Bubble Misalignment Mechanism for Axions

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Axions in Stockholm

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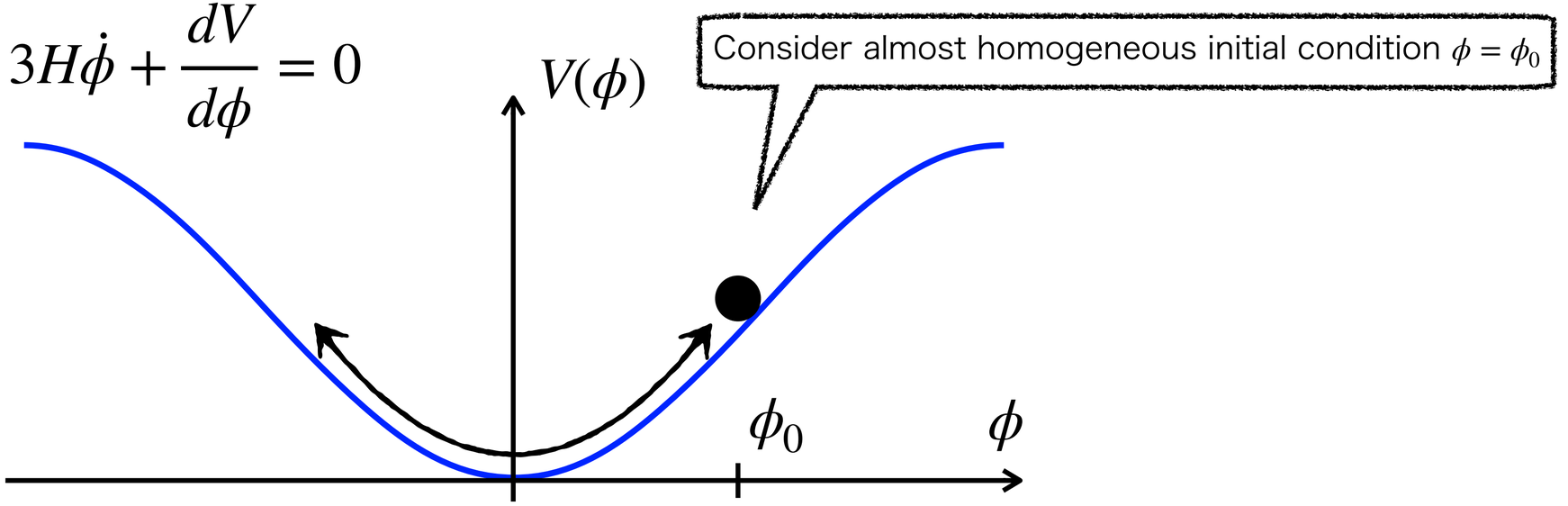
Misalignment Mechanism

Preskill, Wise, Wilczek `83, Abbott, Sikivie `83, Dine, Fischler `83

Axion starts to oscillate after the Hubble parameter H becomes smaller than its mass m_ϕ.

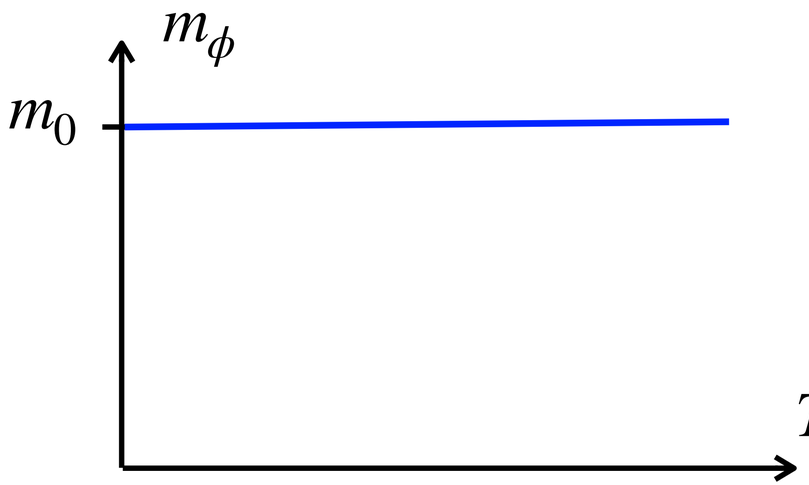
This coherent oscillation acts as dark matter.

$$\ddot{\phi} + 3H\dot{\phi} + \frac{dV}{d\phi} = 0$$



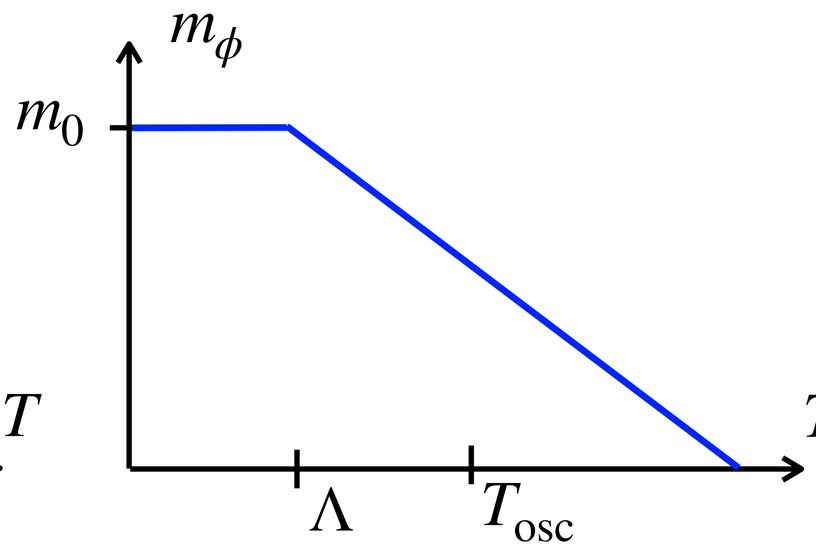
Misalignment with changing mass

constant mass



$$\frac{\rho_\phi}{s} \sim \frac{m_0^2 \phi_0^2}{(M_{\rm p} m_0)^{3/2}}$$

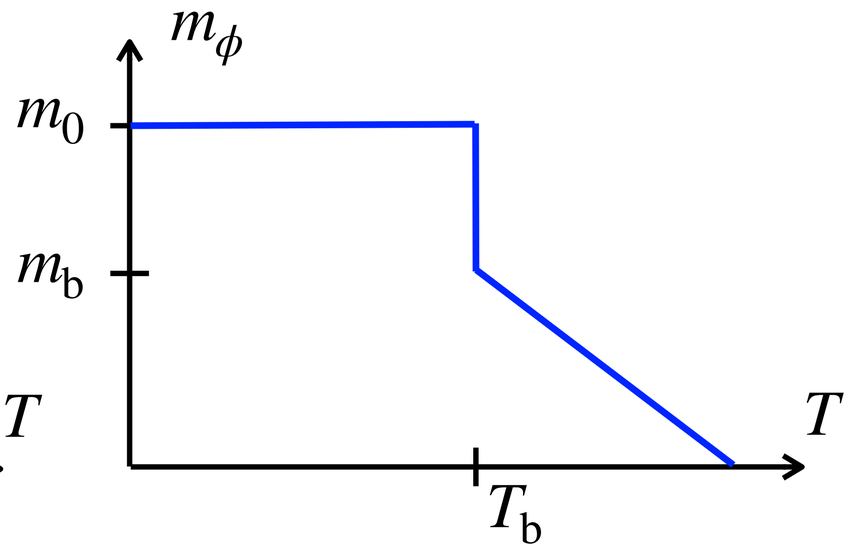
second-order
phase transition



$$\frac{\rho_\phi}{s} \sim \frac{m_0 m_\phi(T_{\rm osc}) \phi_0^2}{T_{\rm osc}^3}$$

$$(T < \Lambda)$$

first-order
phase transition



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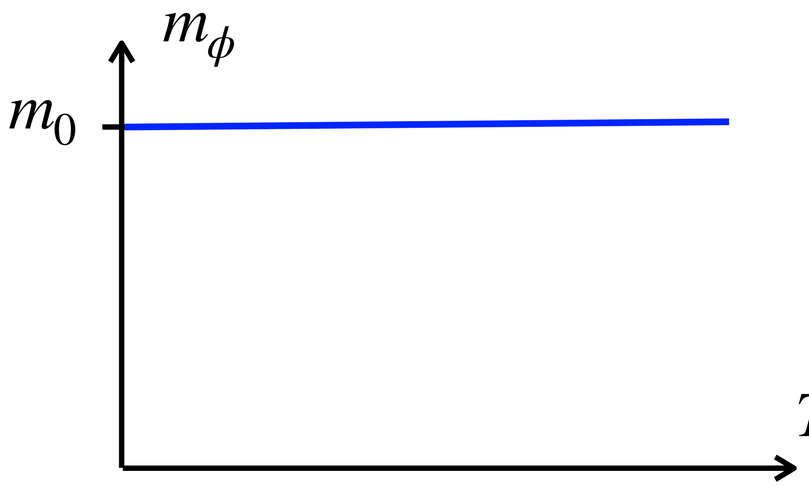
Misalignment with changing mass

constant mass



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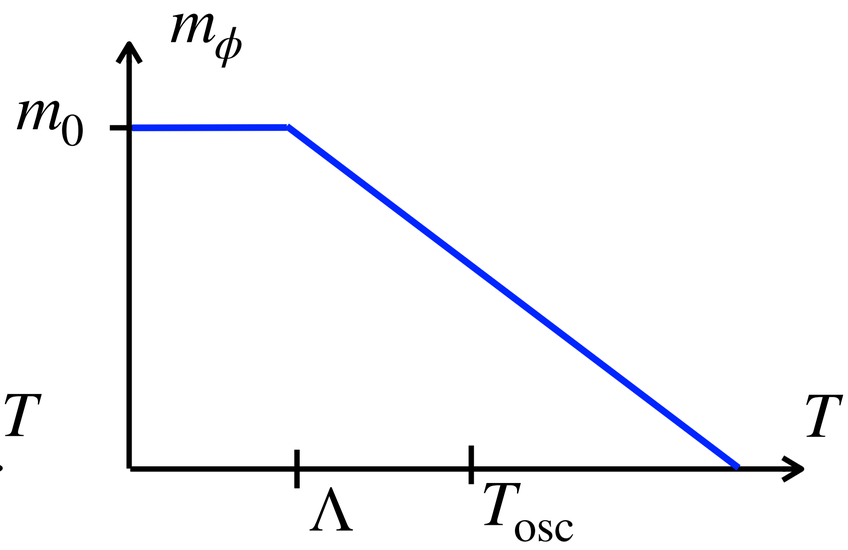

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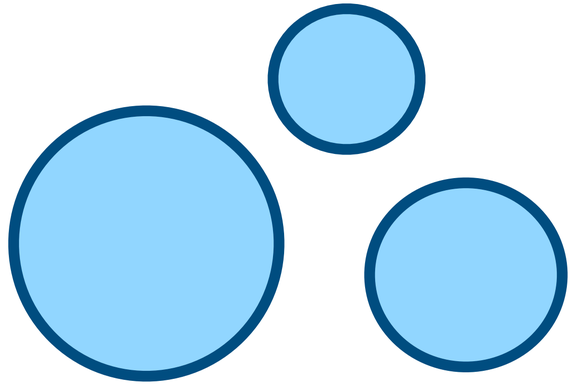

+ inhomogeneity due to the bubbles

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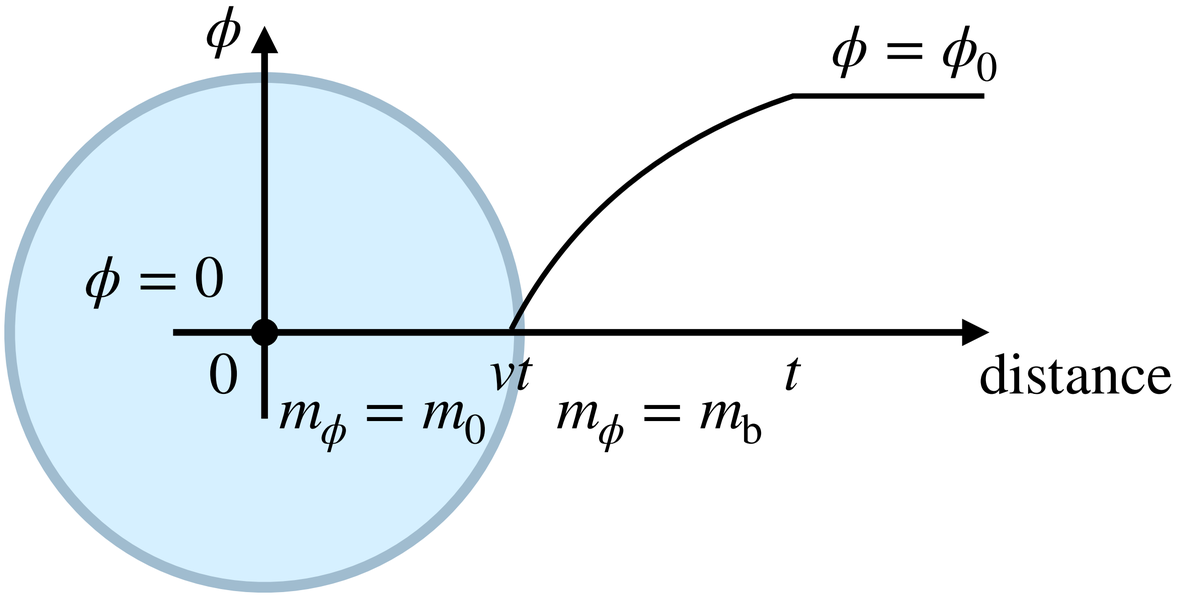
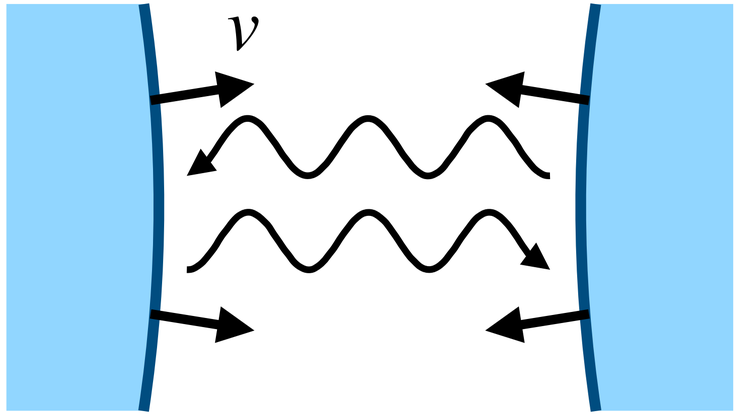
Axion dynamics with bubbles

Focus on the case of $m_0^{-1} <$ duration of phase transition $< m_{\rm b}^{-1}, H_{\rm b}^{-1}$.

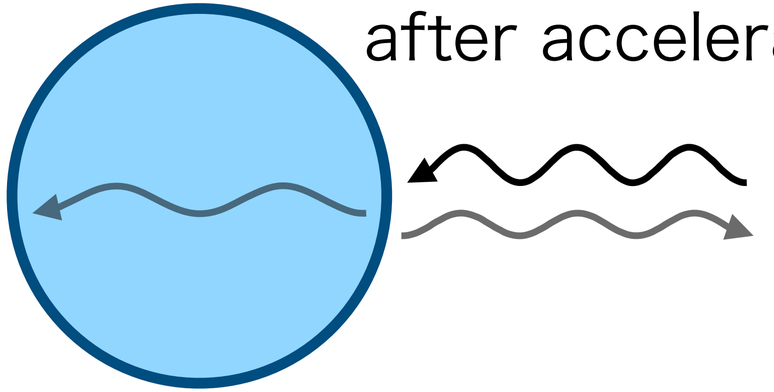
axion shock wave



Fermi acceleration



transmission after acceleration



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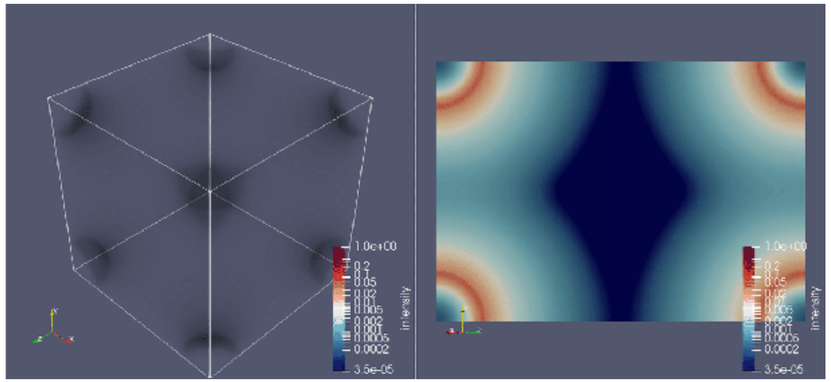

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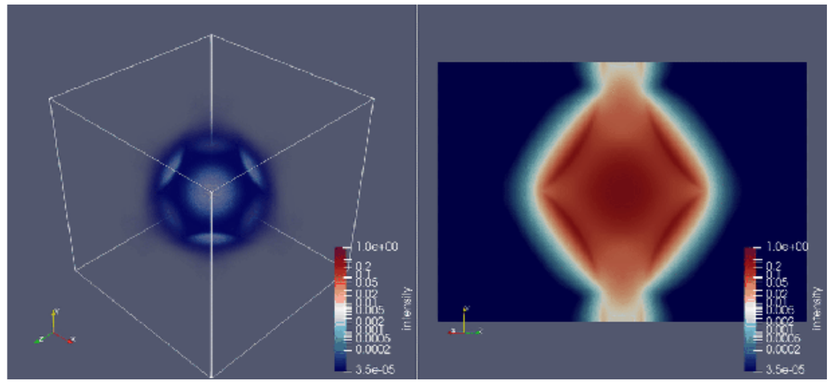

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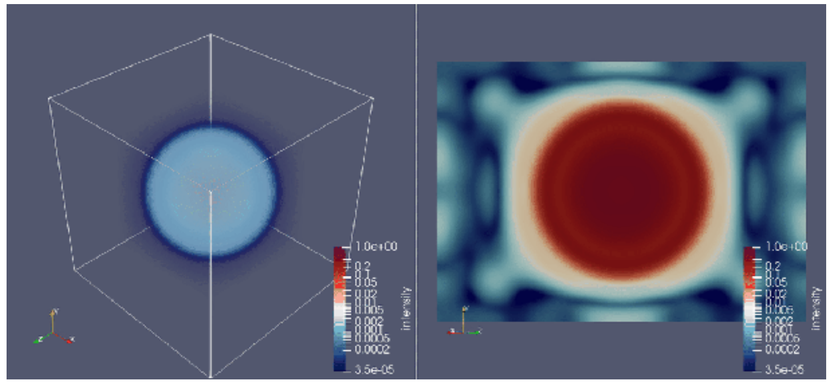
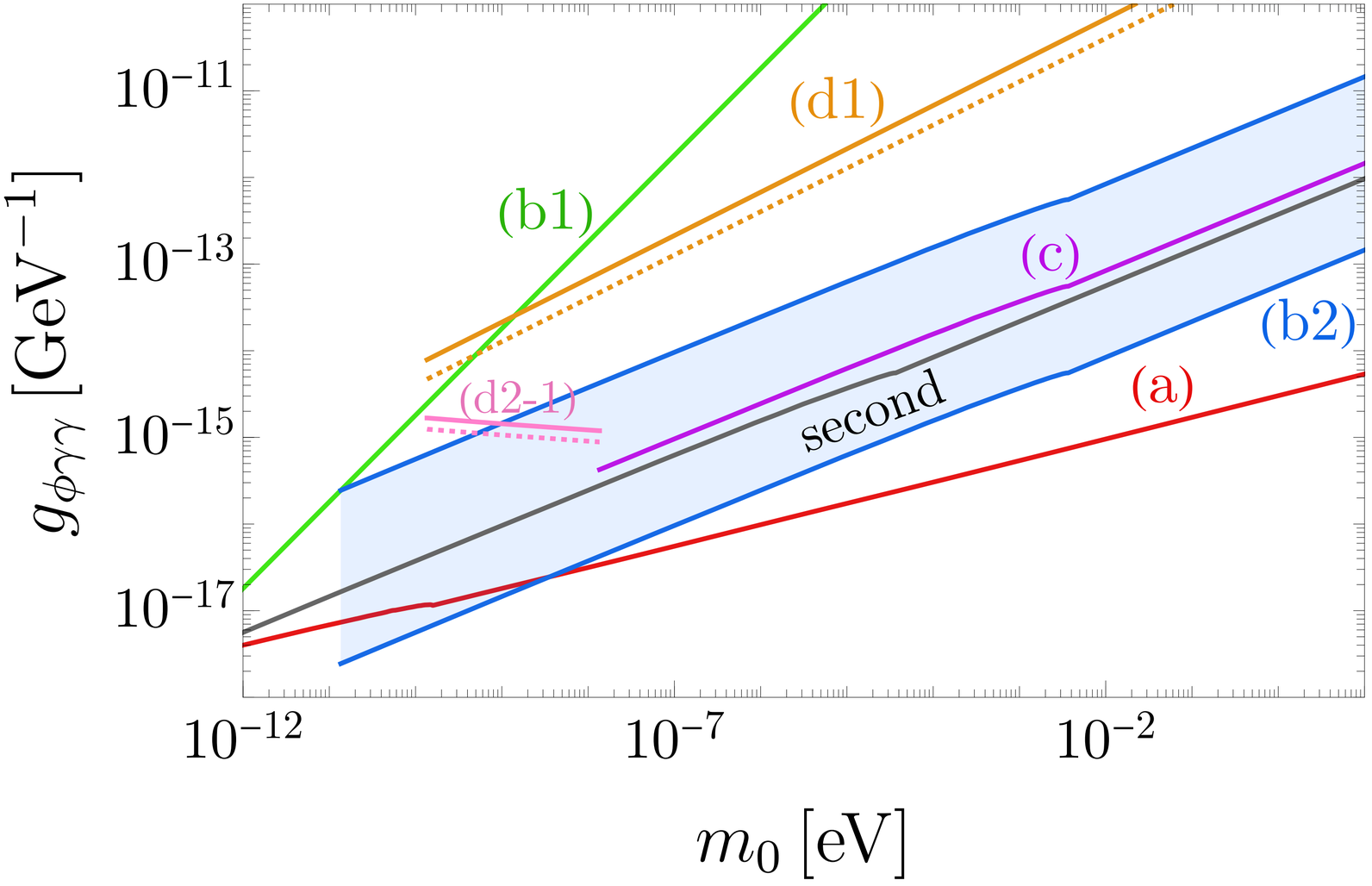


Viable parameters for axions



Constant mass

$$g_{\phi\gamma\gamma} = \alpha/(2\pi f_\phi)$$
$$\phi_0 = f_\phi$$
$$p = 8$$
$$T_\mathrm{b} = 10\,\mathrm{MeV}$$

Summary

- We studied the axion evolution in the FOPT, taking account of the bubble dynamics; **“Bubble misalignment mechanism”.**
- We find that axion is expelled from the interior of the bubbles producing an **axion shock wave** and that **Fermi acceleration** occurs.
- If the axion oscillations are relevant only inside the bubbles during the phase transition, **the axion abundance can be significantly increased** compared to the case of constant axion mass.
- Much to be done: analysis of realistic bubble nucleation, oscillon/I-ball formation, axion minicluster, production of dark photon dark matter, etc.