NEUTRINO FLAVOR TRANSFORMATION AND THE COSMIC LEPTON ASYMMETRY

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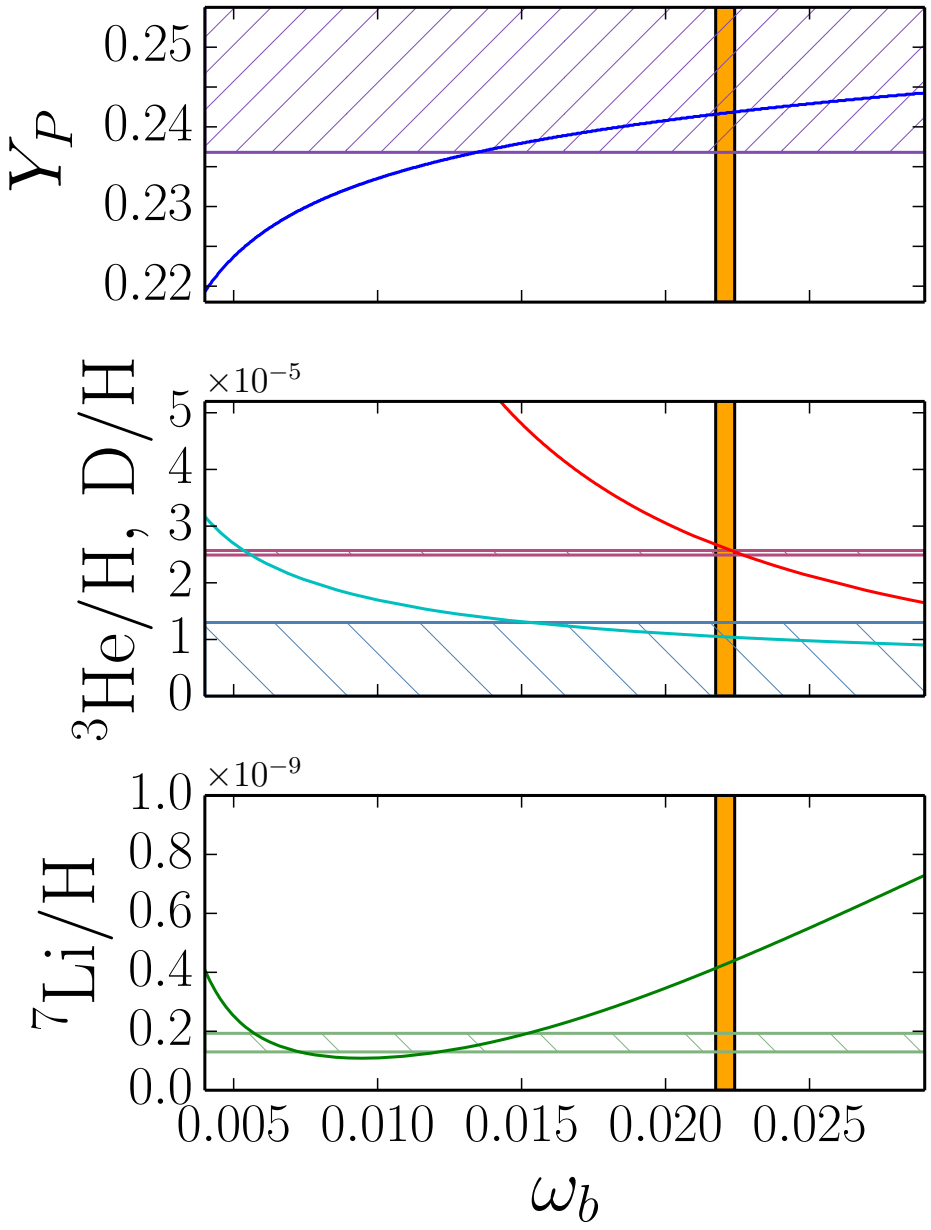
BBN and the CMB agree on the **baryon asymmetry**:

$$\eta \equiv \frac{n_B}{n_\gamma} \approx 6 \times 10^{-10}$$



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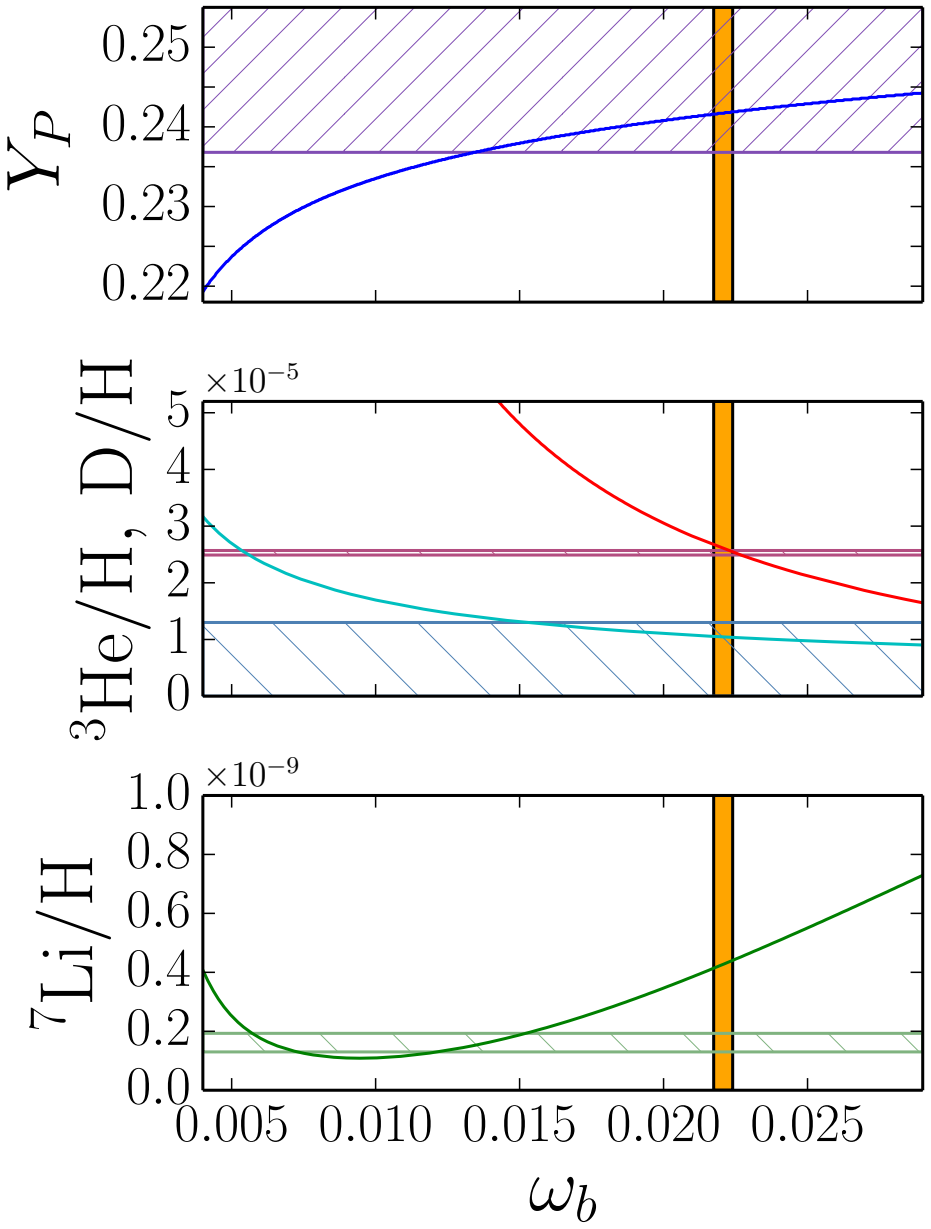

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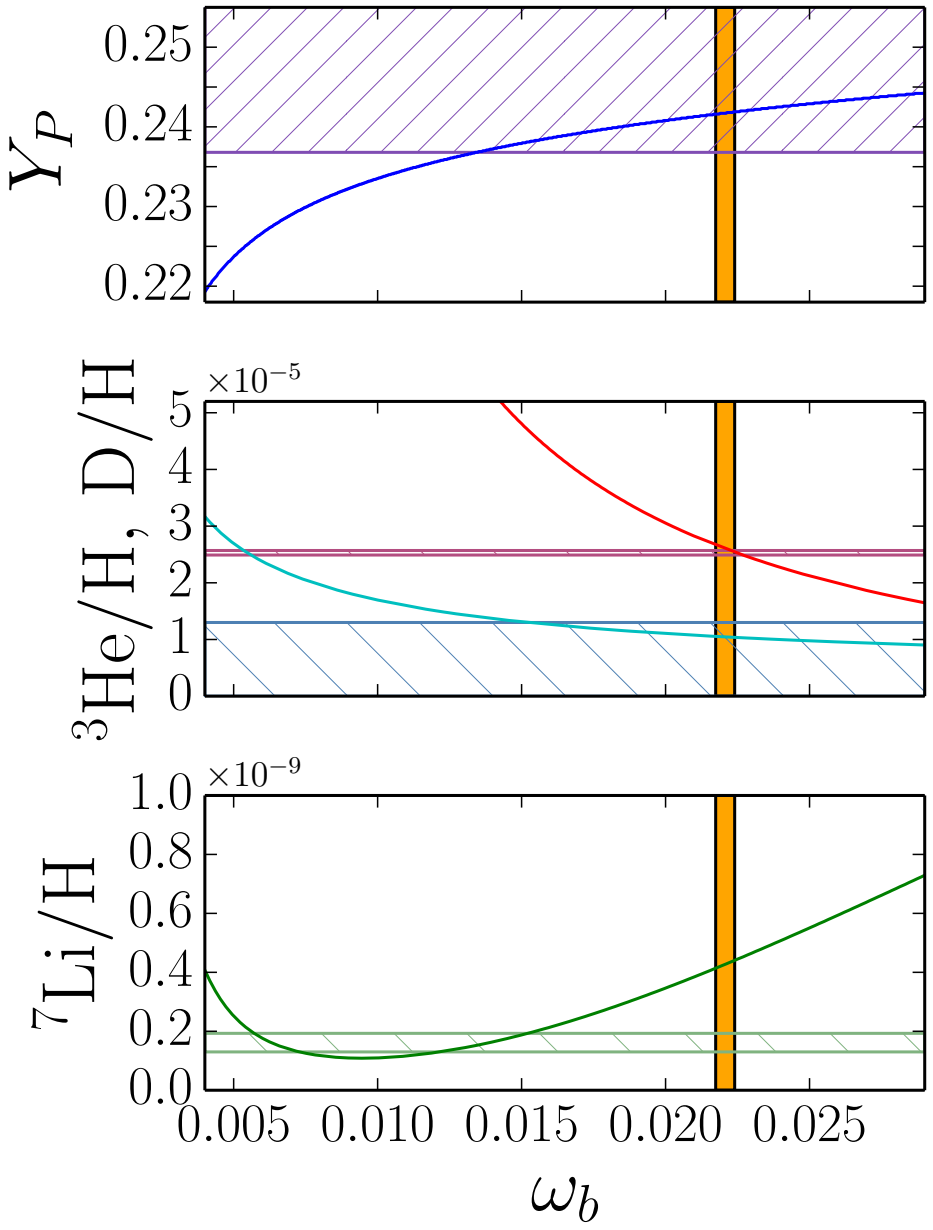

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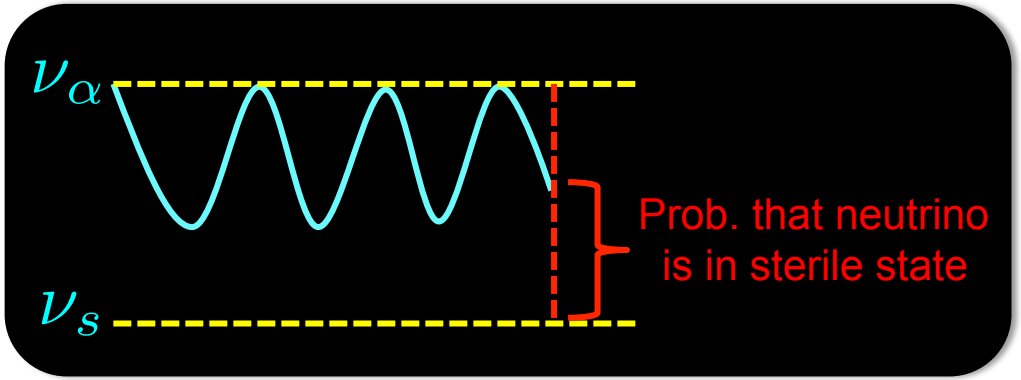
Lepton numbers much larger than the baryon asymmetry are utilized in a viable production scenario for **sterile neutrino dark matter**.



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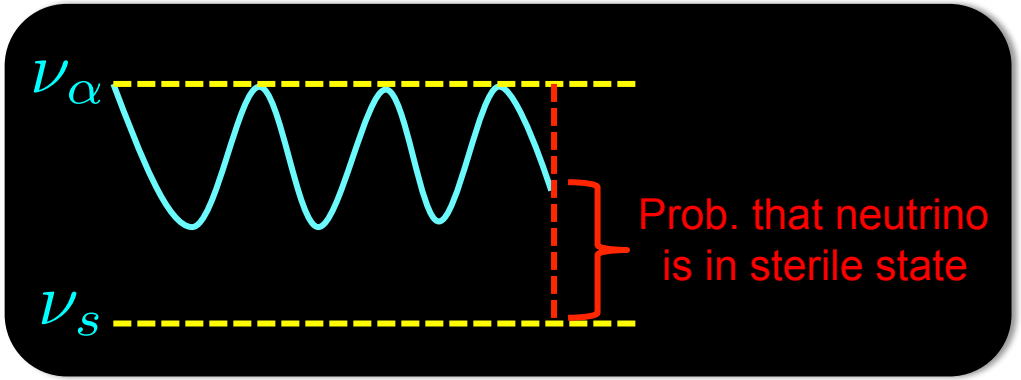

baryon asymmetry

The Standard Model struggles; **leptogenesis** is promising.

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A lepton number **modifies the way neutrino flavor evolves**.
(See next slide.)

Lunardini & Smirnov 2001
Dolgov et al. 2002
Abazajian et al. 2002
Wong 2002
Pastor et al. 2009
Gava & Volpe 2010
Mangano et al. 2011
Mangano et al. 2012
Castorina et al. 2012

Moreover, **BBN** is **sensitive to both lepton number and flavor**:

- An asymmetry drives a faster expansion rate.

$$\nu_e + n \rightleftharpoons p + e^-$$

- $\bar{\nu}_e + p \rightleftharpoons n + e^+$

$$n \rightleftharpoons p + e^- + \bar{\nu}_e$$

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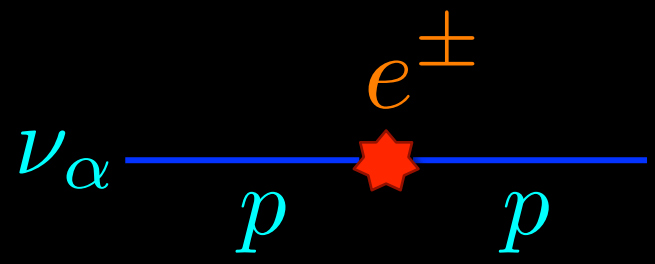
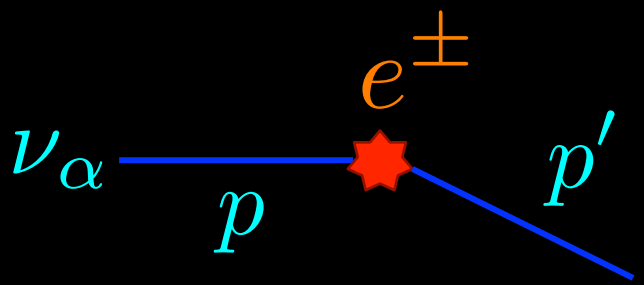
Neutrinos oscillate even in vacuum.
But things get more interesting in medium…





dominates at **low** temp.

"coherent"
$\sim G_F$

"incoherent"
$\sim G_F^2$

dominates at **high** temp.

$$i\left(\partial_t - Hp\partial_p\right)\rho = [\mathcal{H}, \rho] + \mathcal{C}$$

The coherent term is like a nonlinear, matrix-structured index of refraction:

Lepton asymmetry

$$\mathcal{H} \sim \mathcal{H}_{\rm osc} + \int (\rho - \bar{\rho})$$

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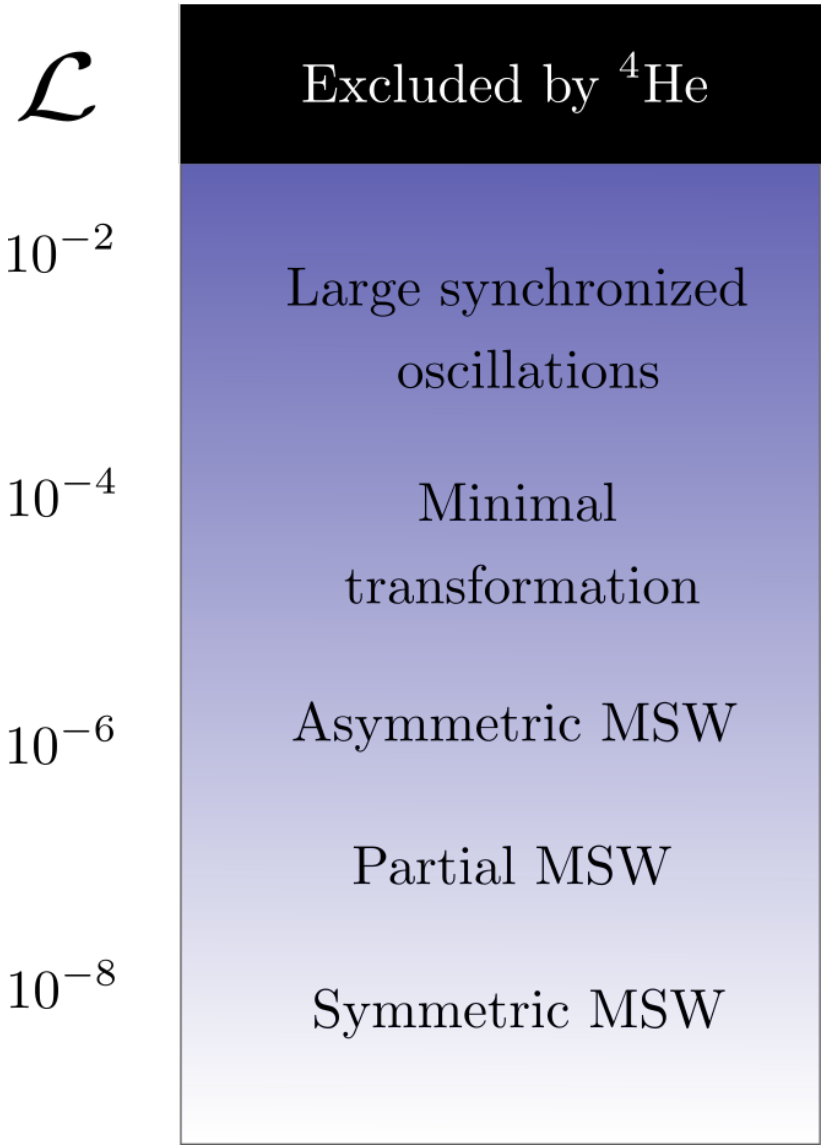
Our calculations have revealed a menagerie of different behaviors for sub-constraint lepton asymmetries…



Johns, Mina, Cirigliano, Paris, and Fuller, PRD 2016

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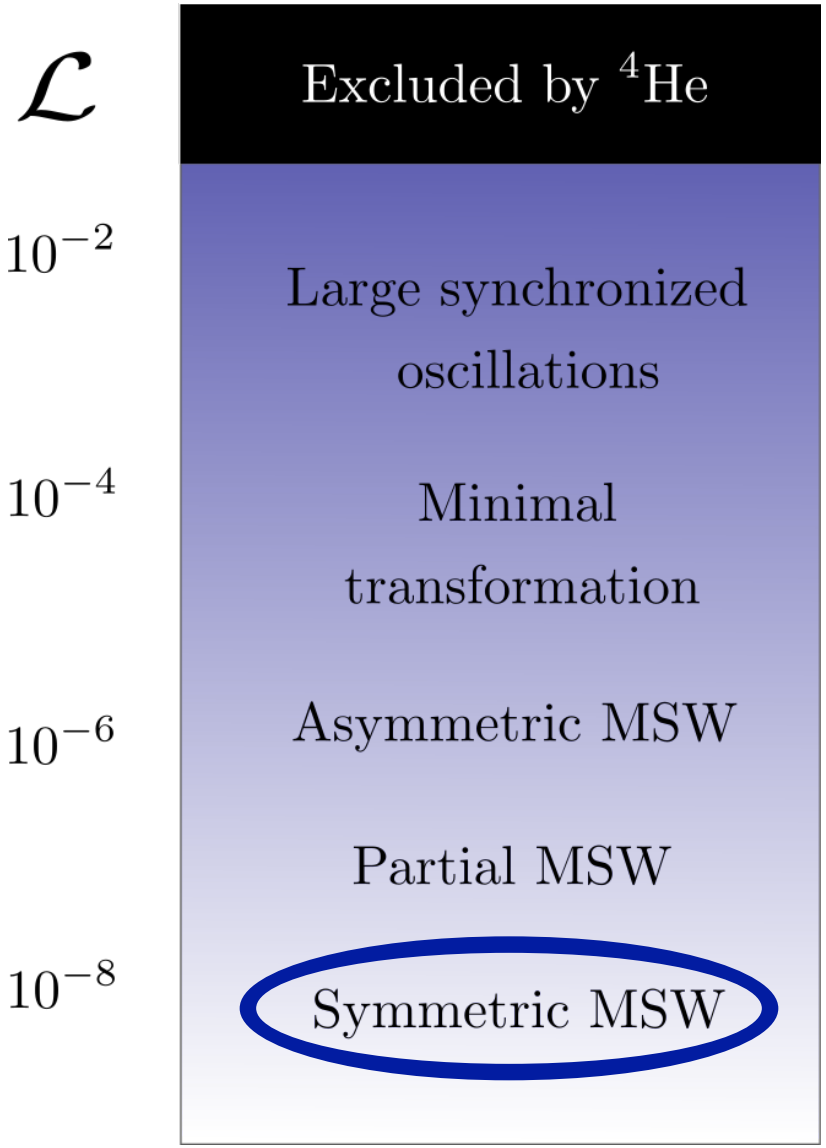

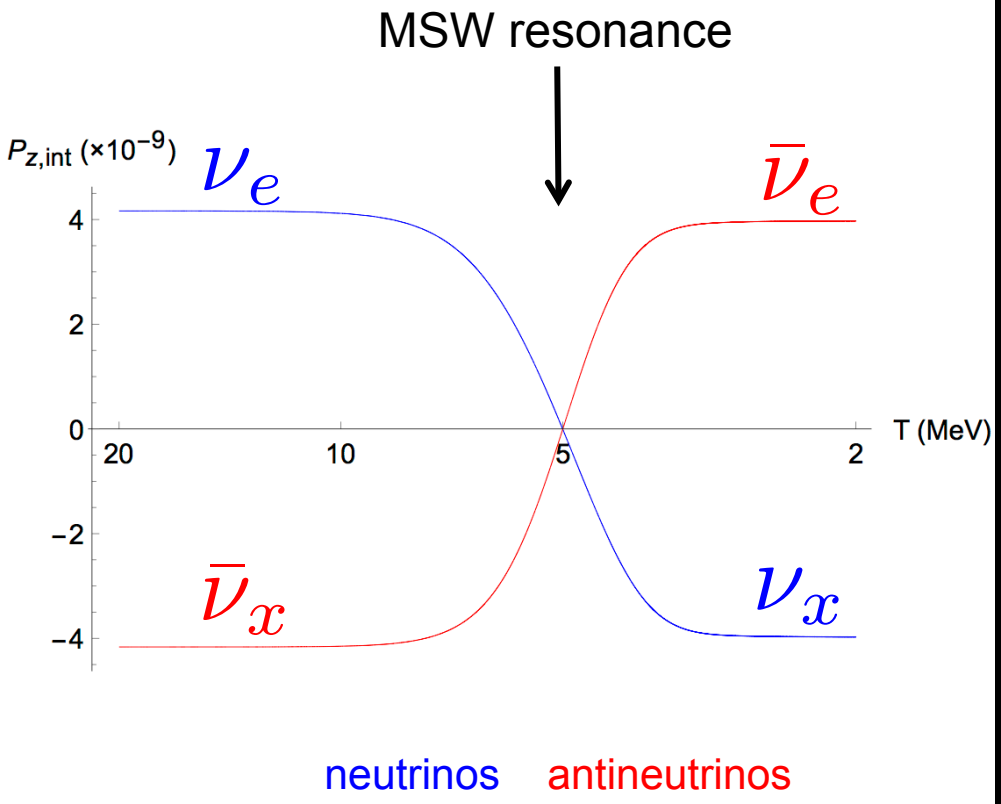

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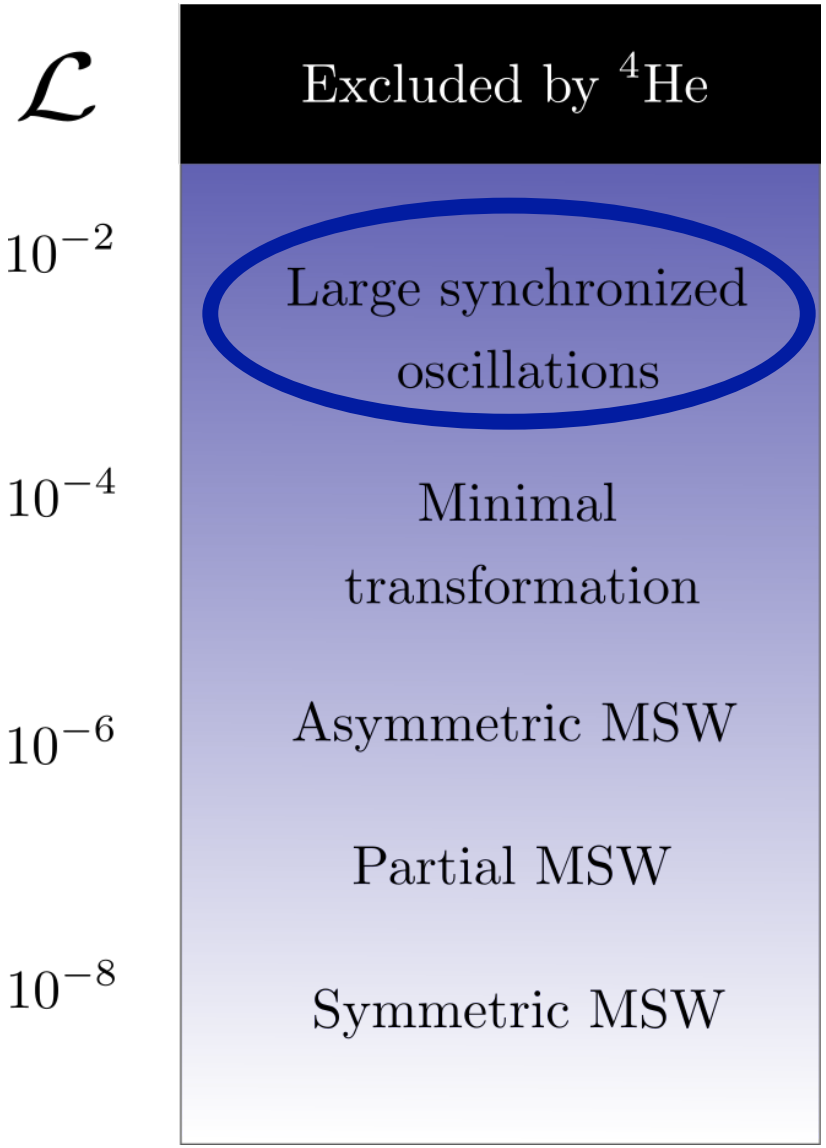

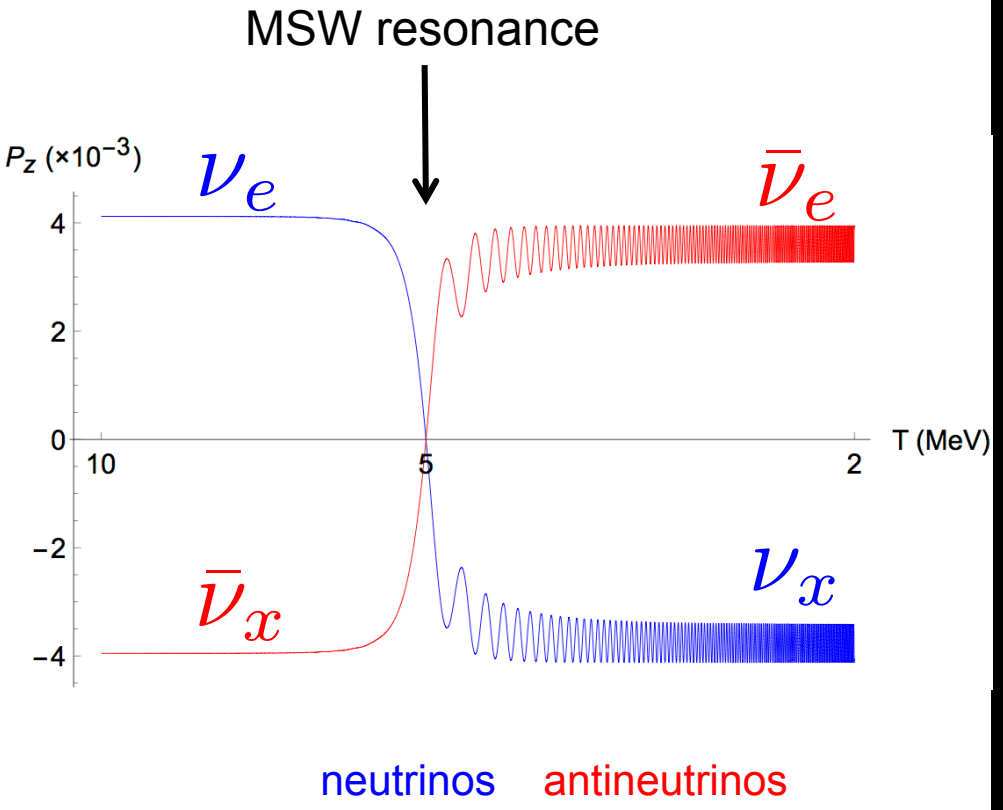

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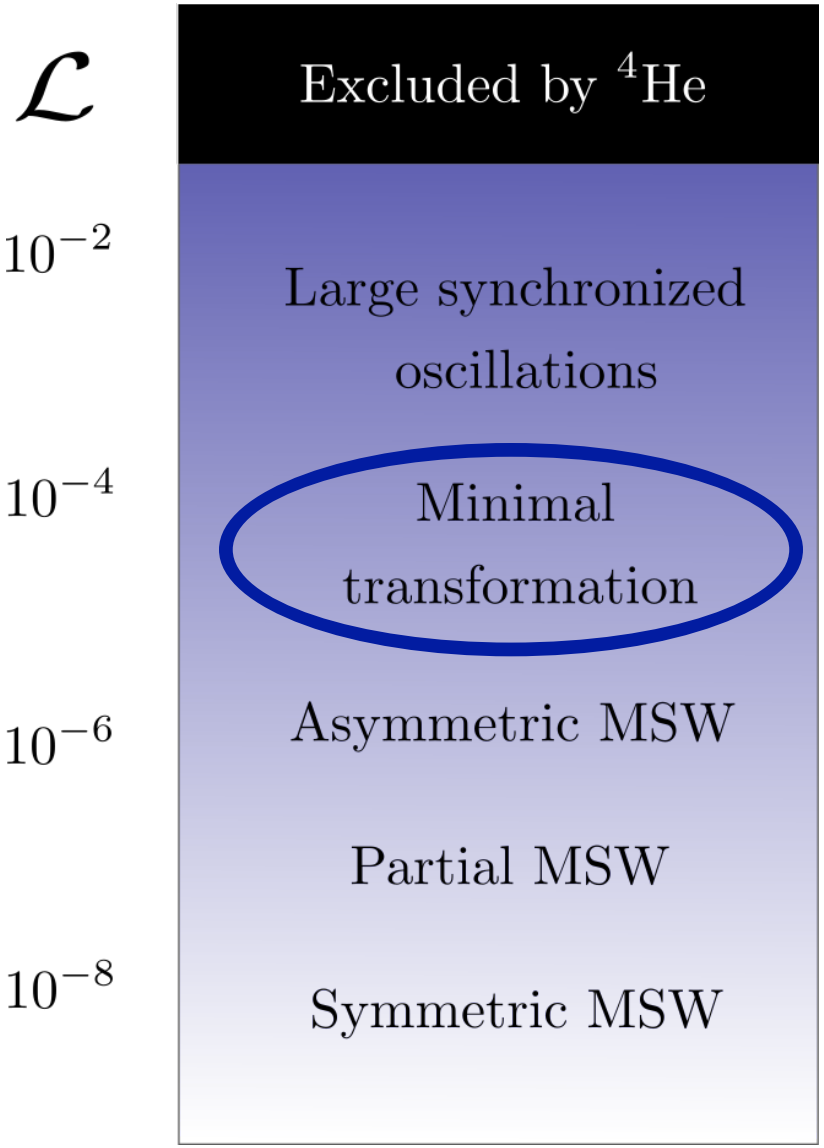

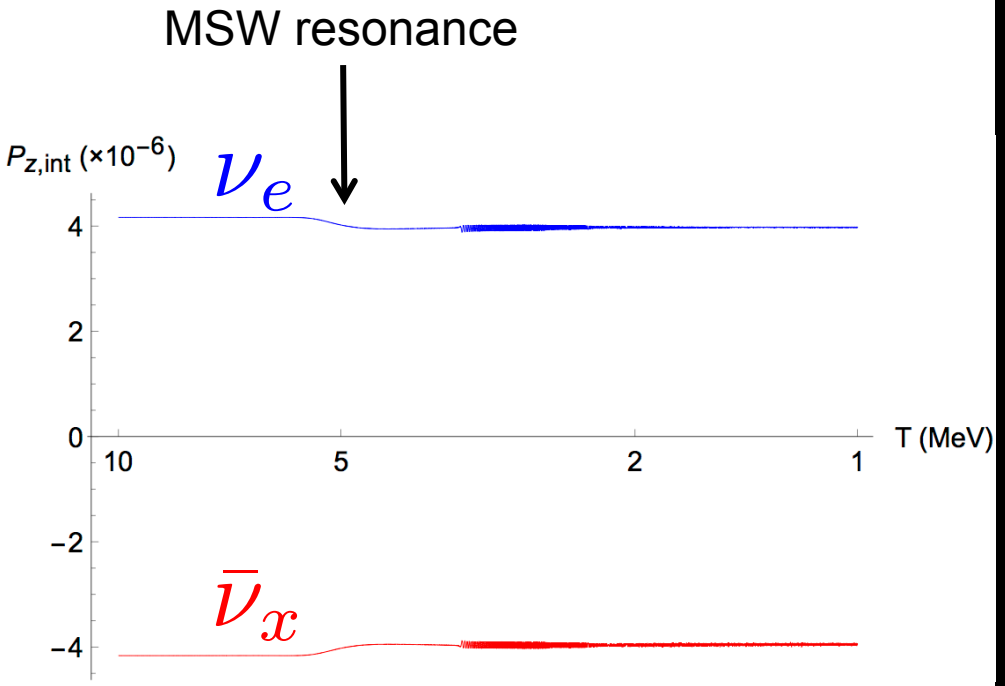

neutrinos antineutrinos

Johns, Mina, Cirigliano, Paris, and Fuller, PRD 2016

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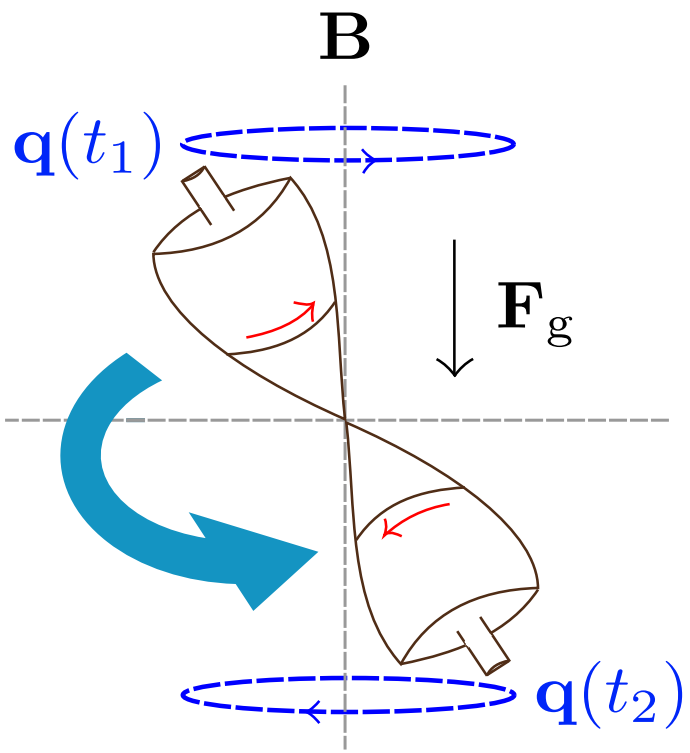
Suppression of flavor conversion…

There is an exact mathematical equivalence between astrophysical neutrino flavor evolution and gyroscopic pendulum motion.

Hannestad et al., PRD 2006
Duan et al., PRD 2007



- **Oscillations in vacuum** correspond to the top **swinging like a pendulum**, with gravity set by vacuum mixing parameters.
- **A lepton asymmetry** corresponds to **the spin of the top**, which induces precession.

Johns and Fuller, PRD 2018

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Wikipedia

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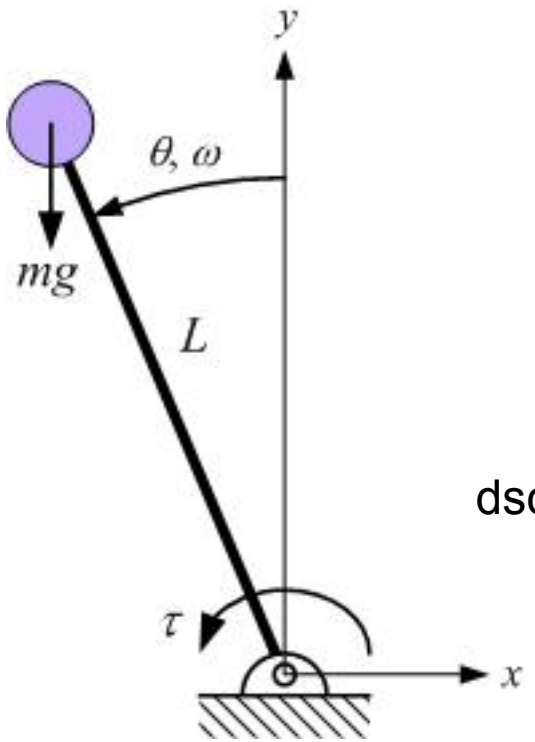
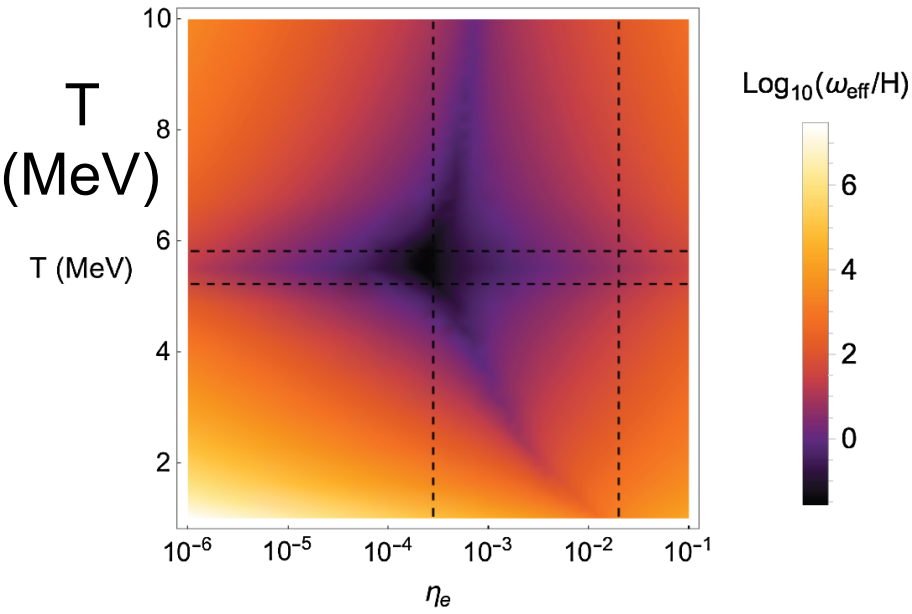
What happens at MSW?

Nonadiabaticity.

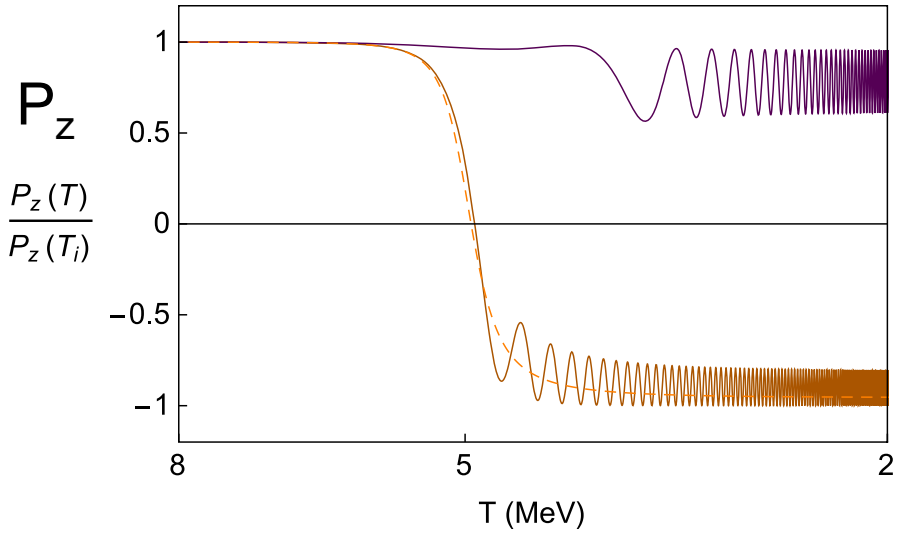


dsc.utrgv.edu

$\mathrm{Log}_{10}[\omega_{\mathrm{eff}}/H]$



η_e



T (MeV)

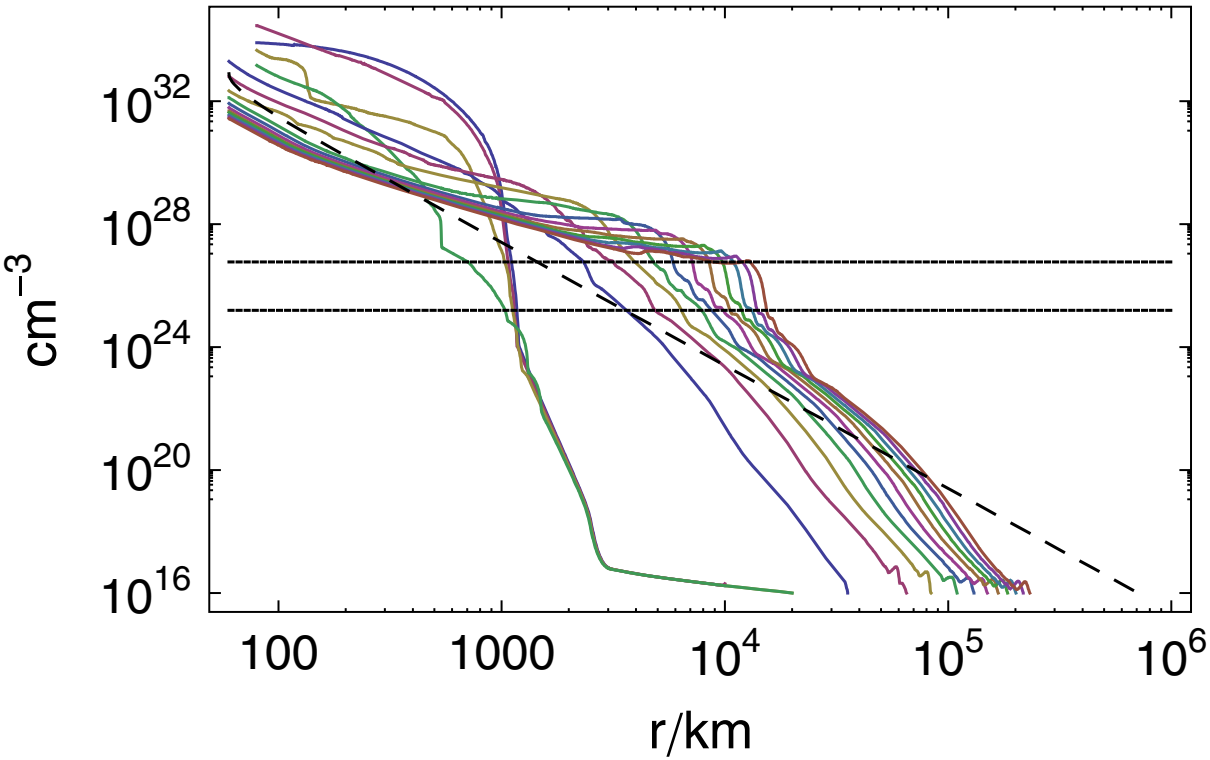
This explains the minimal-transformation regime.

This ω_{eff} phenomenon might also apply to compact-object environments…

Example:

O-Ne-Mg supernovae

Lunardini, Muller, Janka, PRD 2008



SNe (canonical) $\langle E_{\nu_e} \rangle < \langle E_{\bar{\nu}_e} \rangle < \langle E_{\nu_x} \rangle$

EU (asymmetric) $\langle E_{\nu_e} \rangle < \langle E_{\nu_x} \rangle < \langle E_{\bar{\nu}_e} \rangle$ (e.g.)

CONCLUSION

- Lepton asymmetries are associated with **a rich array of flavor phenomena**. This talk emphasized a new one, which can **suppress resonant flavor conversion**.

- Ongoing project: Realistic coupling of **neutrinos, nuclides, and plasma** over the weak-decoupling / BBN epoch.
  (Building on Grohs et al., PRD 2016.)

- Open questions: How does this relate to **compact objects**? Or to **flavor instabilities**? (e.g., Shalgar et al., PLB 2017.)

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