Decoherence in Supernova Neutrino Transformations suppressed by deleptonization

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OUTLINE

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Setup of the problem.

Coherent evolution vs. decoherence.

Role of the model parameters.

Conclusions.

INTRODUCTION

- The crucial phenomenon $\nu_e\bar{\nu}_e \rightarrow \nu_x\bar{\nu}_x$ driven by atm Δm^2 and θ_{13}.

[Pastor and Raffelt, (2002). astro-ph/0207281]
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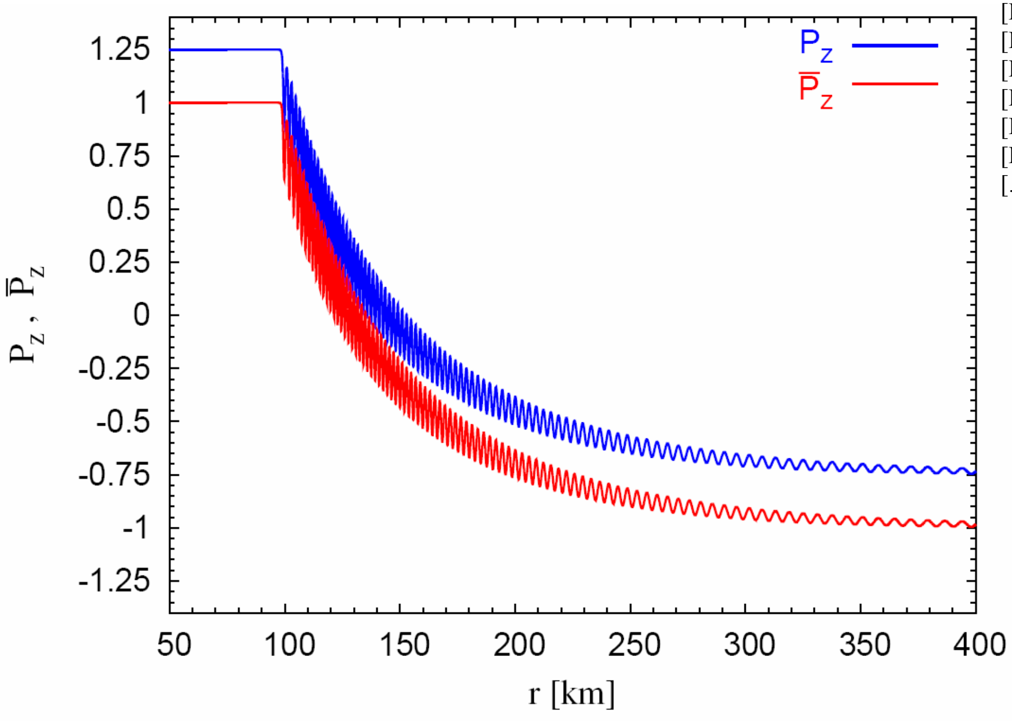
[...]



$$\text{prob}(\bar{\nu}_e) = \tfrac{1}{2}(1+\bar{P}_z)$$

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- SN context evolution similar to the single-angle case.
- Our main goal is to quantify the validity of this approximation and study the role of the different model parameters.

SETUP OF THE PROBLEM

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where:

$$\omega = \left\langle \frac{\Delta m^2}{2E} \right\rangle \qquad \mathbf{B} = (\sin 2\theta, 0, \pm\cos 2\theta)$$

$$\lambda_r = \sqrt{2} G_F\, n_{e^-}(r) \qquad \mu = \sqrt{2} G_F \left(F^R_{\bar\nu_e} - F^R_{\bar\nu_x}\right)$$

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- Normalization at the ν-sphere:

$$P = |\mathbf{P}| = 1+\epsilon \quad \text{and} \quad \bar{P} = |\bar{\mathbf{P}}| = 1$$

$$\epsilon = \frac{F(\nu_e)-F(\nu_x)}{F(\bar{\nu}_e)-F(\bar{\nu}_x)} - 1 = \frac{F(\nu_e)-F(\bar{\nu}_e)}{F(\bar{\nu}_e)-F(\bar{\nu}_x)}; \qquad F(\nu_x) = F(\bar{\nu}_x)\,.$$

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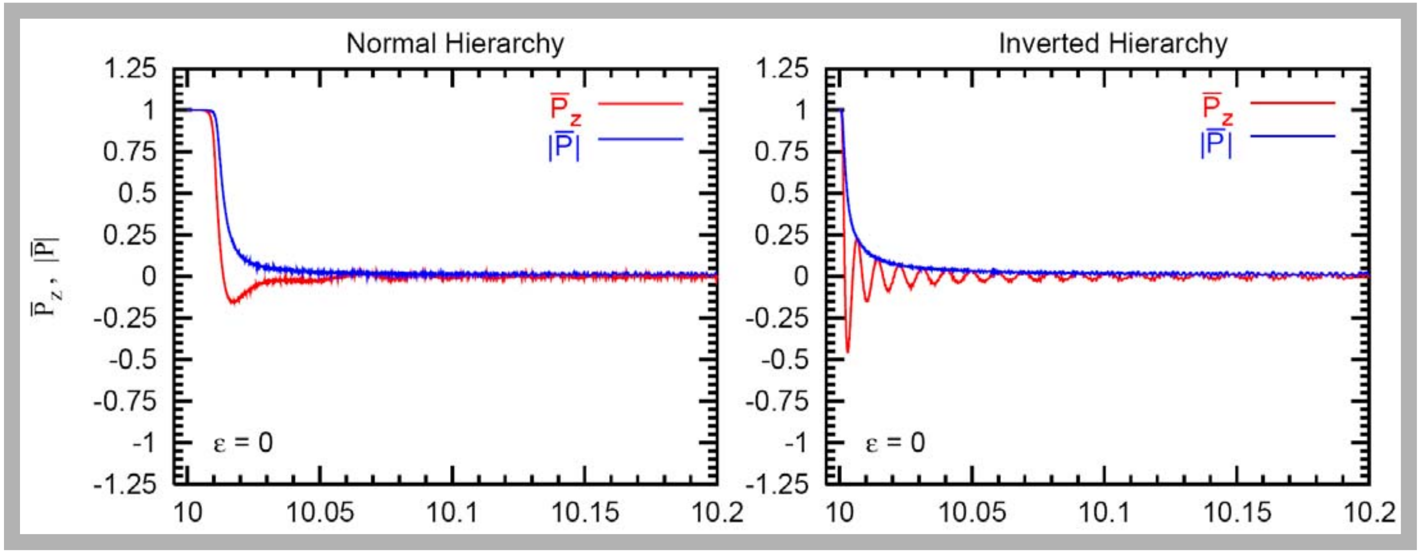
Parameter	Standard value
ϵ	0.25
μ	$7\times 10^5\ \mathrm{km}^{-1}$
ω	$0.3\ \mathrm{km}^{-1}$
$\sin 2\theta$	10^{-3}

COHERENT EVOLUTION VS DECOHERENCE

- The flavor content decoheres quickly for both NH and IH.



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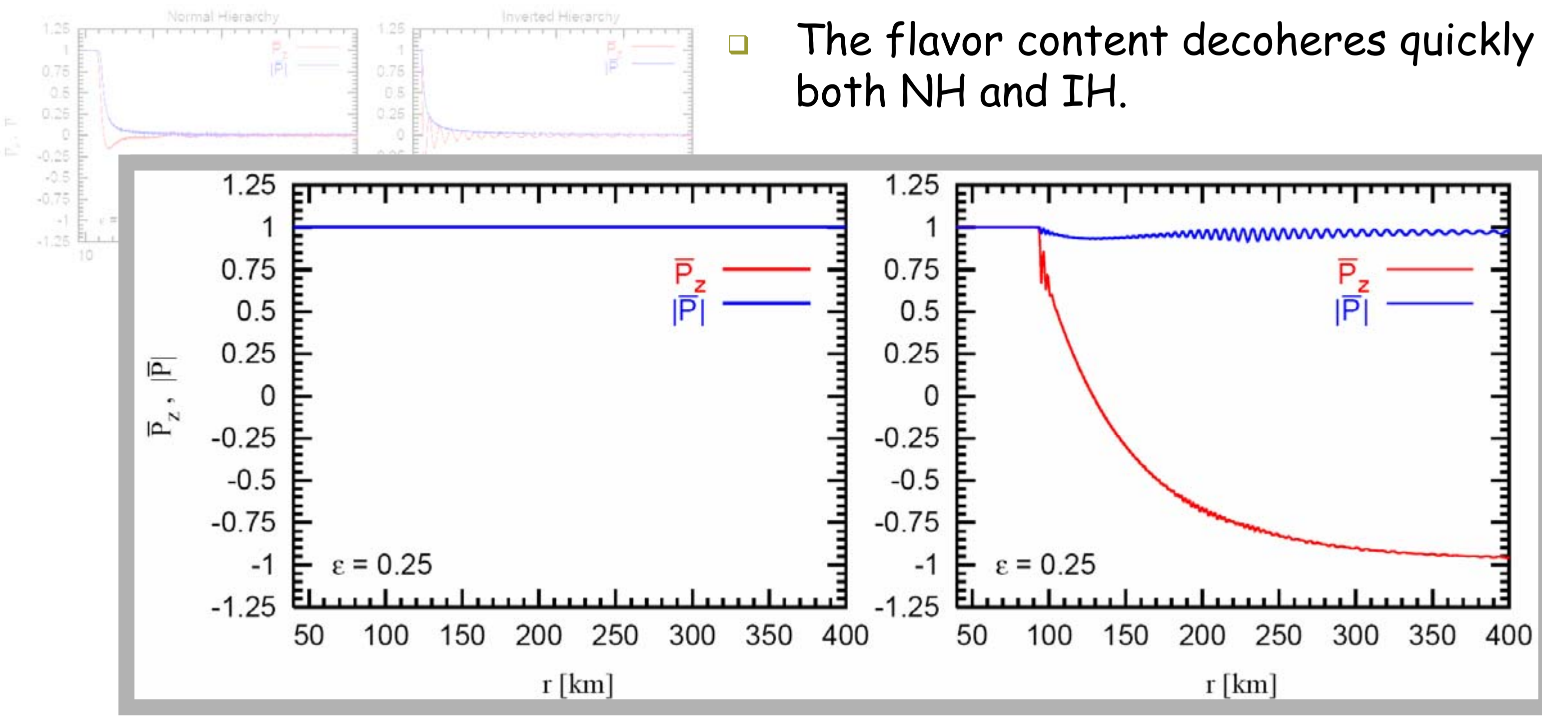

- NH: nothing visible happens, in analogy to the single-angle case.
- IH: similar to the single-angle case. The nutations wash out quickly. P shrinks a bit after r_{synch}.

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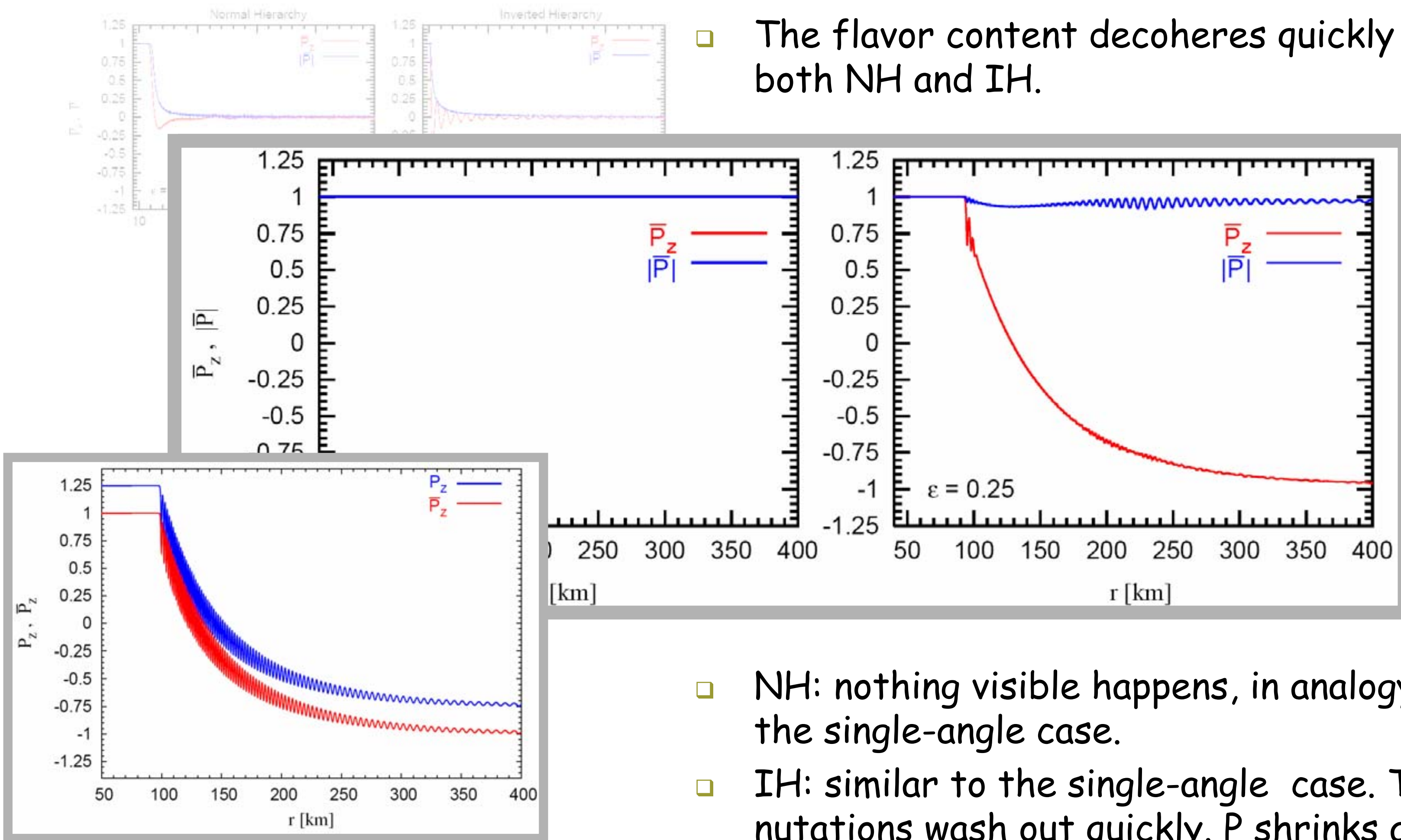

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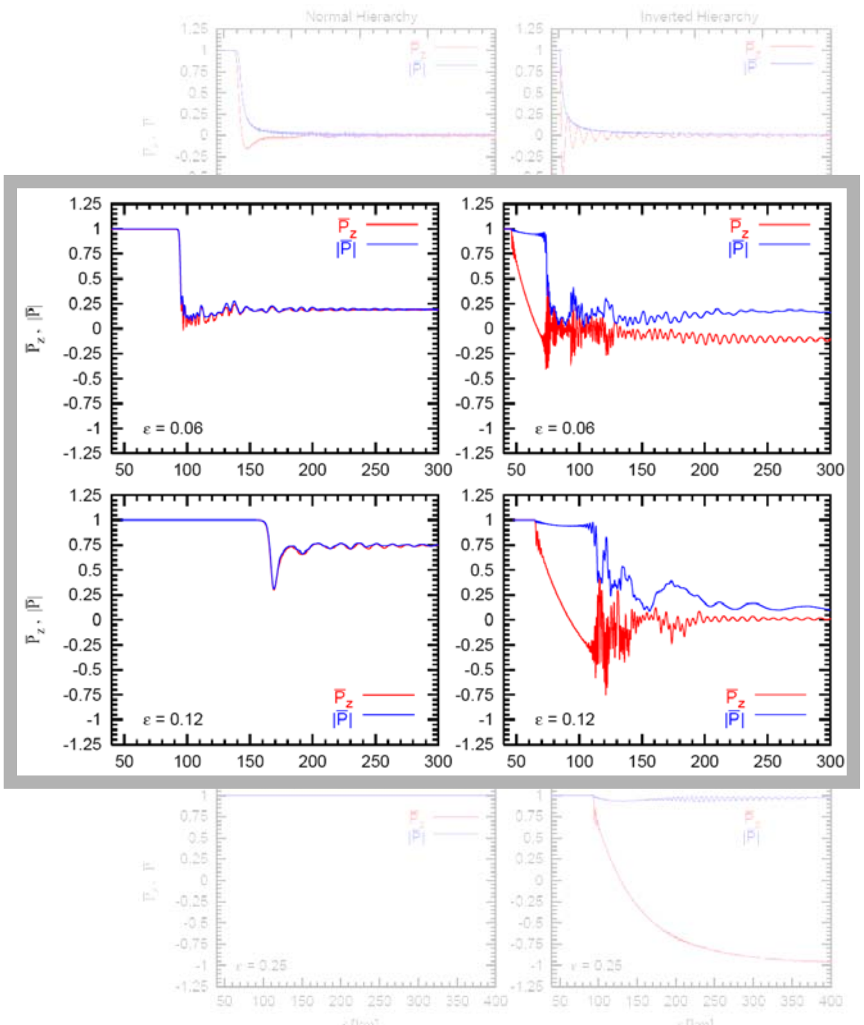

- The flavor content decoheres quickly for both NH and IH.

- NH: large and abrupt decoherence far beyond r_{synch}.
- IH: at first analogous to ε = 0.25, at some larger radius P shrinks significantly. Partial decoherence.

- NH: the length P also shrinks, but closely tracks P_z.
- IH: qualitatively equivalent to ε = 0.06.

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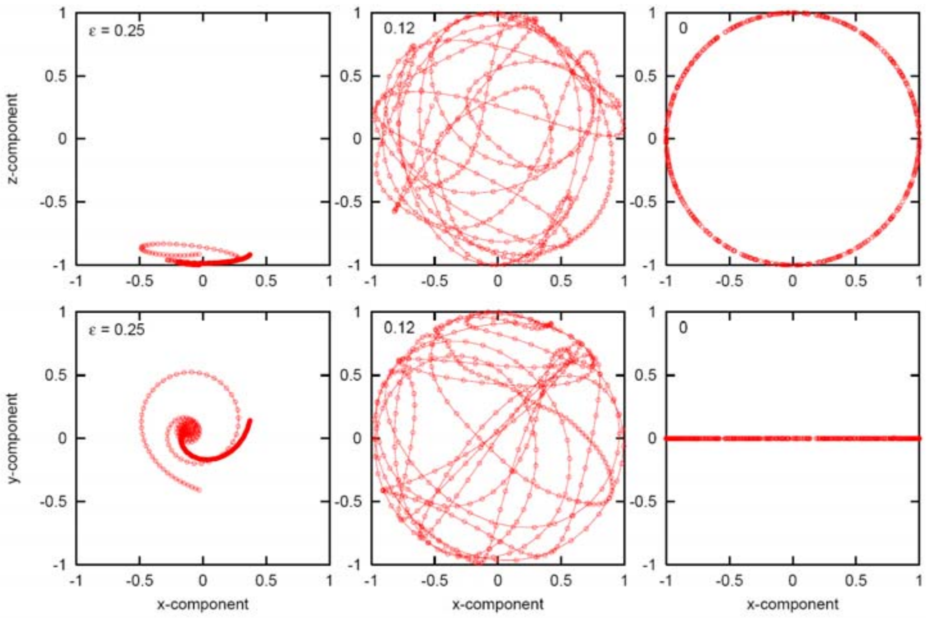
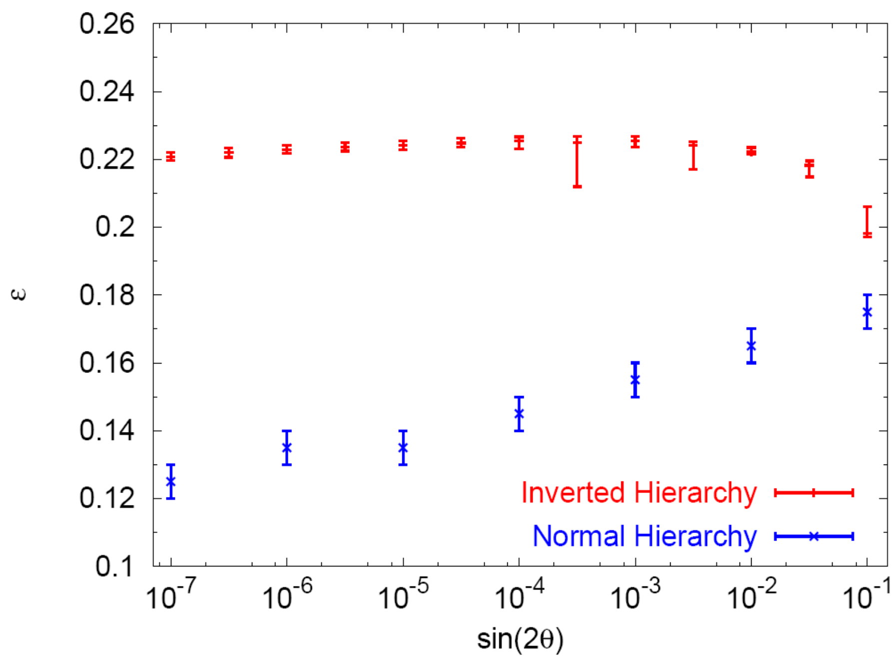
COHERENT EVOLUTION VS DECOHERENCE

- Final location on the unit sphere of 500 antineutrino polarization vectors
- Small asymmetry ($\varepsilon = 0.12$)



ROLE OF MODEL PARAMETERS

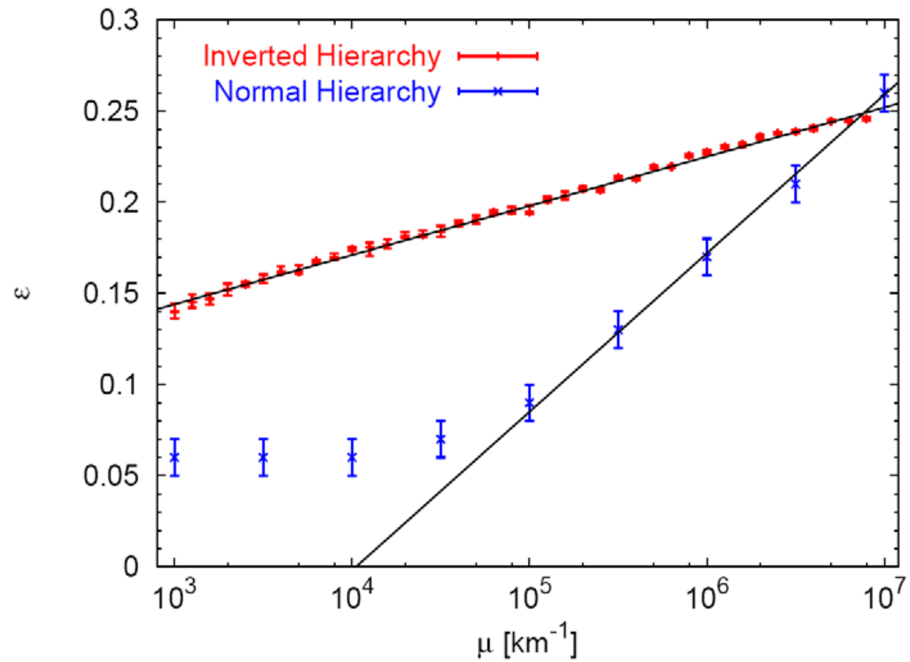
- Mixing angle:
  - IH: multi-angle decoherence is virtually independent of sin 2θ, except for very large θ.
  - NH: strong dependence of the critical ε on $\log_{10}(\sin 2\theta)$



ROLE OF MODEL PARAMETERS

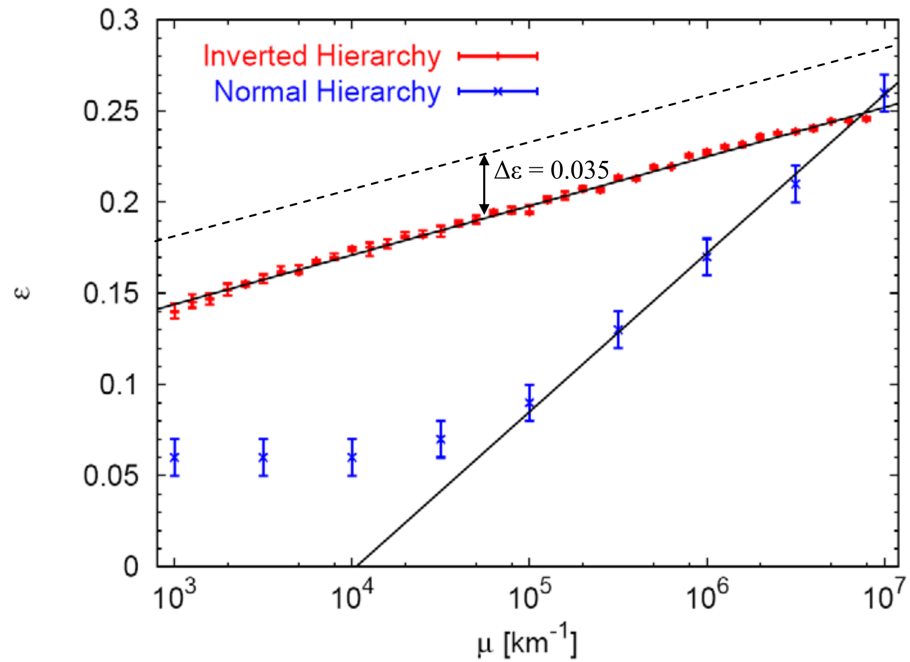
- Effective interaction strength:

$$\epsilon_{\rm IH} \approx 0.225 + 0.027 \log_{10}\left(\frac{\mu}{10^6\ \rm km^{-1}}\right)$$
$$\epsilon_{\rm NH} \approx 0.172 + 0.087 \log_{10}\left(\frac{\mu}{10^6\ \rm km^{-1}}\right)$$



ROLE OF MODEL PARAMETERS

- Vacuum oscillation frequency:
  - IH: If we increase ω from 0.3 km^{-1} (our standard value) to 1 km^{-1}, the ε-μ-contour parallel-shifted by about 0.035.



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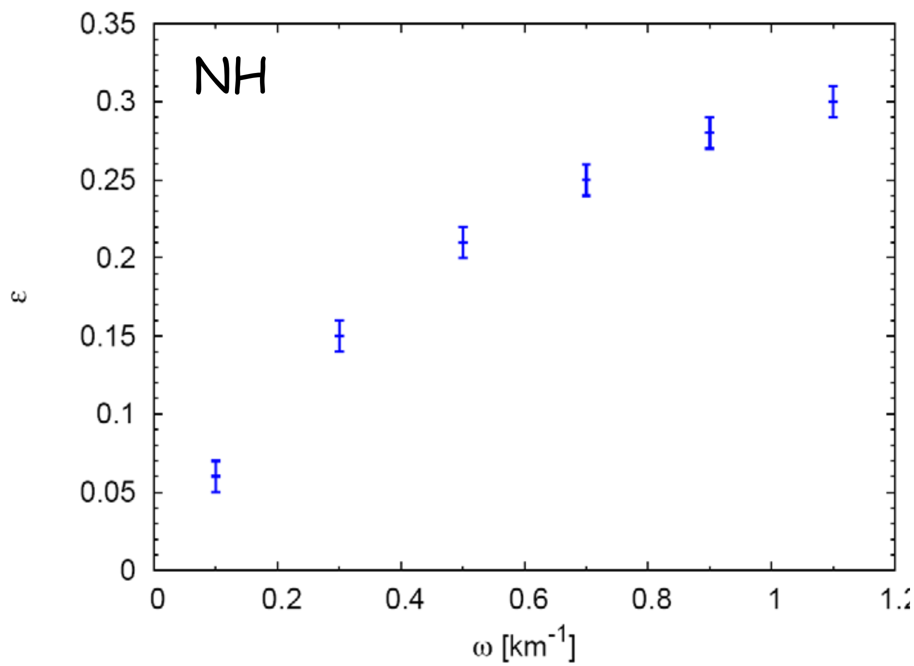
  - IH: If we increase ω from 0.3 km^{-1} (our standard value) to 1 km^{-1}, the ε-μ-contour parallel-shifted by about 0.035.
  - NH: more sensitive to ω.



CONCLUSIONS

- We have explored numerically the range of parameters where different forms of evolution dominate in a realistic SN scenario.
- For realistic supernova deleptonization fluxes, kinematical decoherence among different angular modes likely irrelevant.
- Multi-angle effects seem to be subdominant.
- Good news:
  - We do not have to worry about multi-angle decoherence.
  - We can use the single-angle approximation which requires a lot less of computational time.