Gravitational Particle Production of Scalar Dark Matter in α-Attractor Models of Inflation

ArXiv:2101.11621

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This Talk

Superheavy scalar dark matter from gravitational particle production in α-attractor models of inflation

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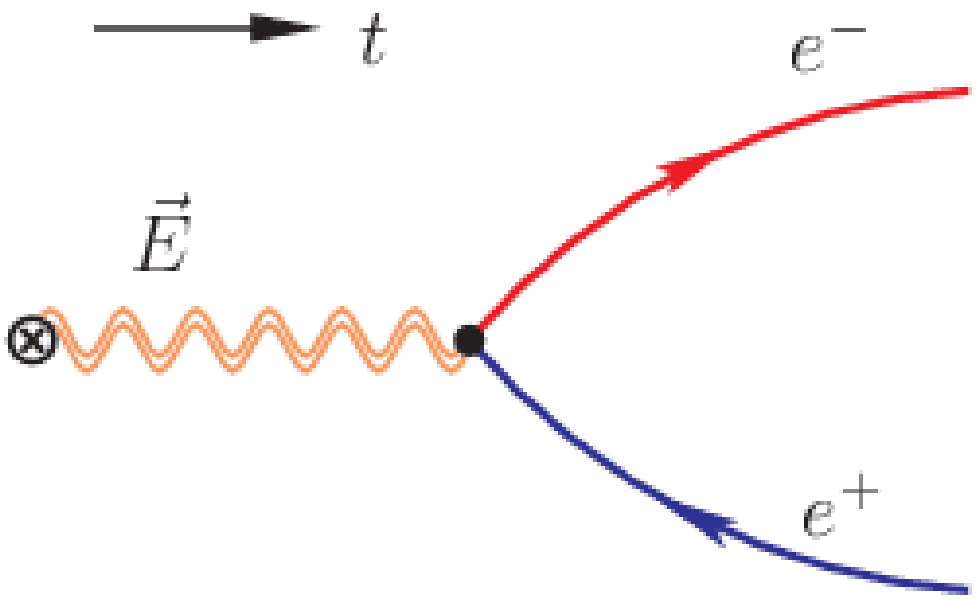
Gravitational Particle Production

- Strong gravitational field can produce particles out of vacuum.
- Analogue: Schwinger effect



Chung, Daniel J. H. and Kolb, Edward W. and Riotto, Antonio, *Superheavy dark matter*
J Audretsch and G Schafer 1978, *Thermal particle production in a radiation dominated Robertson-Walker universe*
N. D. Birrell and P. C. Davies, *Quantum fields in curved space*
And so on…

Gravitational Particle Production

- EOM for particle production:

$$[\partial_\eta^2 - \boldsymbol{\nabla}^2 + a^2 m_{\rm eff}^2](a\chi) = 0$$

$$m_{\rm eff}^2 = m_\chi^2 + \frac{1}{6}R$$

- Production induced by time-varying *a* and *R* !

Inflation

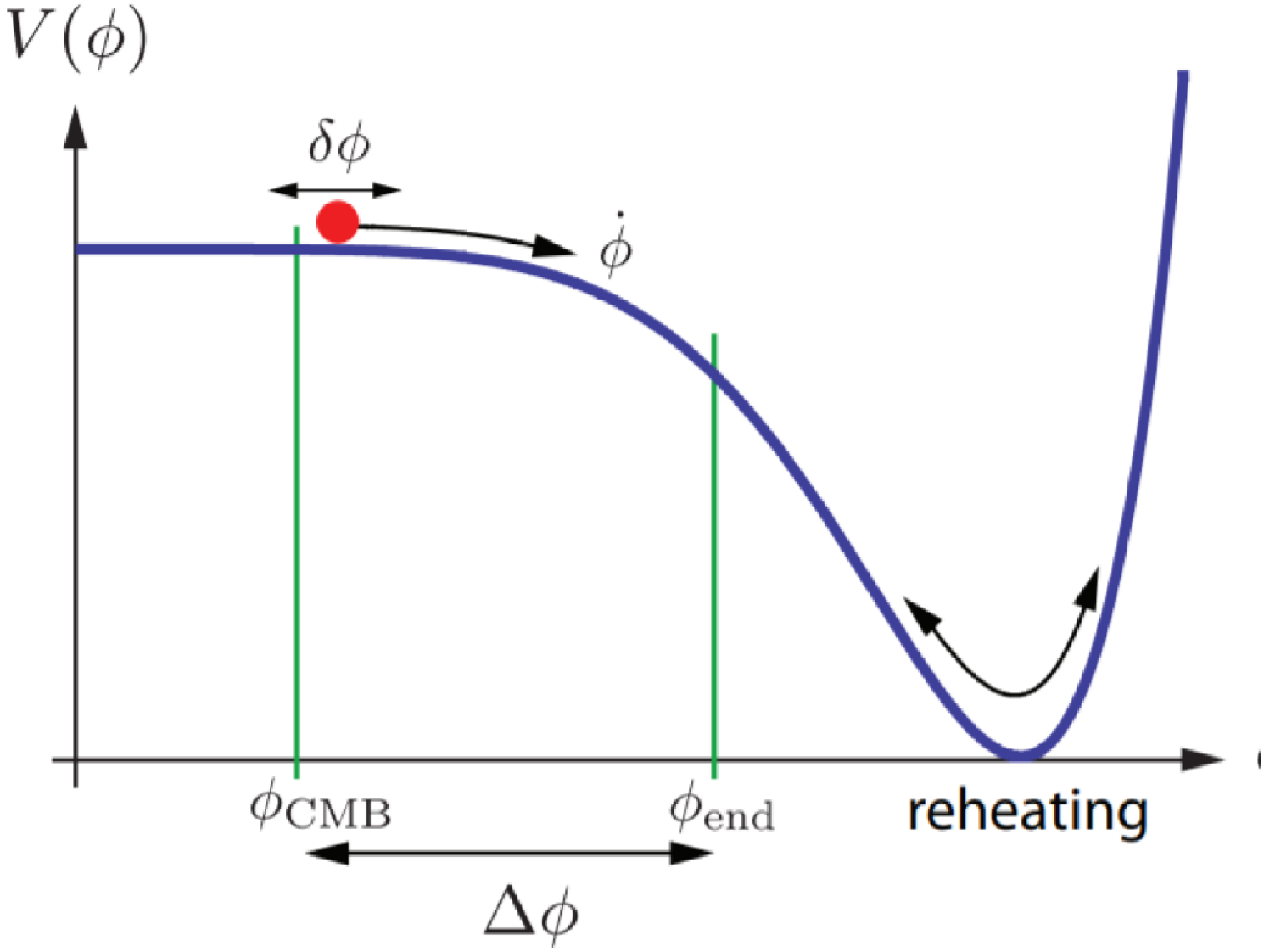
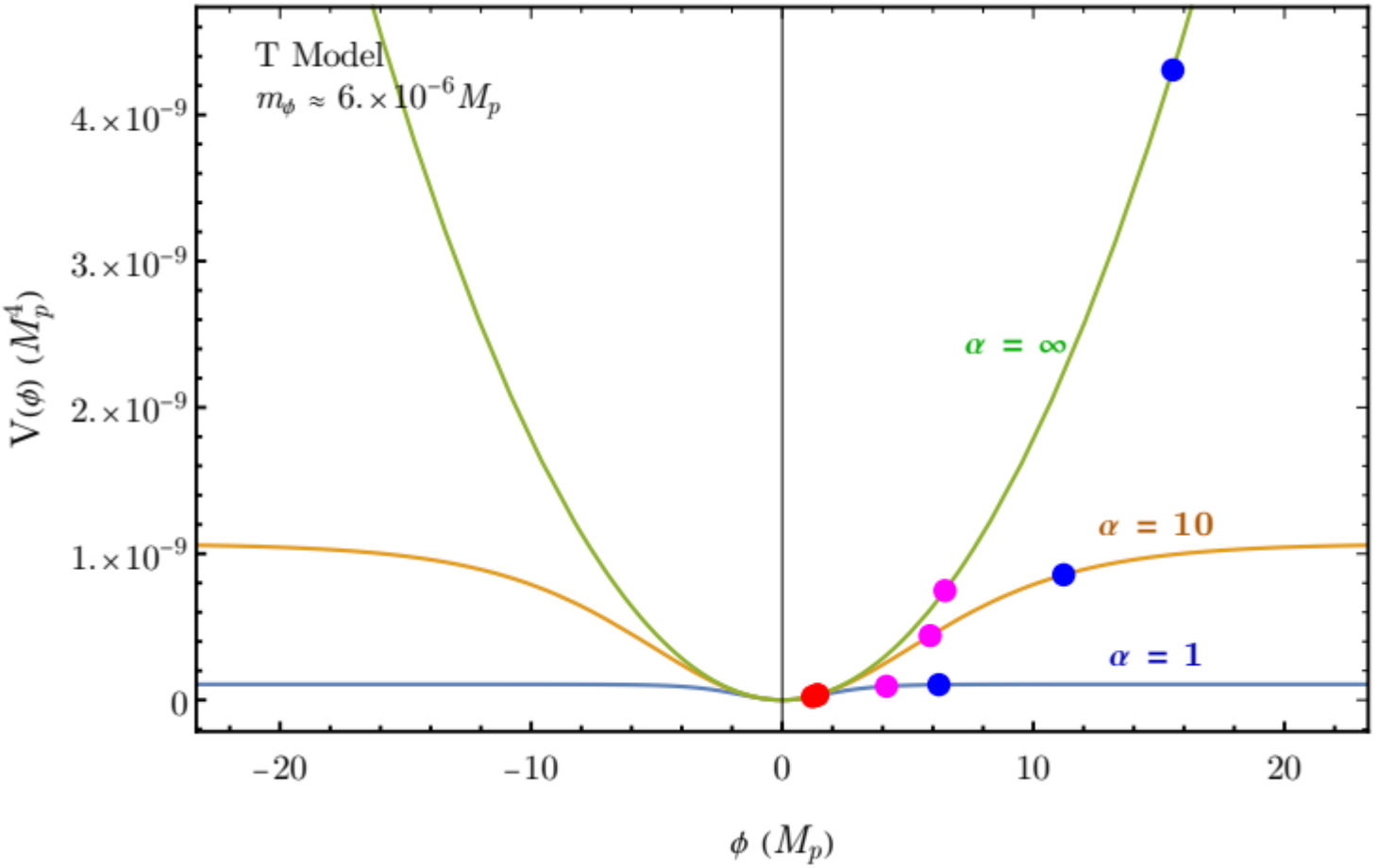


Figure due to A. Mazumdar

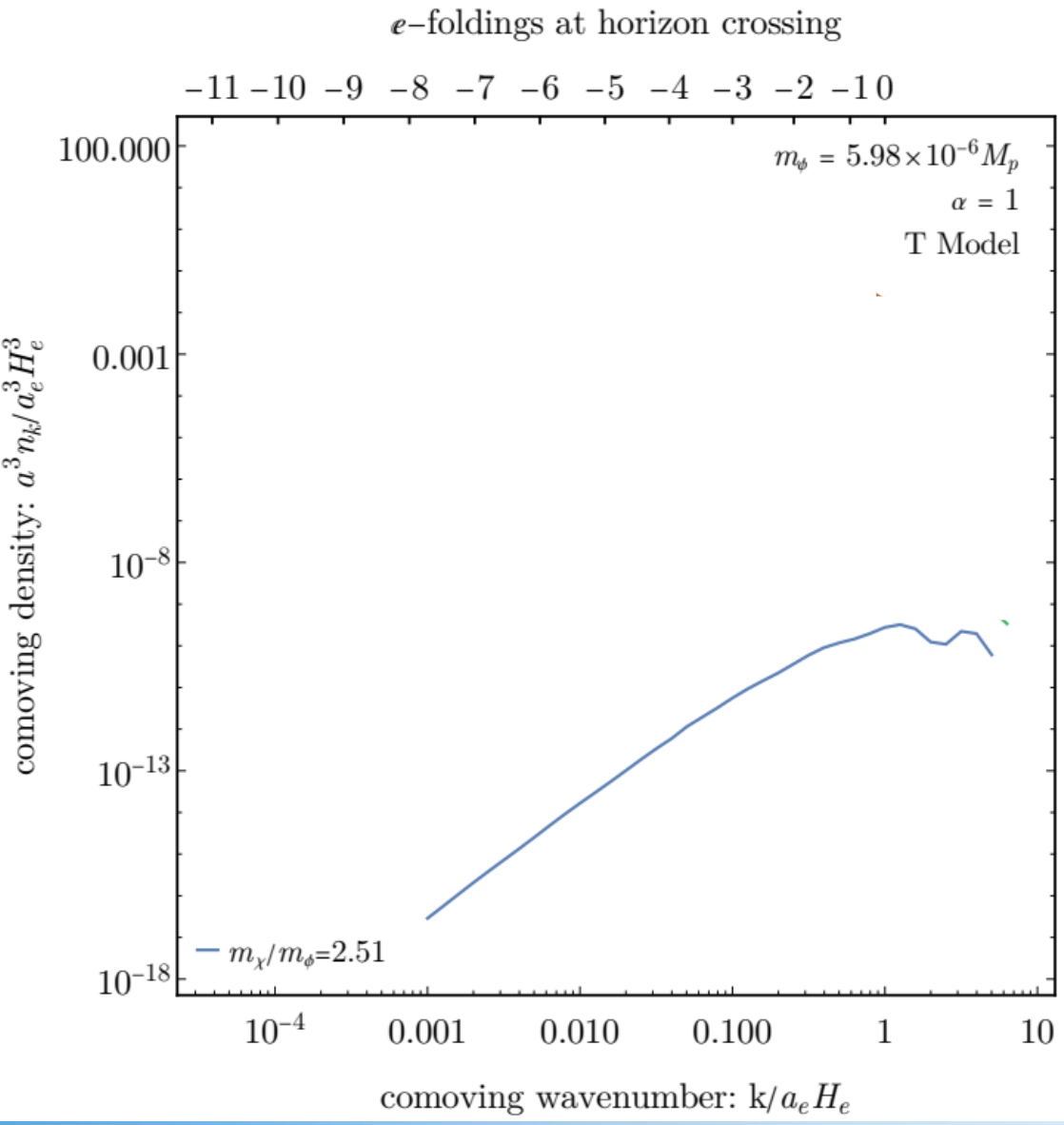
Alpha-attractor

- A class of inflaton potential...

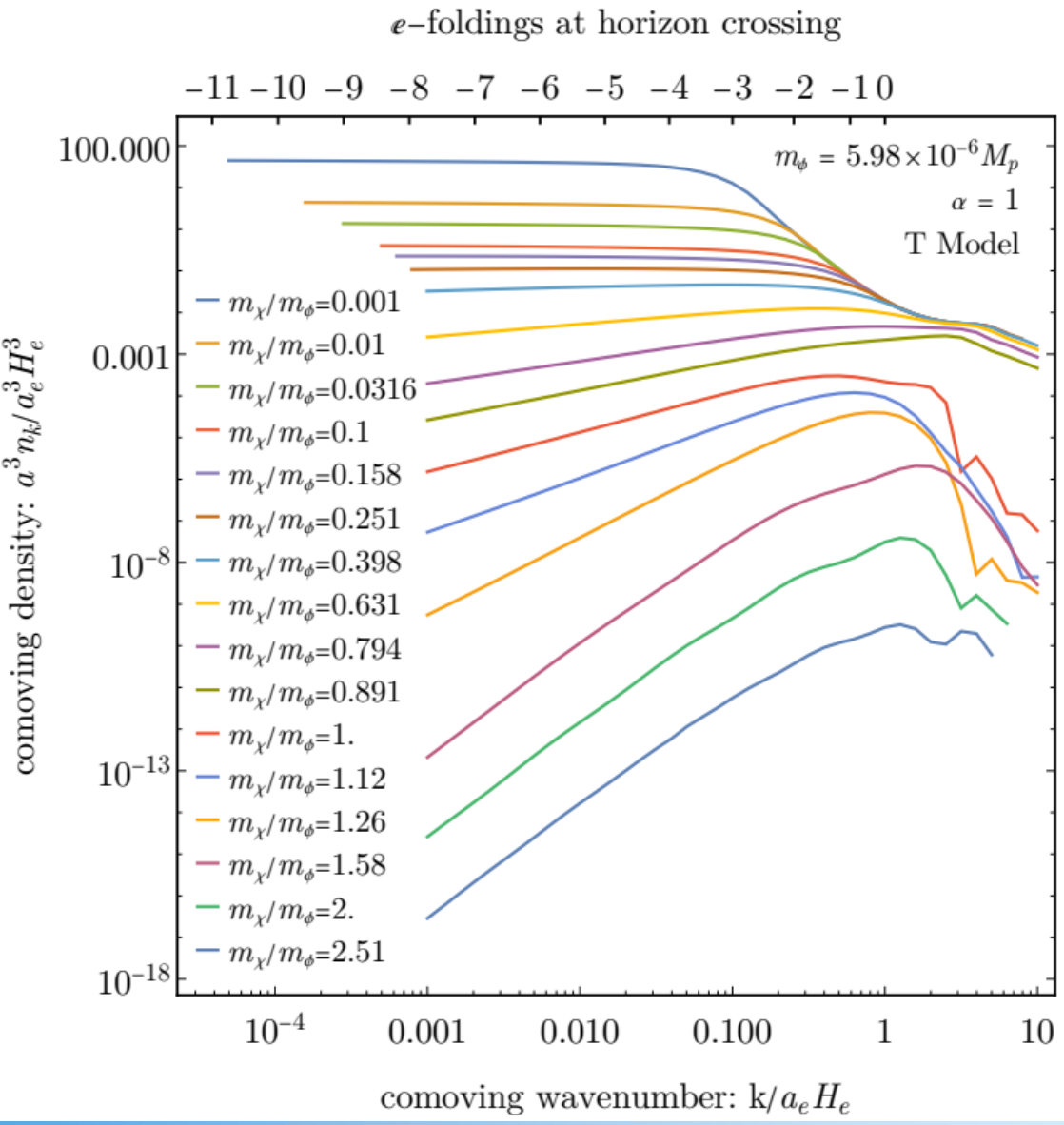


Renata Kallosh and Andrei Linde, *Planck, LHC, and α-attractors*

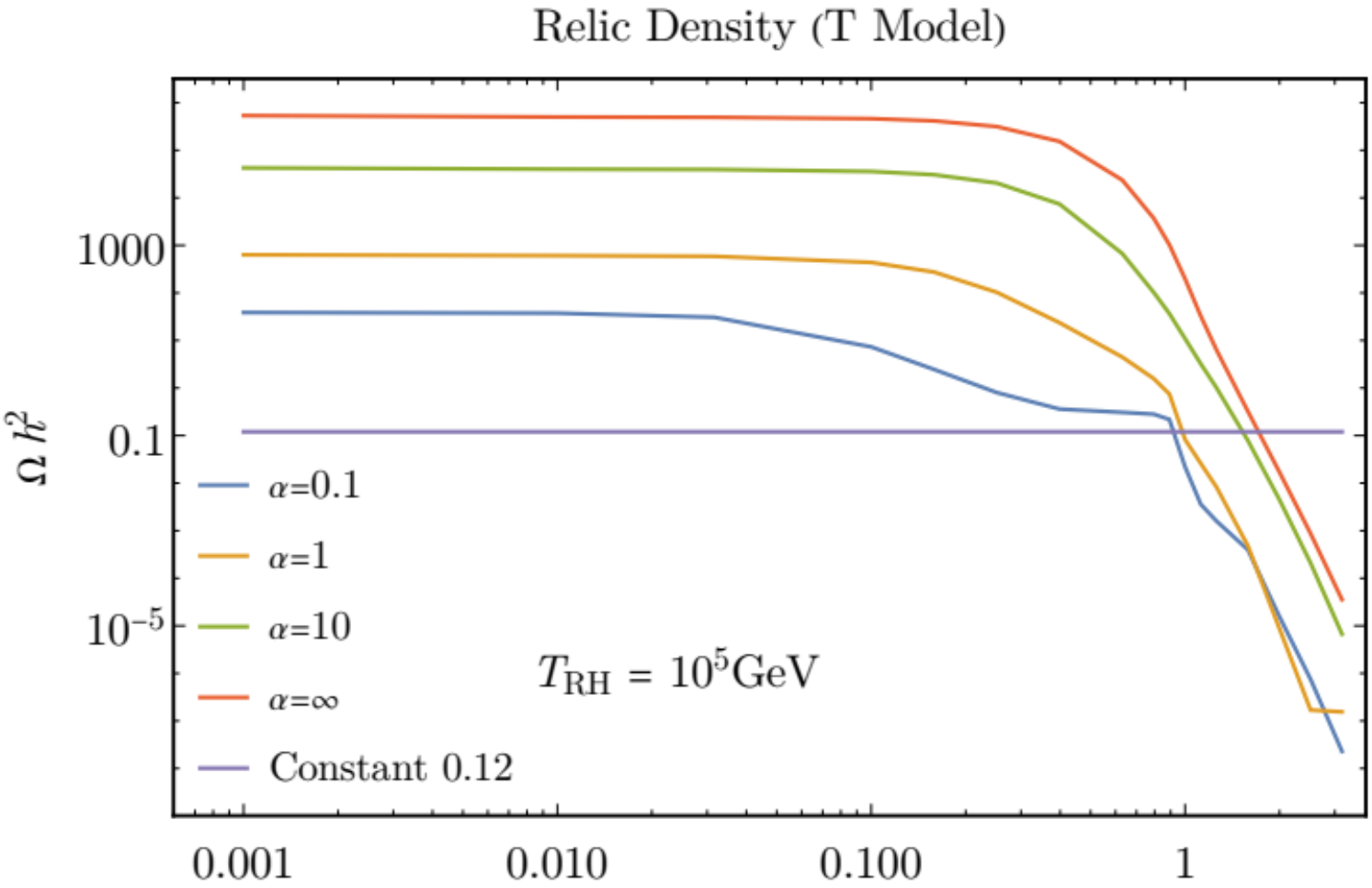
Relic density spectrum



Relic density spectrum



Relic abundance



$$\Omega h^2 = \left(\frac{\pi^2 g_{*S,0} T_0^3}{270 M_p H_{100}^2}\right)\left(\frac{m_\chi H_e T_{\rm RH}}{M_p^3}\right)\left(\frac{a^3 n}{a_e^3 H_e^3}\right)$$

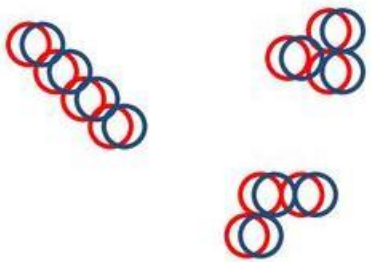
Isocurvature

- Isocurvature is also generated.

$$S_{DM,\gamma} = \frac{\delta n_{DM}}{n_{DM}} - \frac{\delta n_{\gamma}}{n_{\gamma}}$$ (DM-photon isocurvature)

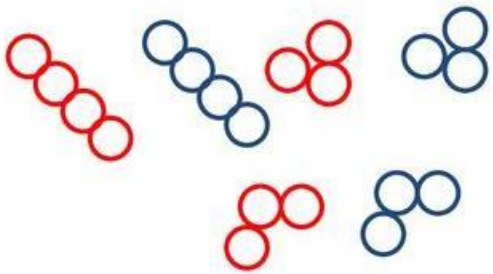
adiabatic density inhomogeneity

$S_{DM,\gamma} = 0$



isocurvature density inhomogeneity

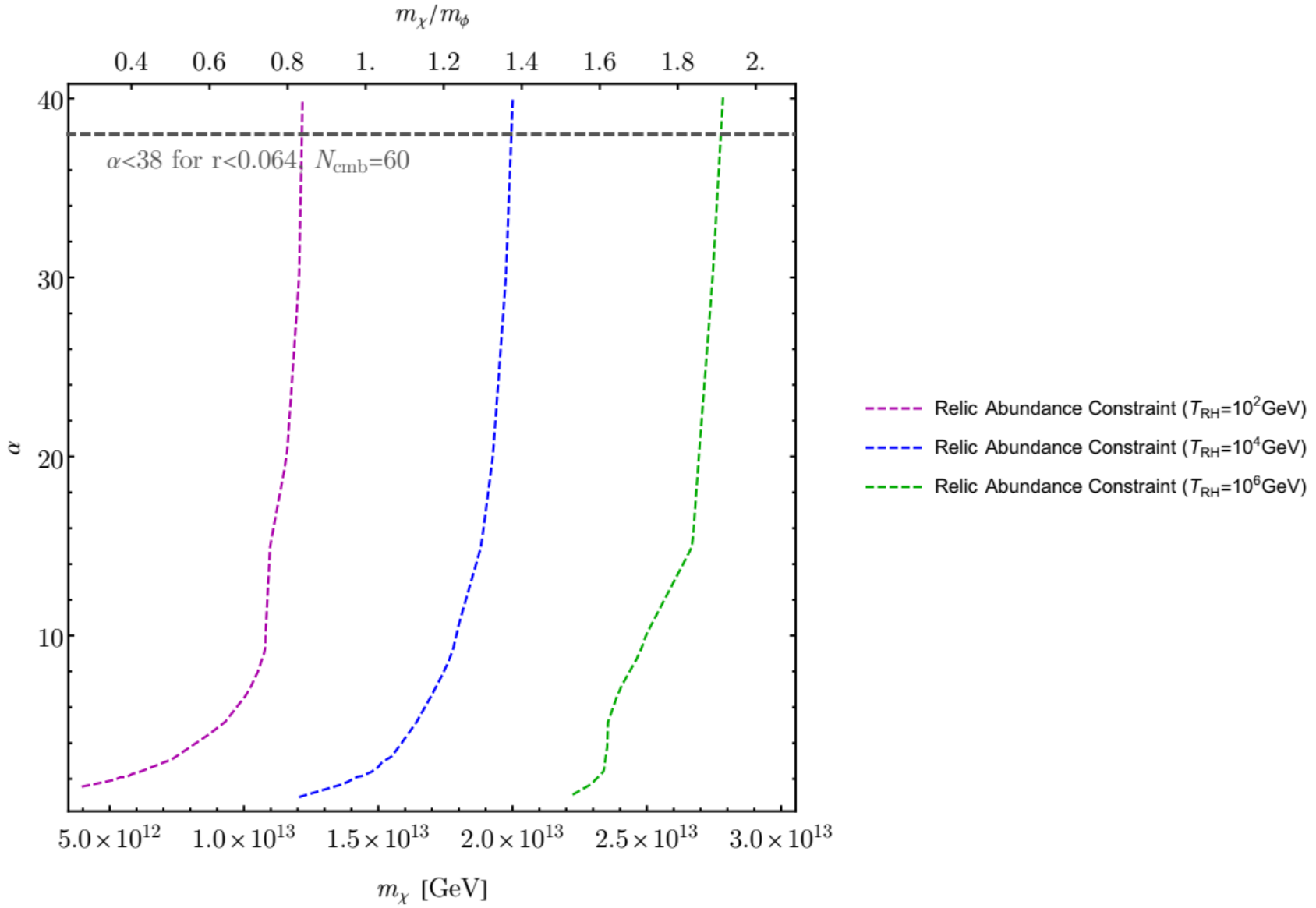
$S_{DM,\gamma} \neq 0$



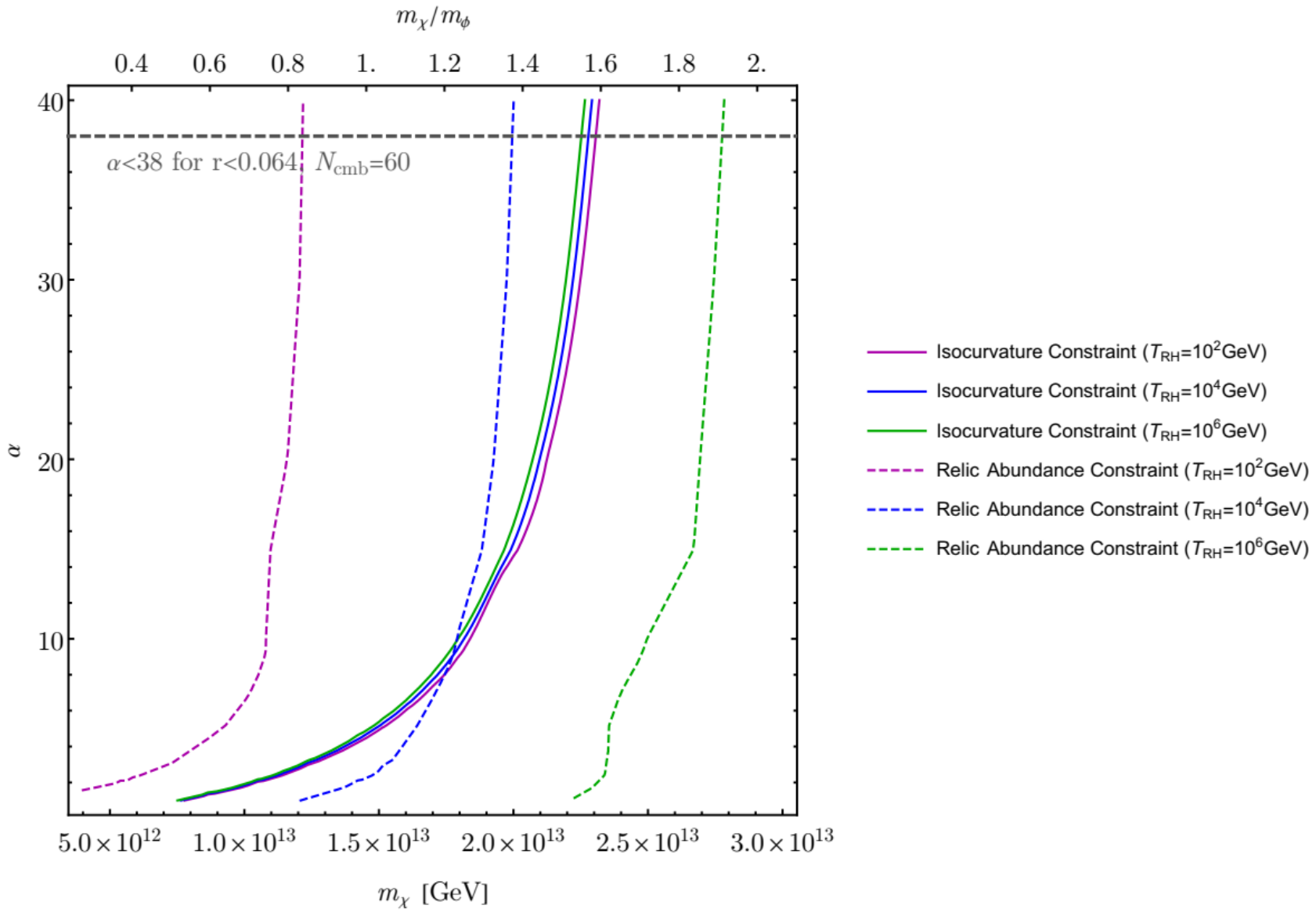
Planck 2018 gives isocurvature constraint β_iso < 0.035

Figure due to Daniel J. Chung

Constraints



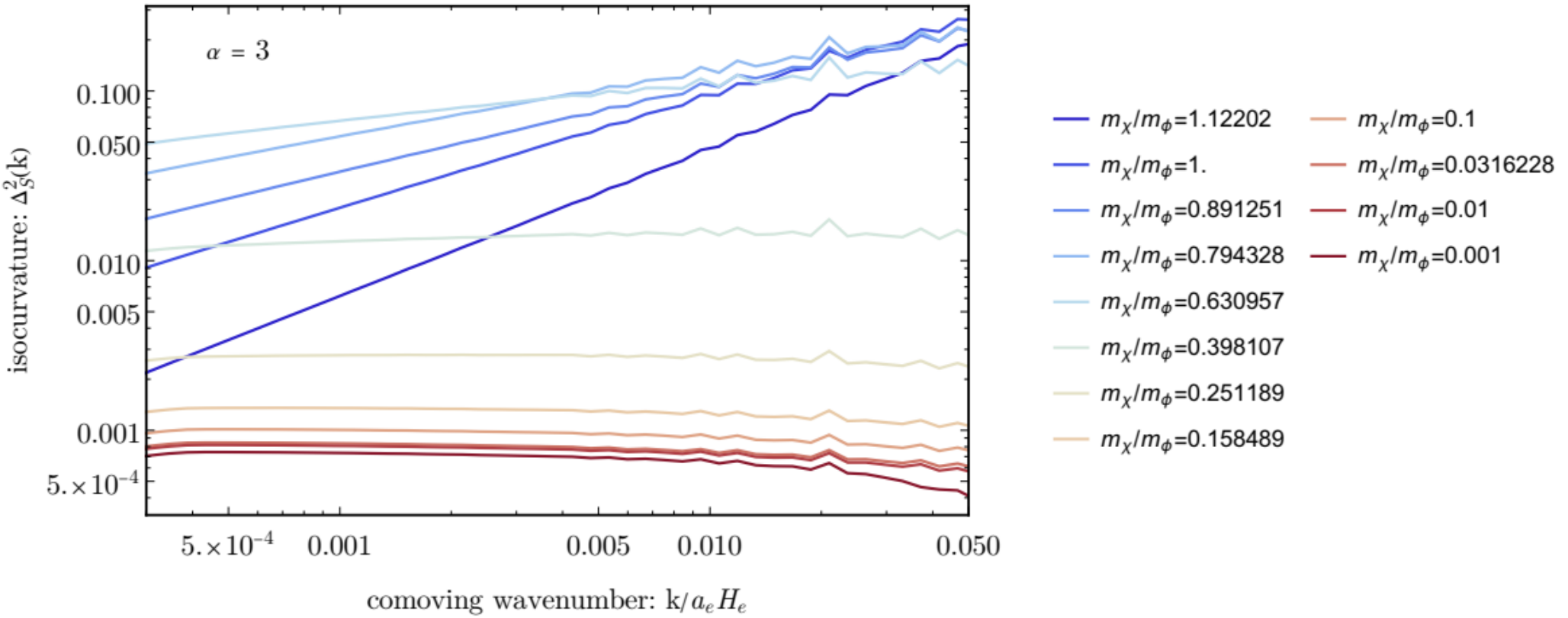
Constraints



Conclusion

- Supermassive particles can be produced by gravity during inflation sourced by alpha-attractor potentials.
- This process generates isocurvature perturbations, which we may be able to detect in the future.

Extra


α = 3
0.100
0.050
0.010
0.005
0.001
5.×10⁻⁴
isocurvature: Δ²_S(k)
5.×10⁻⁴
0.001
0.005
0.010
0.050
comoving wavenumber: k/a_e H_e
m_χ/m_φ=1.12202
m_χ/m_φ=1.
m_χ/m_φ=0.891251
m_χ/m_φ=0.794328
m_χ/m_φ=0.630957
m_χ/m_φ=0.398107
m_χ/m_φ=0.251189
m_χ/m_φ=0.158489
m_χ/m_φ=0.1
m_χ/m_φ=0.0316228
m_χ/m_φ=0.01
m_χ/m_φ=0.001