TESTING THE PHASE-TRANSITION ORIGIN OF THE GRAVITATIONAL-WAVE BACKGROUND WITH LENSING

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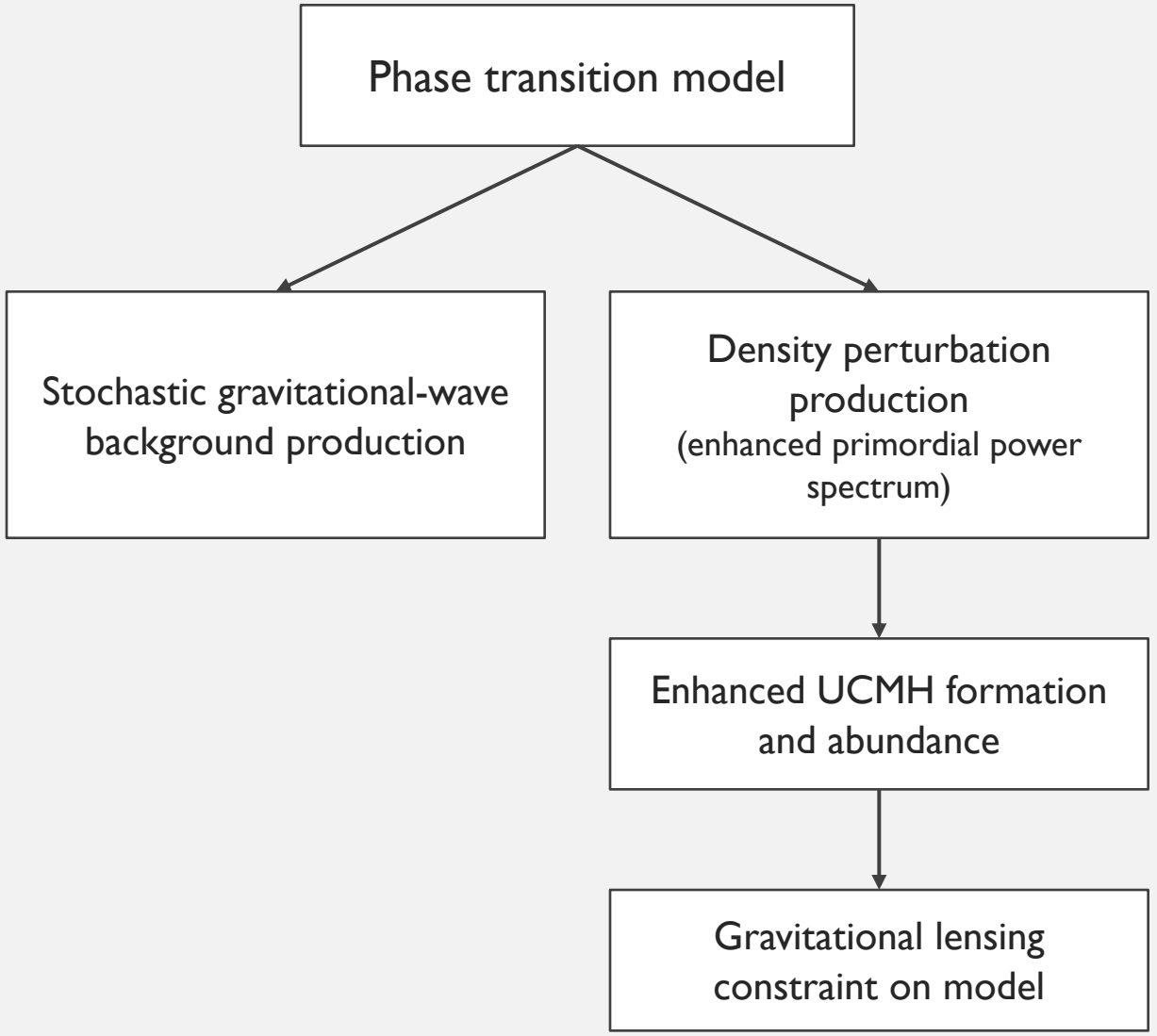
CORE TAKEAWAYS

- Dark-sector first-order phase transition (FOPT) is a motivated source of gravitational-wave background
- FOPT generates density perturbations that enhance the formation of ultra-compact minihalos (UCMHs)
- Using gravitational lensing, the predicted UCMH abundance can constrain regions of the phase-transition parameter space capable of sourcing the observed gravitational-wave background

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GRAVITATIONAL-WAVE BACKGROUND

- In 2023, pulsar timing array experiments revealed the existence of a stochastic gravitational-wave background. [G. Agazie *et al.* 2023]

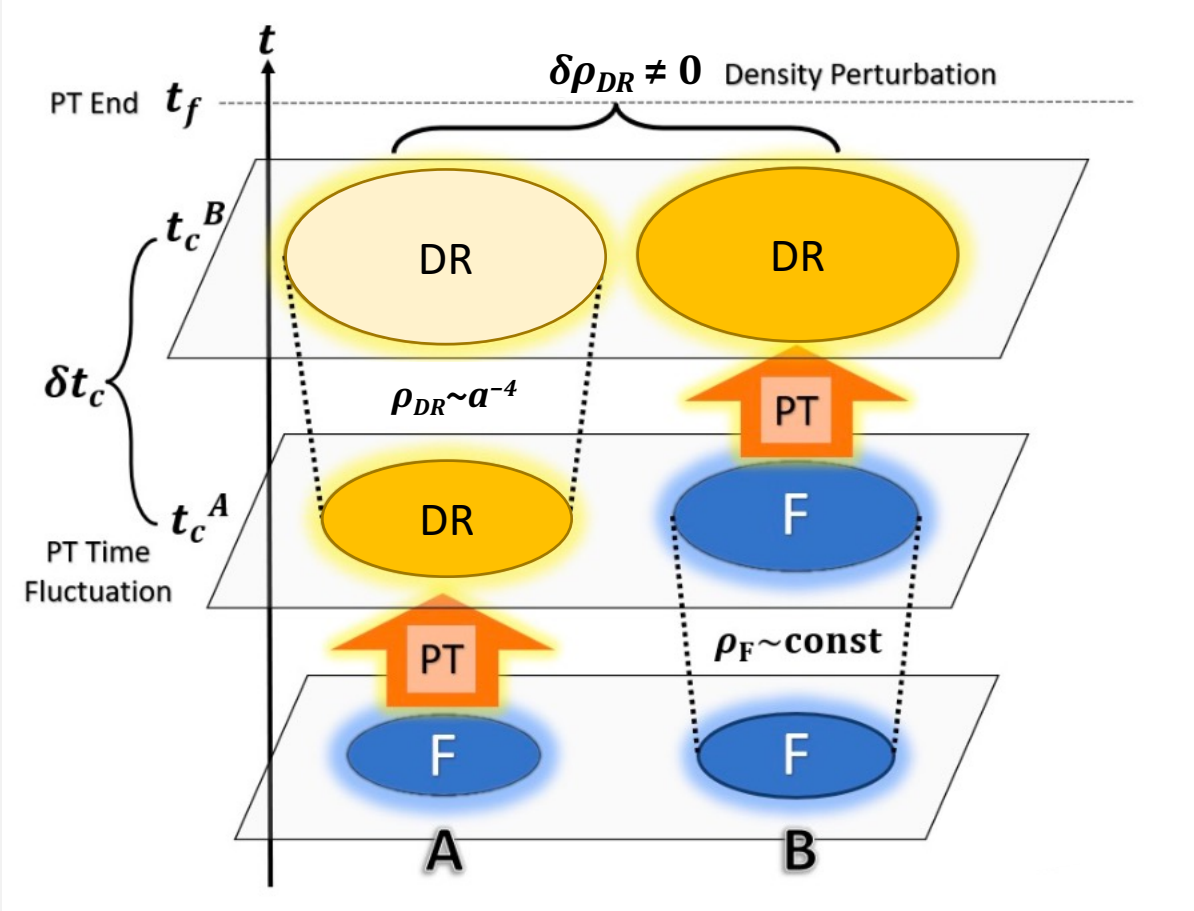


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FOPT

- $f_{DR} \equiv \rho_{DR}/\rho_{tot}$
- $\beta/H_{PT} \equiv \beta/H(t_f)$
- $T_{PT} \equiv T(t_f)$

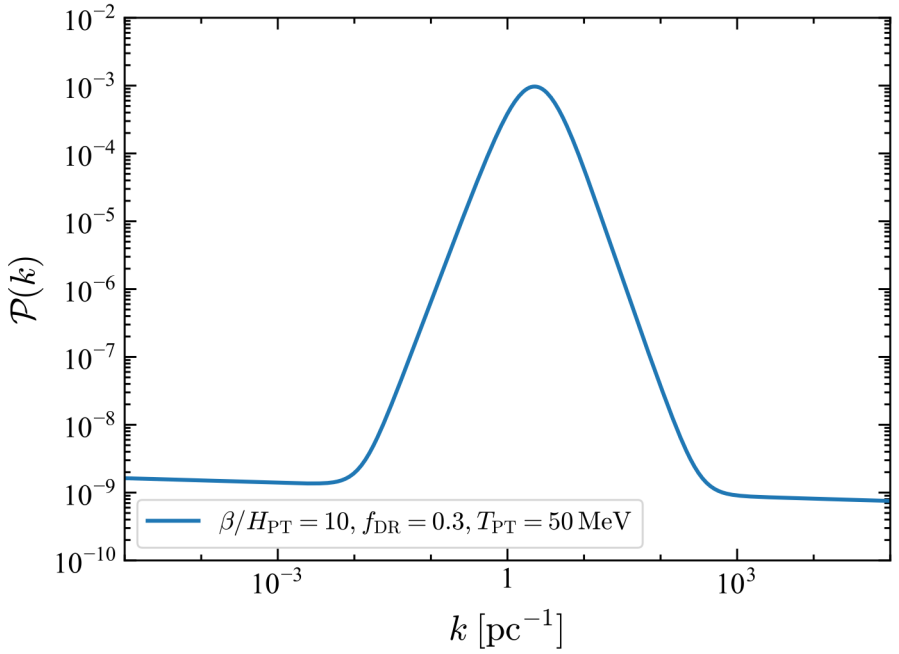


[K. Greene *et al.* 2026]

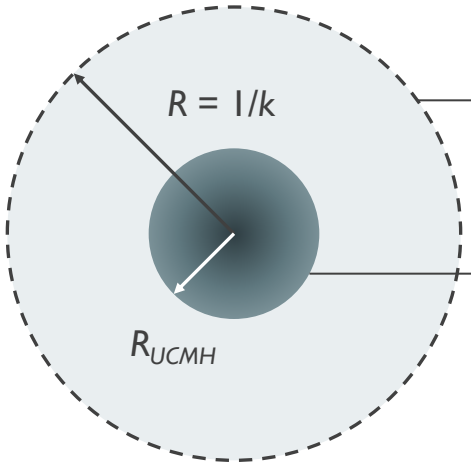
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UCMH FORMATION

Primordial power spectrum $P(k)$



Collapse inside the horizon



Horizon entry sphere

- $R = 1/k$
- M = DM mass inside R

UCMH

- $R_{\rm UCMH} \propto (1 + z_c)^{-1}\, M^{1/3}$
- $\rho \propto r^{-3/2}$

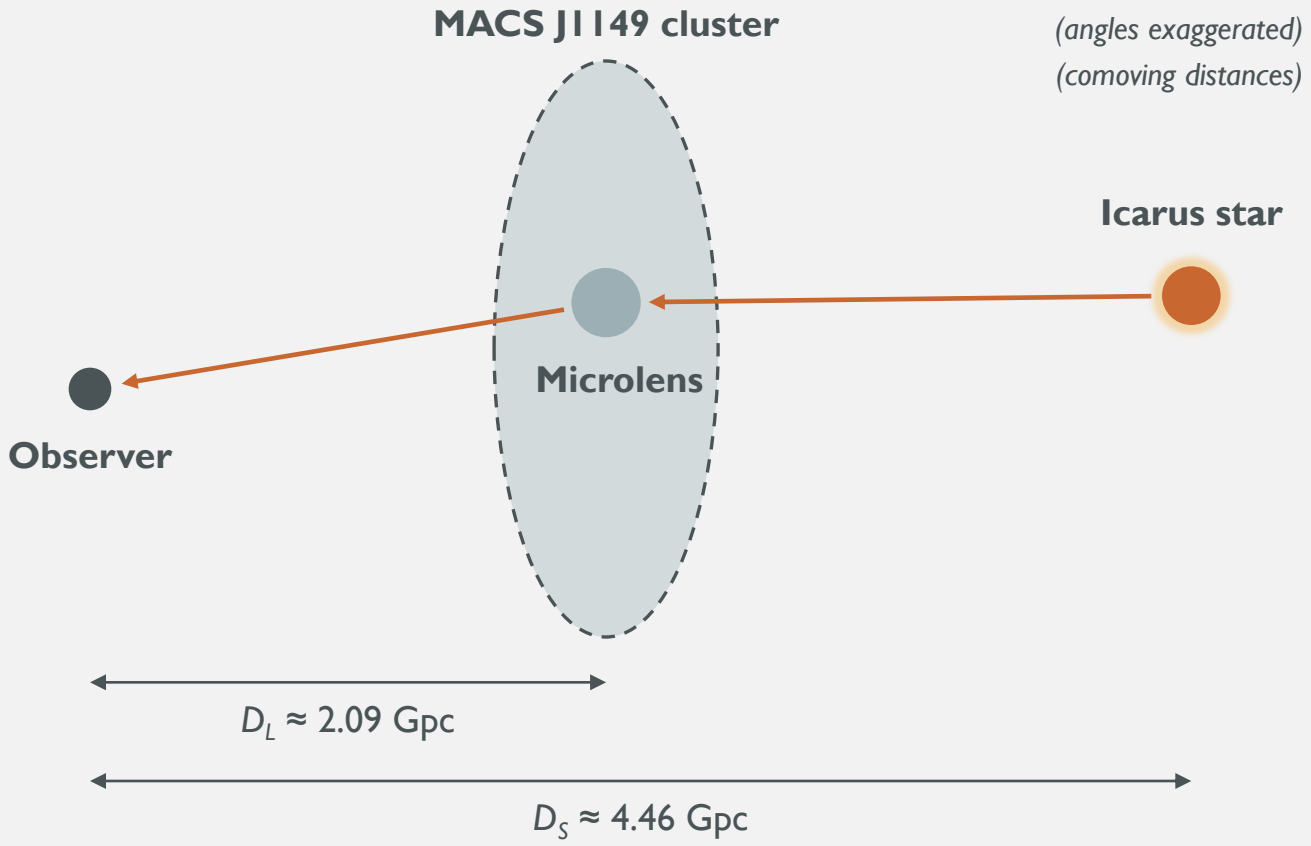
Assumption: collapse at $z_c \geq 1000$, well before hierarchical structure formation. [M. S. Delos *et al.* 2017]

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ICARUS LENSING CONSTRAINT

- A microlens inside a galaxy cluster can magnify a background star by over a thousand-fold
- Observed peak brightness of Icarus bounds UCMH abundance
- PT model constrained if $\mathrm{F}(M; z_c) > f_{DM}^{max}(M; z_c)$, where

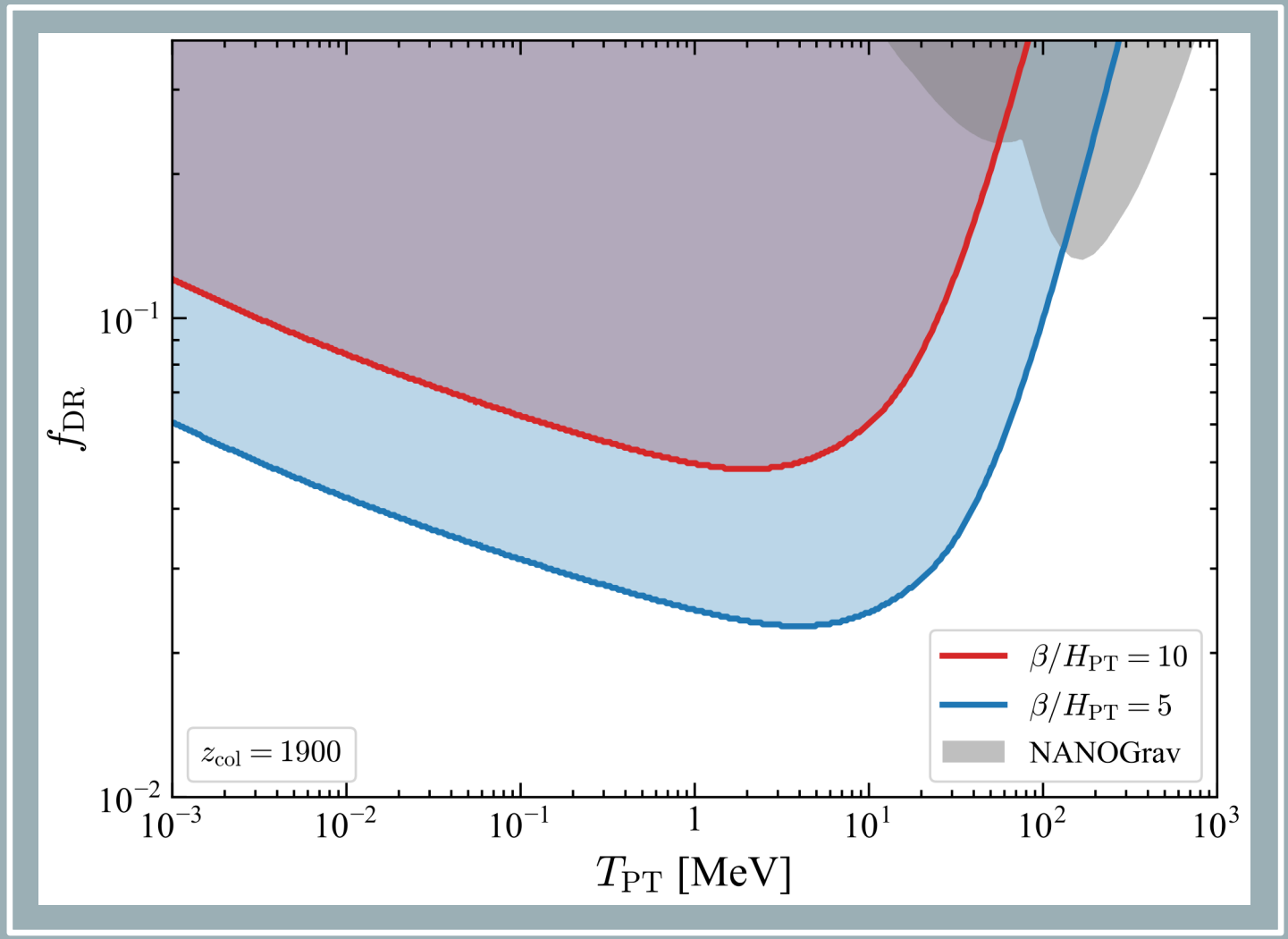
$$\mathrm{F}(M; z_c) = \frac{1}{\sqrt{2\pi}\sigma(M, z_c)} \int_{\delta_{sc}}^{\infty} \exp\left(-\frac{\delta^2}{2\sigma^2(M; z_c)}\right) d\delta$$



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PRELIMINARY RESULTS



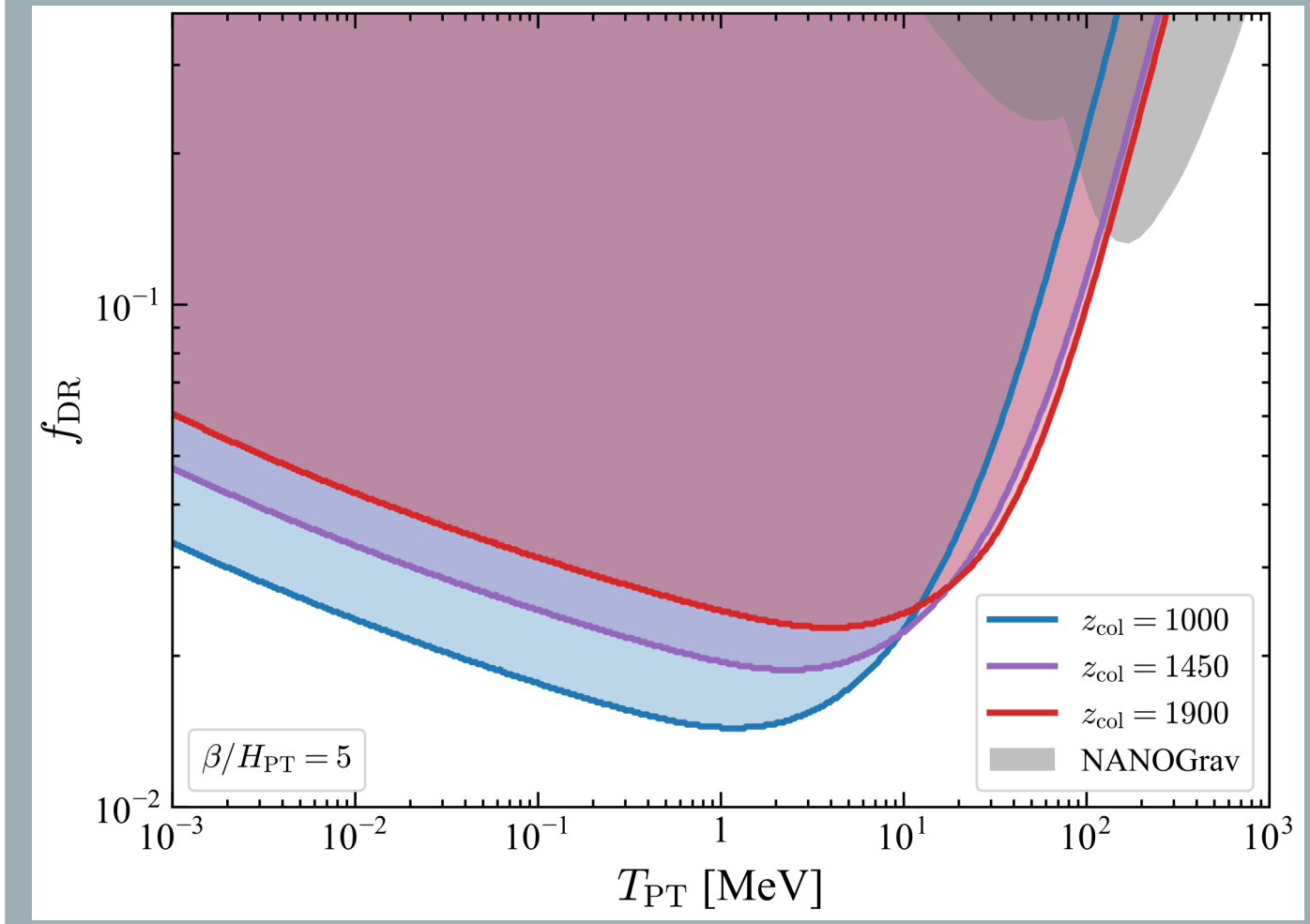
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CONCLUSION

- A dark-sector FOPT that sources the PTA signal also produces UCMHs, giving an independent test through gravitational lensing
- Using the recorded peak brightness of Icarus, we constrained a large region of the phase-transition parameter space capable of sourcing the gravitational-wave background

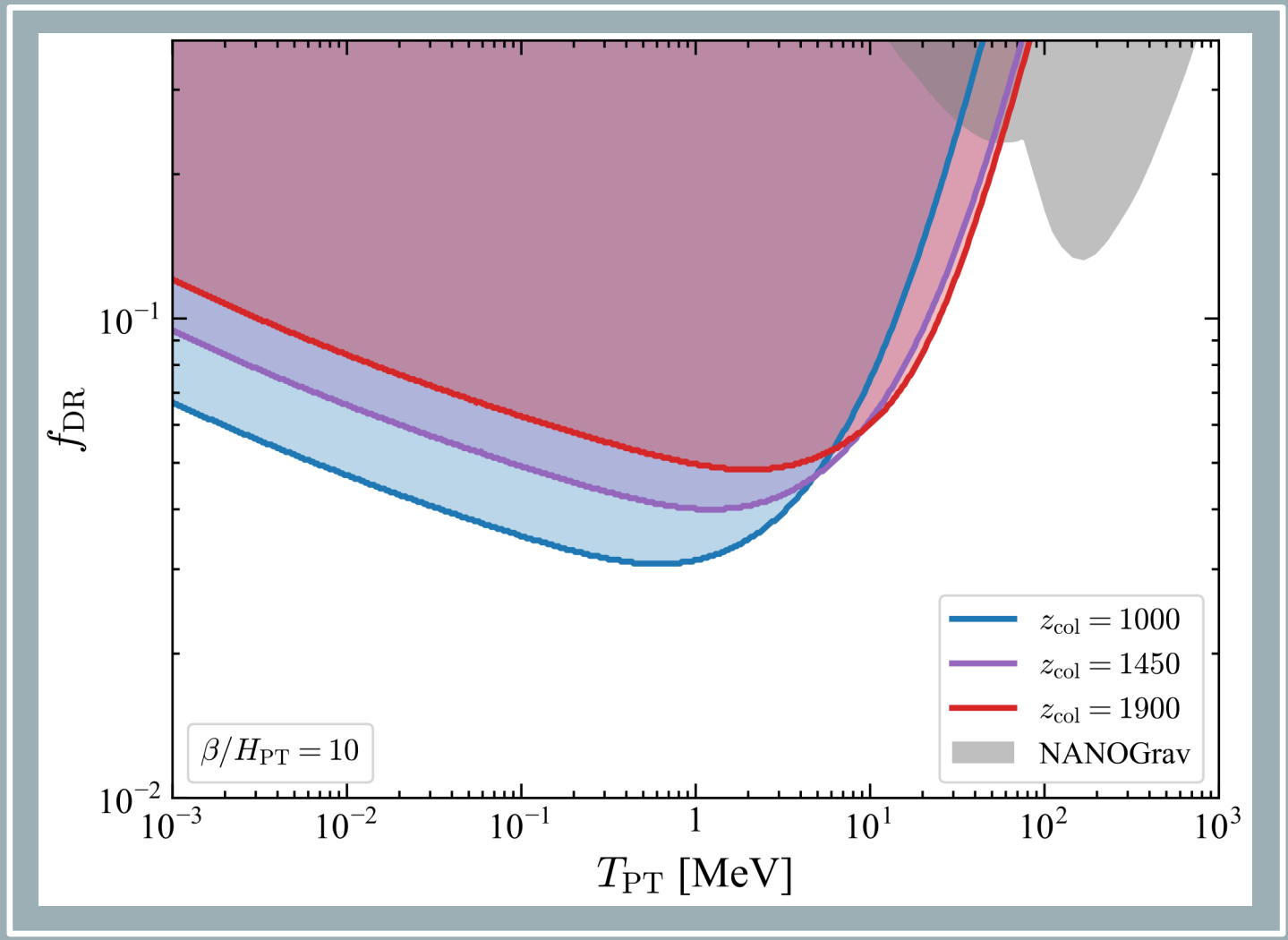
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$\beta / H_{PT} = 5$



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$\beta / H_{PT} = 10$



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