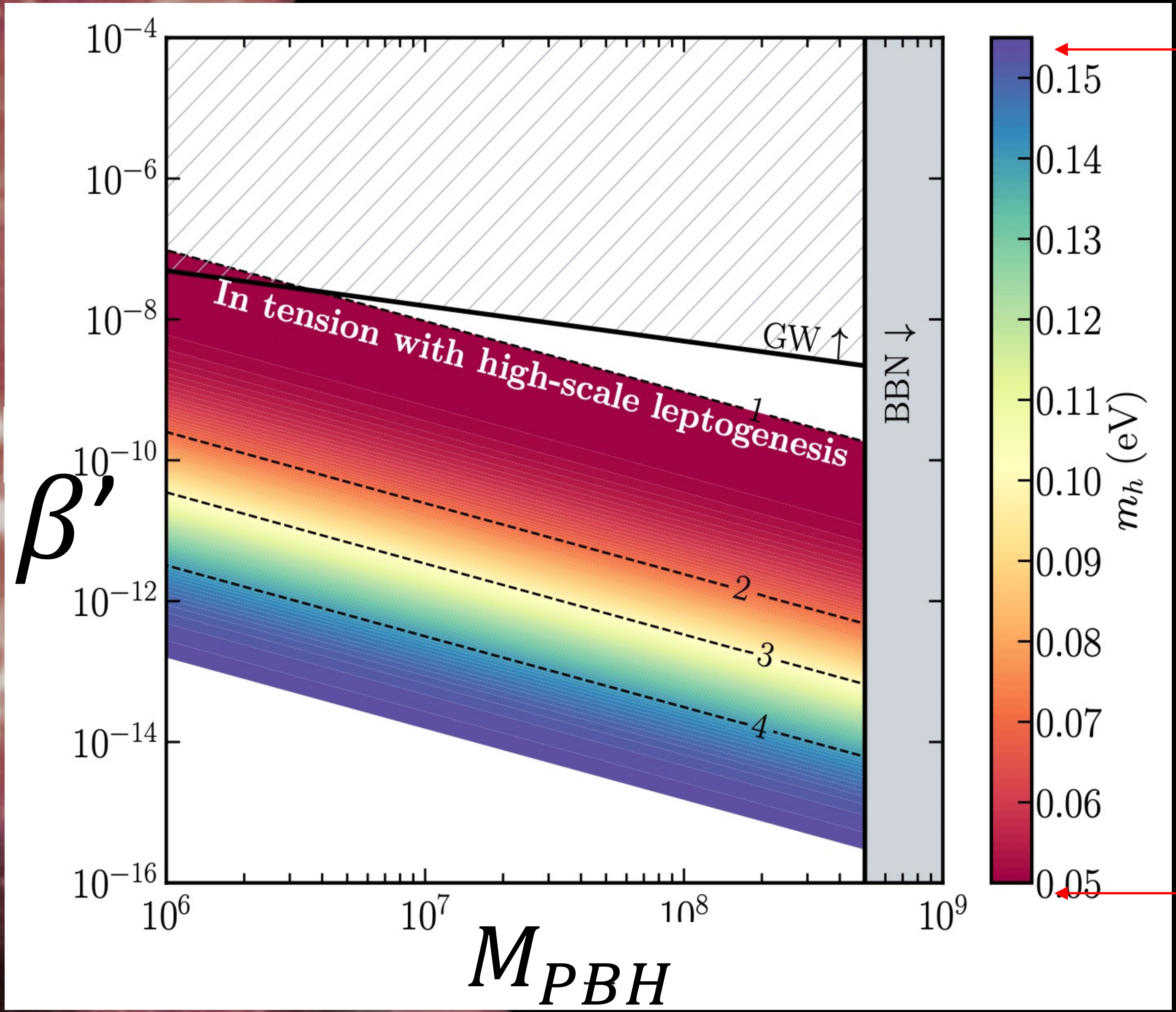
PBHs can exclude leptogenesis (and vice versa)

Calabrese et al. 2305.13369



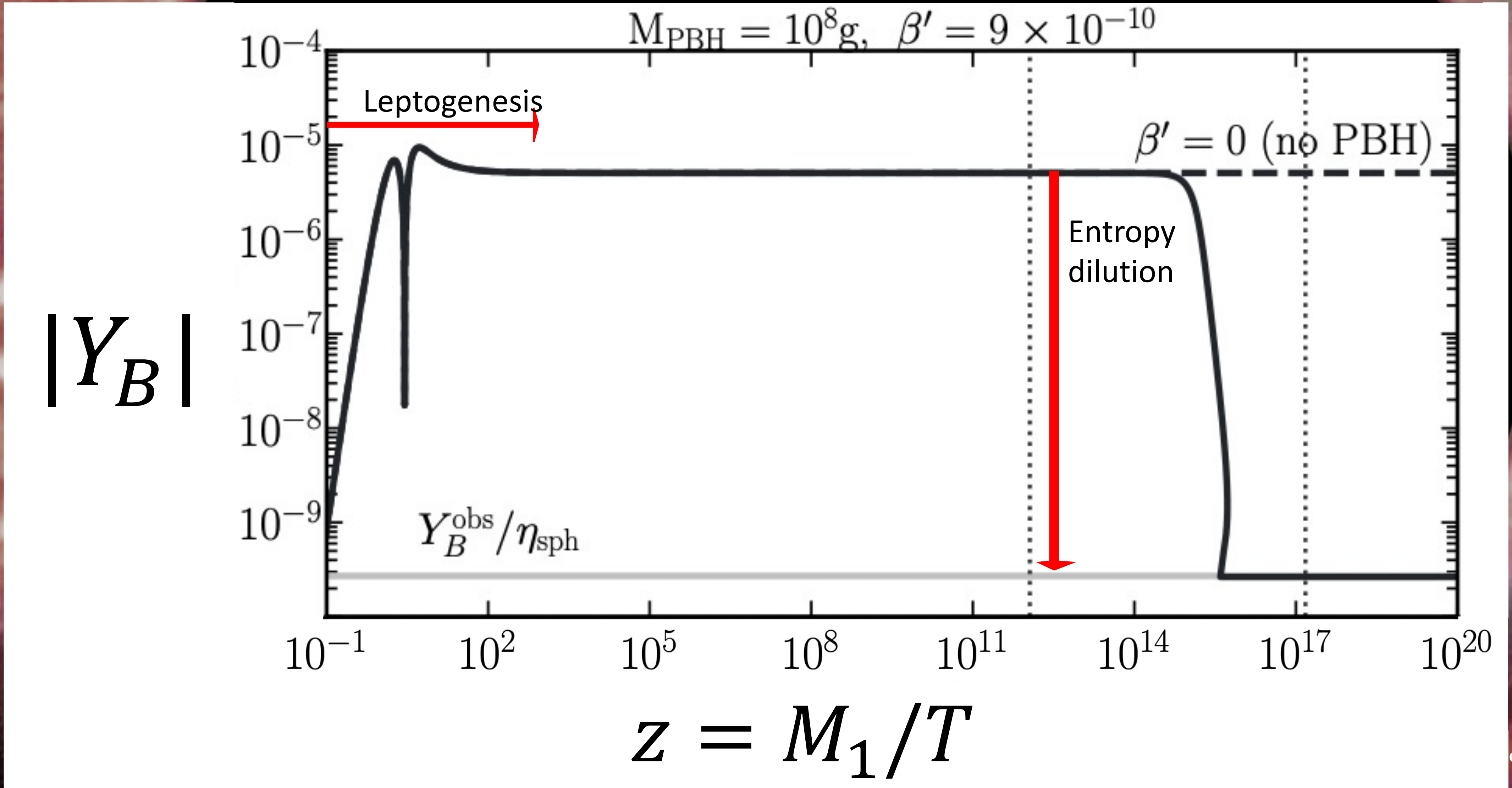
Upper bound for leptogenesis

The mutual exclusion limits become more severe with heavier active neutrino masses

Oscillation data lower bound

The Mechanism

Primary effect: entropy injection



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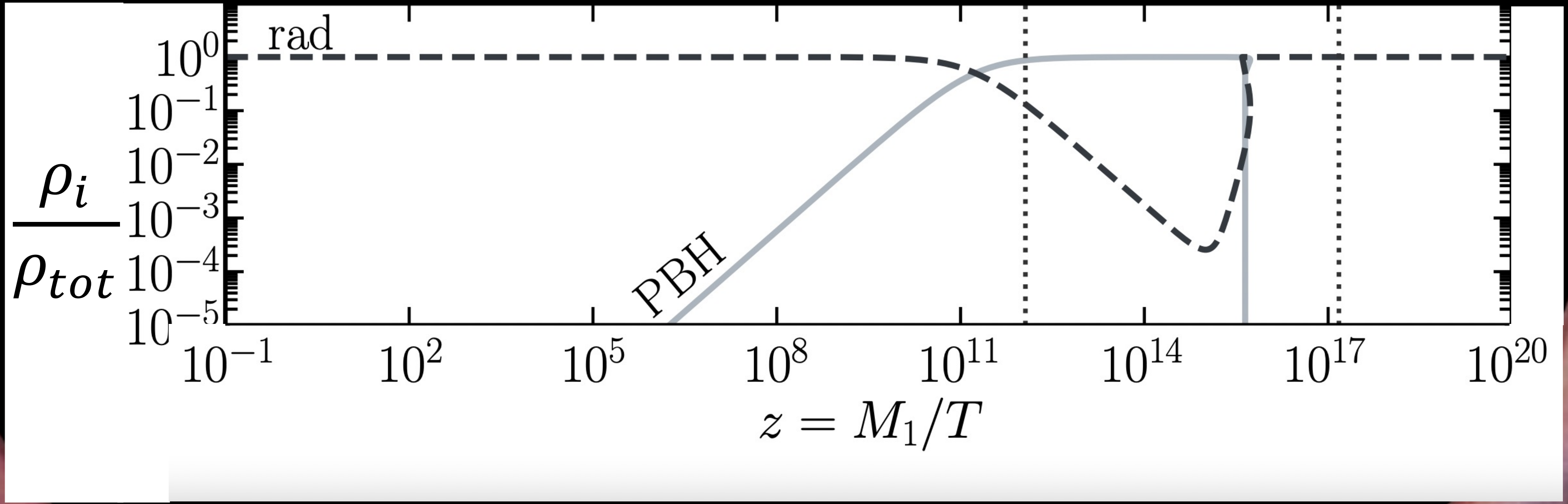
Leptogenesis is unaffected

$$\frac{dY_{B-L}}{d\alpha} = \frac{\ln(10)}{H}\left[\epsilon(\mathcal{N}_{N_1} - \mathcal{N}_{N_1}^{eq})\Gamma^T + \left(\frac{1}{2}\frac{\mathcal{N}_{N_1}^{eq}}{\mathcal{N}_\ell^{eq}}\Gamma^T + \frac{a^3\gamma}{\mathcal{N}_\ell^{eq}}\right)Y_{B-L}\right]$$



No production of RHNs by PBHs

Low scale leptogenesis

Paradigm must be now modified to account for more realistic dynamics

$$zsH\frac{dY_L^{\ell i}}{dz} = \gamma_D\left[\left(\frac{Y_{N_i}}{Y_{N_i}^{\rm eq}}-1\right)\epsilon_{\ell\ell}^i\right] + P_{\ell i}\frac{Y_L^{\ell i}}{Y_\ell^{\rm eq}}\left(\frac{\gamma_N}{2}+2\gamma_{S_t}+\gamma_{S_s}\frac{Y_{N_i}}{Y_{N_i}^{\rm eq}}\right)$$

Flavour effects since the charged lepton Yukawa rates are in Equilibrium

$$\gamma_{N\to LH} = \frac{m_N^3}{\pi^2 z}K_1(z)\,\Gamma_{N\to LH}\ ,$$

$$\gamma_{H\to NL} = \frac{m_H^2\, m_N}{\pi^2 z}K_1\left(\frac{m_H}{m_N}z\right)2\,\Gamma_{H\to NL}$$

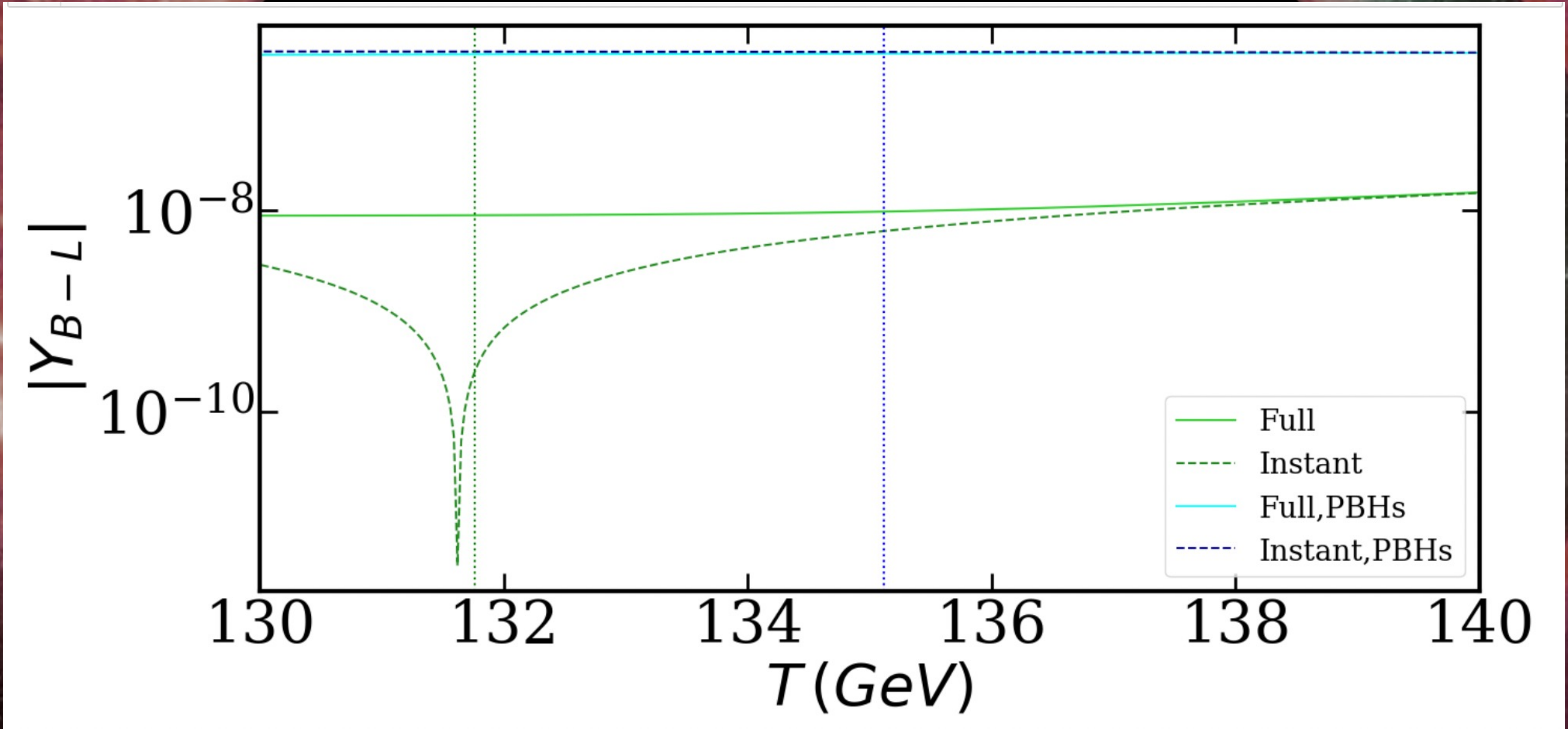
2 to 2 scattering rates involving gauge bosons are now dominant at low temperatures

Specific kinematic possibilities must be tracked accounting for thermal masses and the EWPT

Dynamics at low scale so the normal approximation of instant sphaleron freeze out is no longer valid

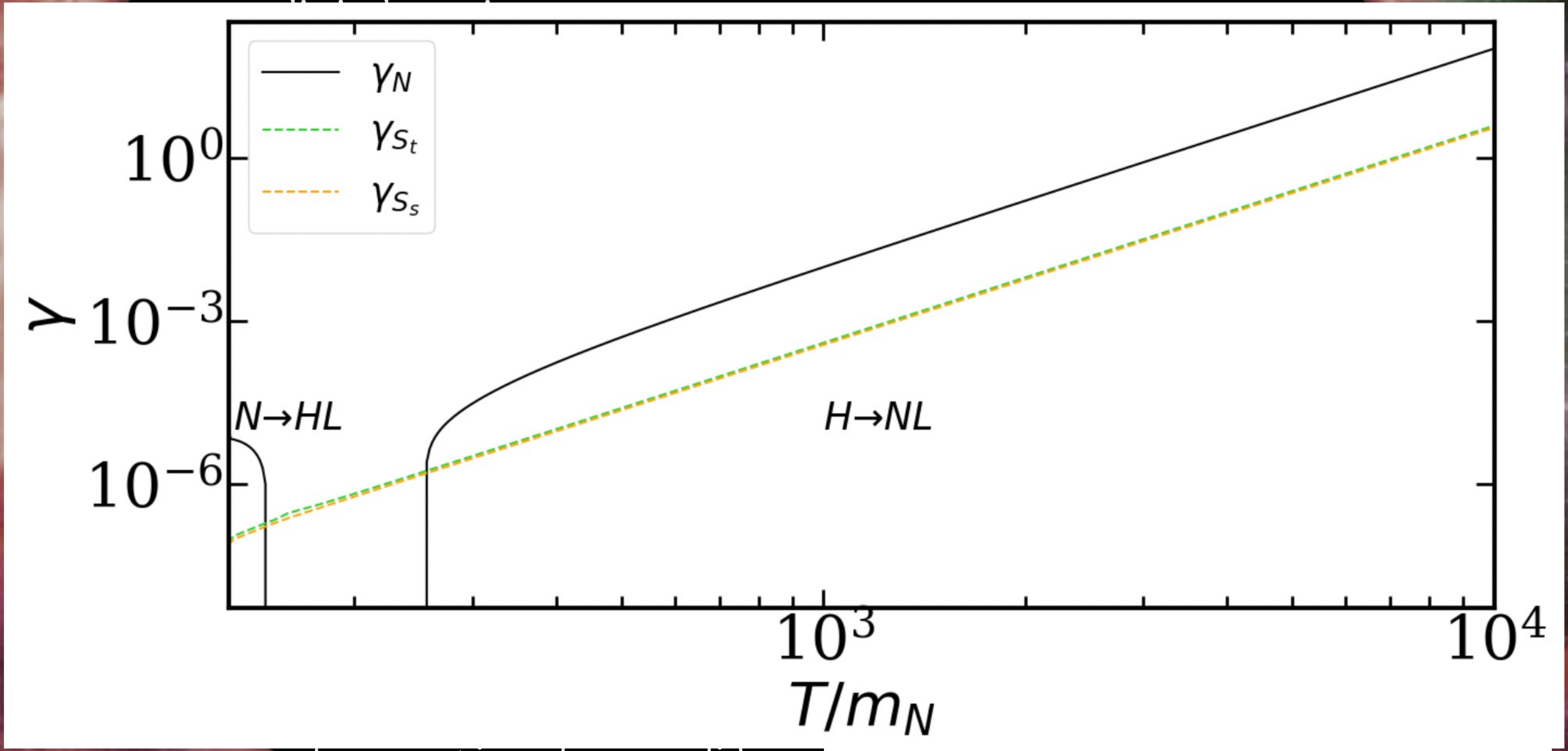
$$\frac{d(B(T))}{dT}\frac{dT}{dt} = -\Gamma_B(T)\left(B(T)+\chi(T)\Delta(T)\right)$$

Low scale leptogenesis



Low scale leptogenesis

Paradigm must be now modified to account for more



freeze out is no longer valid

Entropy dilution

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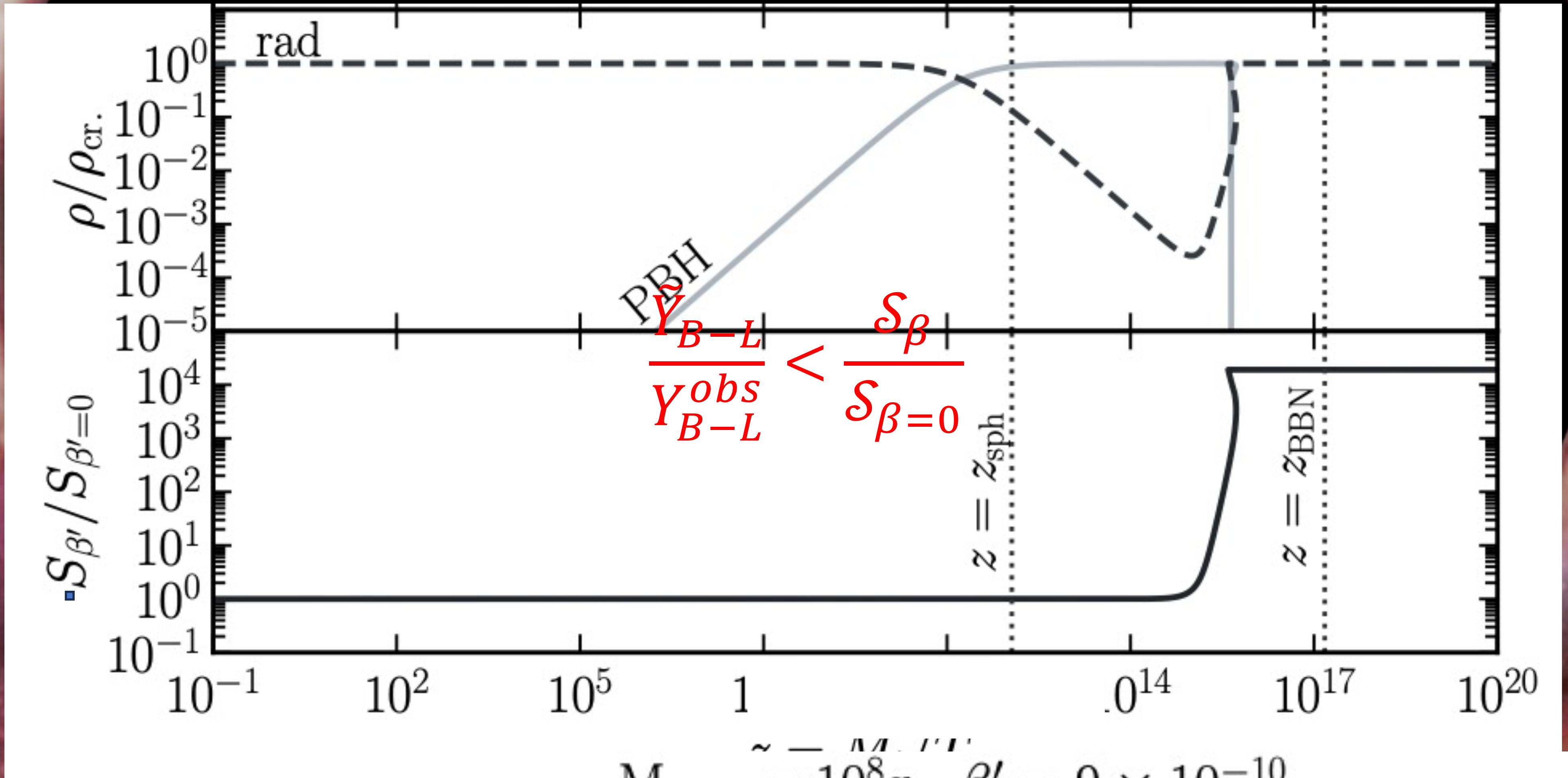
$$Y_{B-L} \equiv \frac{\mathcal{N}_{B-L}}{\mathcal{S}}$$

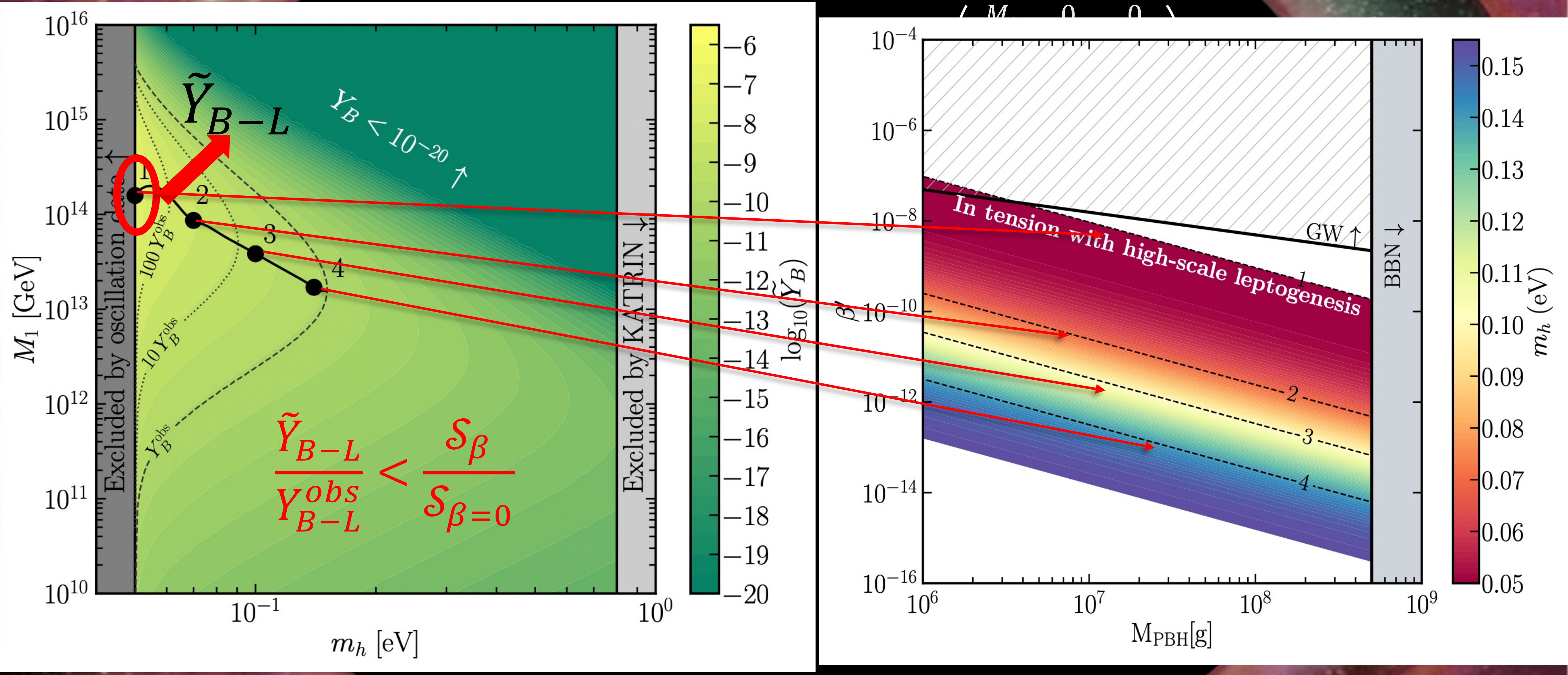
$$\mathcal{S}_{\beta}/\mathcal{S}_{\beta=0}(\beta, M_{PBH})$$

Domination → Evaporation



$$\frac{Y_{B-L}}{Y_{B-L}^{obs}} < \frac{\mathcal{S}_{\beta}}{\mathcal{S}_{\beta=0}}$$

The maximum asymmetry



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Conclusions

PBHs in the mass range $10^6 g \leq M_{PBH} < 10^9 g$
do evaporate long after leptogenesis concludes

Their evaporation is assosciated with a sudden and potentially huge injection of entropy

High scale leptogenesis has a maximum achievable asymmetry

If the PBHs inject enough entropy to dilute away this maximum, the PBHs and leptogenesis are in tension

We show that even tiny populations of PBHs can be excluded by leptogenesis and vice versa

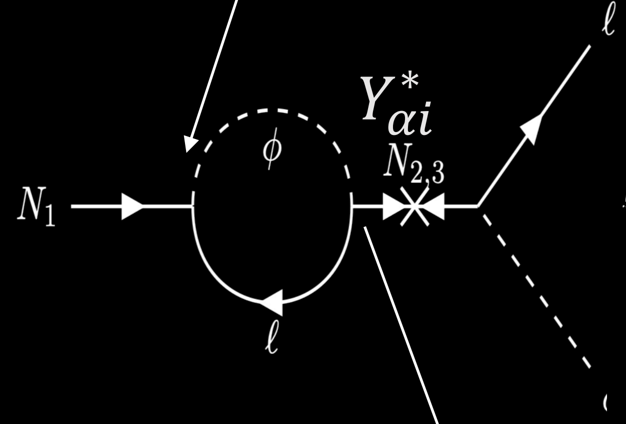
High scale leptogenesis

The SM is extended by 3 singlet fermions

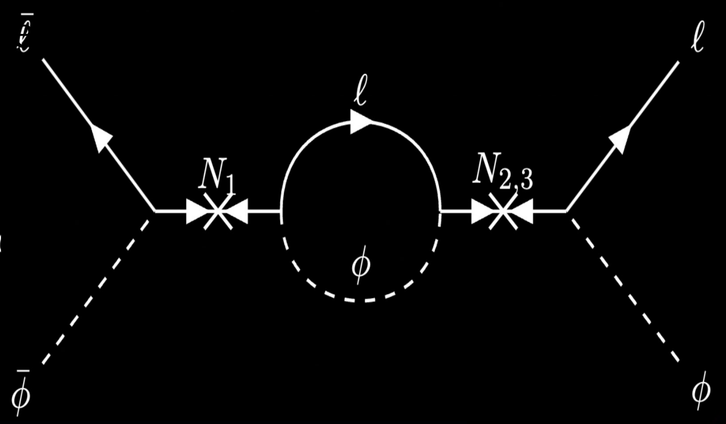
$$\mathcal{L}_N = -\frac{1}{2}\bar{N}^c \hat{M} N \; - Y\bar{\ell}\widetilde{\Phi}N + h.c.$$

$$\begin{pmatrix} M_1 & 0 & 0 \\ 0 & M_2 & 0 \\ 0 & 0 & M_3 \end{pmatrix}$$

$$M_1 \ll M_{2,3}$$



Washout processes work to erase the asymmetry



$$Y = \frac{1}{v_{EW}}\sqrt{\hat{M}} \cdot R \cdot \sqrt{\hat{m}_\nu} \cdot U^\dagger_{PMNS}$$

Casas-Ibarra parameterisation,

we take $\Delta m^2{}_{sol} \ll \Delta m^2{}_{atm}$

$R = R_{13}(\theta_{13} = x + iy)$

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