Higgs Inflation: *Particle Factory*

Evan McDonough
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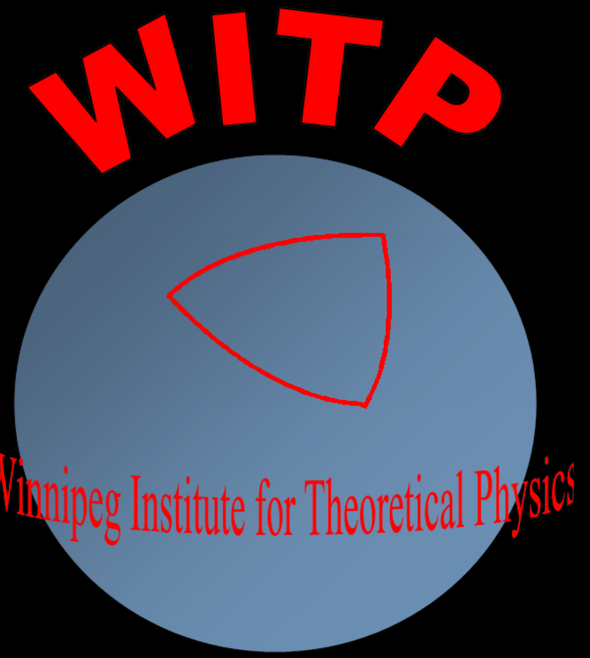
Department of Physics

June 22, 2026
CAP Congress

Based on Chowdhury, Kolb, Jenks, EM
JHEP ‘26



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Plan for today:

1. Particle Cosmology & Cosmic Inflation
2. Particle Production
3. Higgs Inflation: Particle Factory

Hot off the presses: *Non-thermal Leptogenesis*

Particle Cosmology circa 1948

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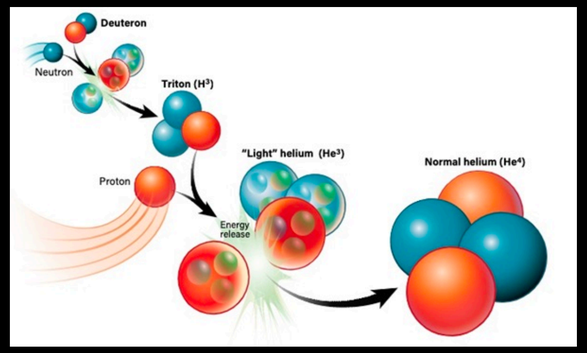
Big Bang Nucleosynthesis

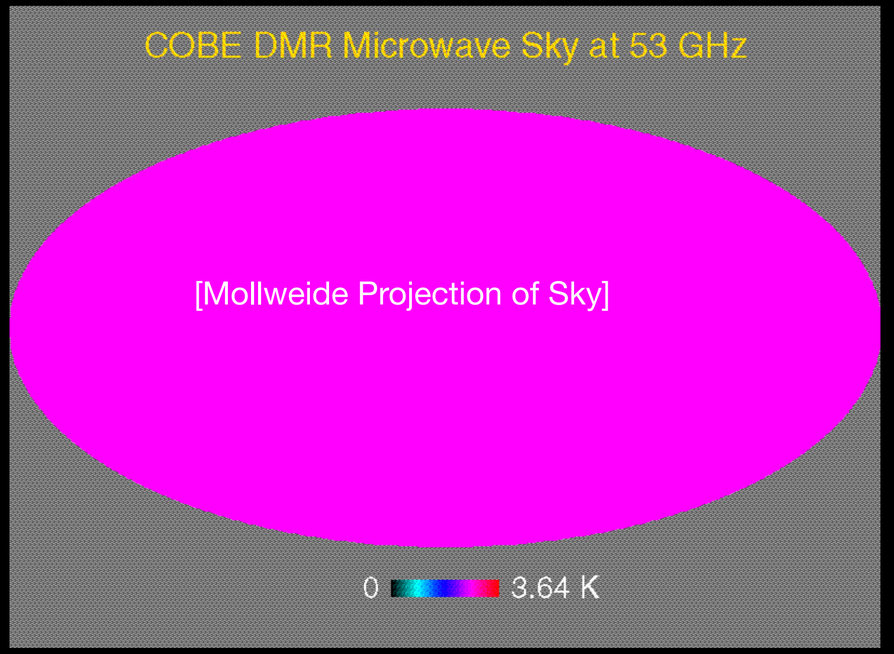
The "$\alpha\beta\gamma$" paper : 1948 Alpher, Bethe, Gamow



Fantastic agreement with observations

Cosmic Microwave Background

Predicted: 1948 Alpher & Herman
Discovered: 1964 Penzias & Wilson.
Nobel Prize: 1978



1980's: Start of the Modern Era

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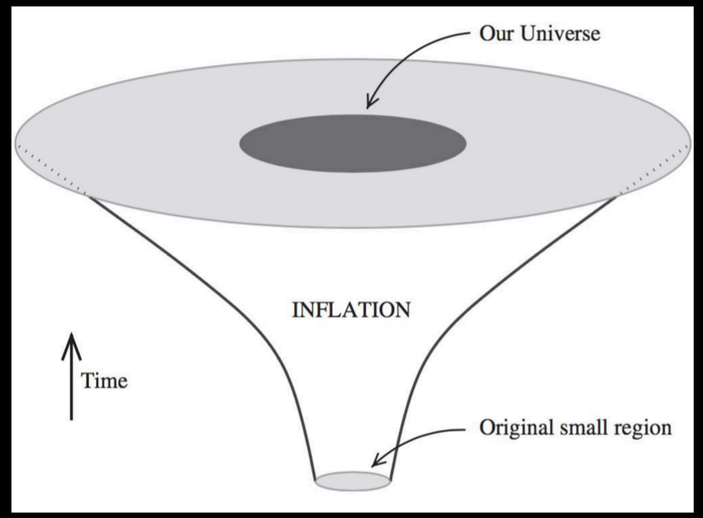
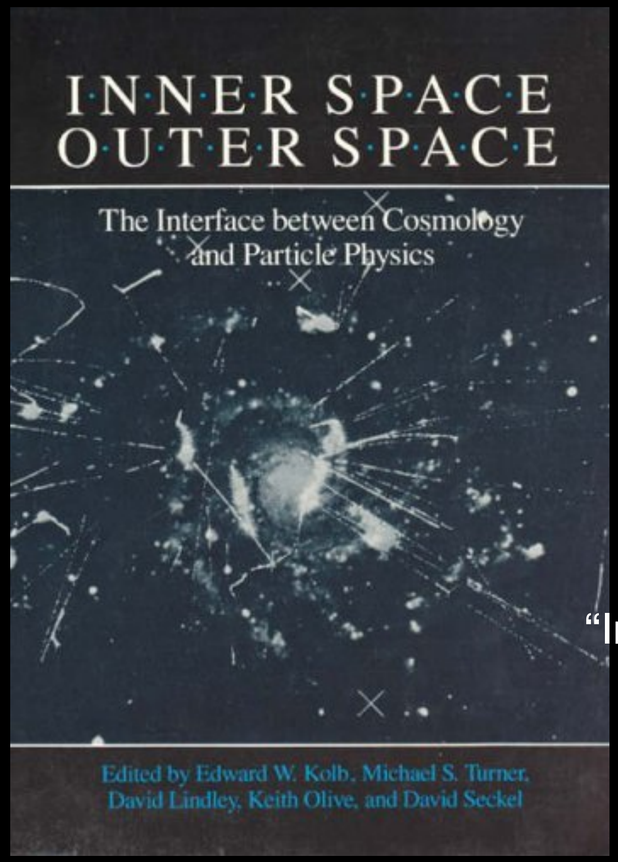
Cosmic Inflation
1980
Guth, + others



Particle Astrophysics Division, Fermilab
1983
Dir. Edward Kolb



WIMP Miracle

Goldberg (1983).
Hagelin, Nanopoulos, Olive, Srednicki (1984).
Steigman & Turner (1985)

1984 conference:
"Inner Space Outer Space"

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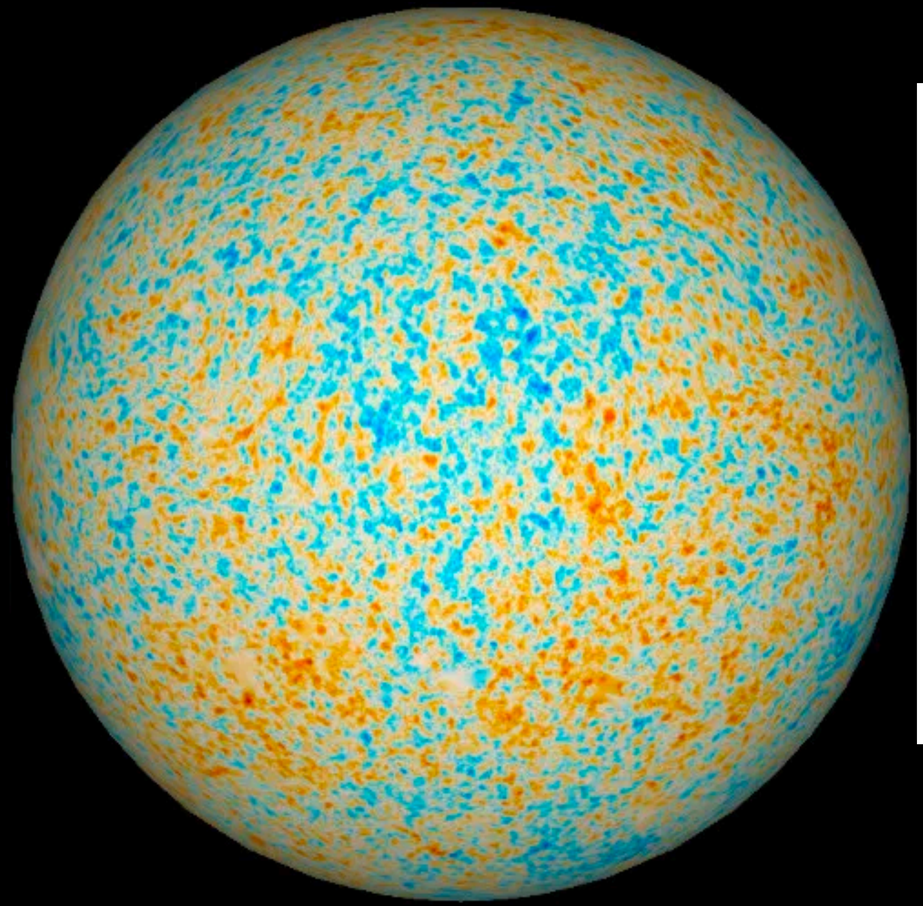
Evidence for Dark Matter



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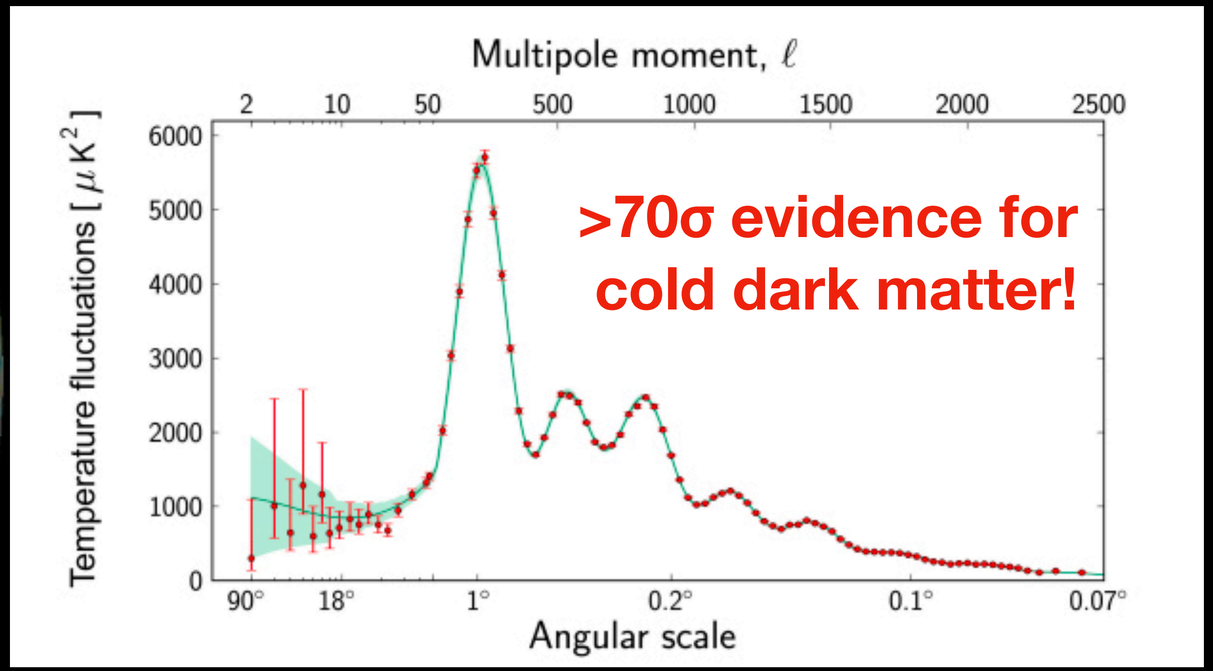

Cosmic Inflation: Cosmological Collider

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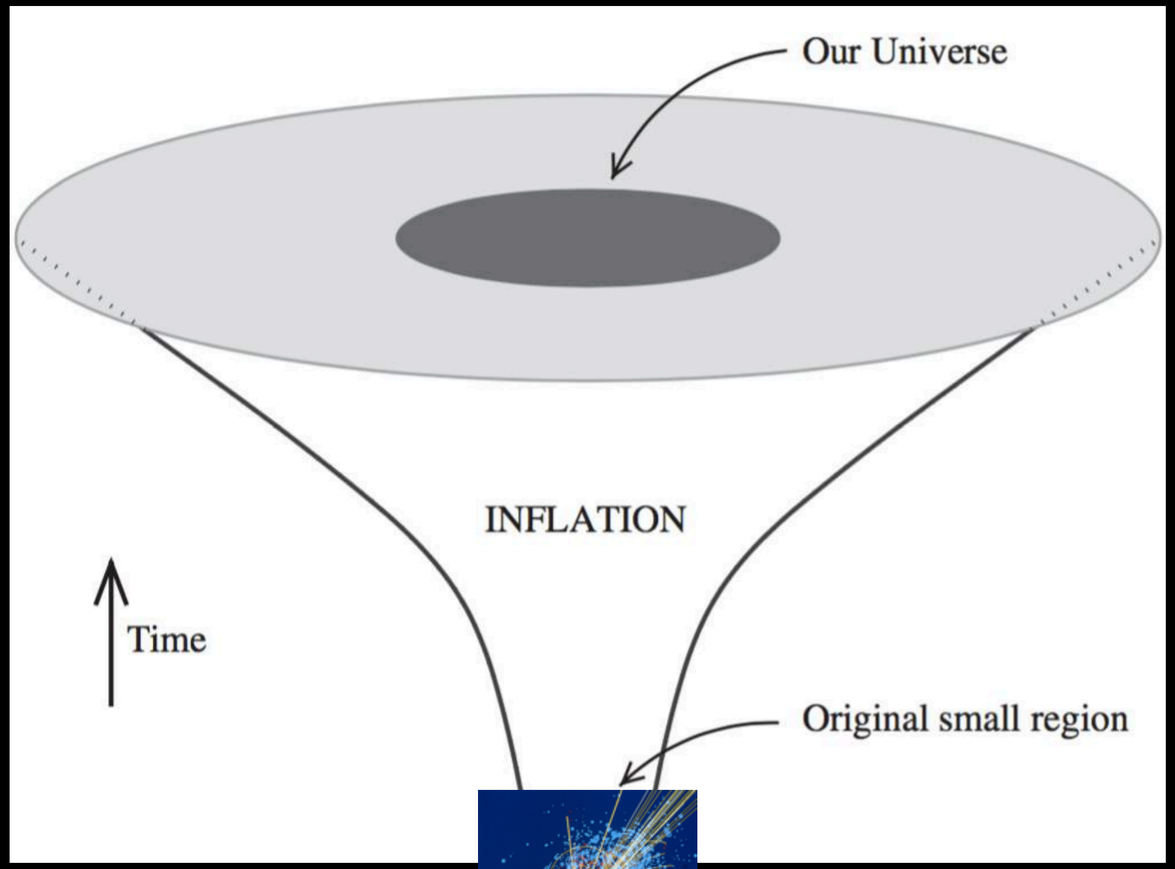

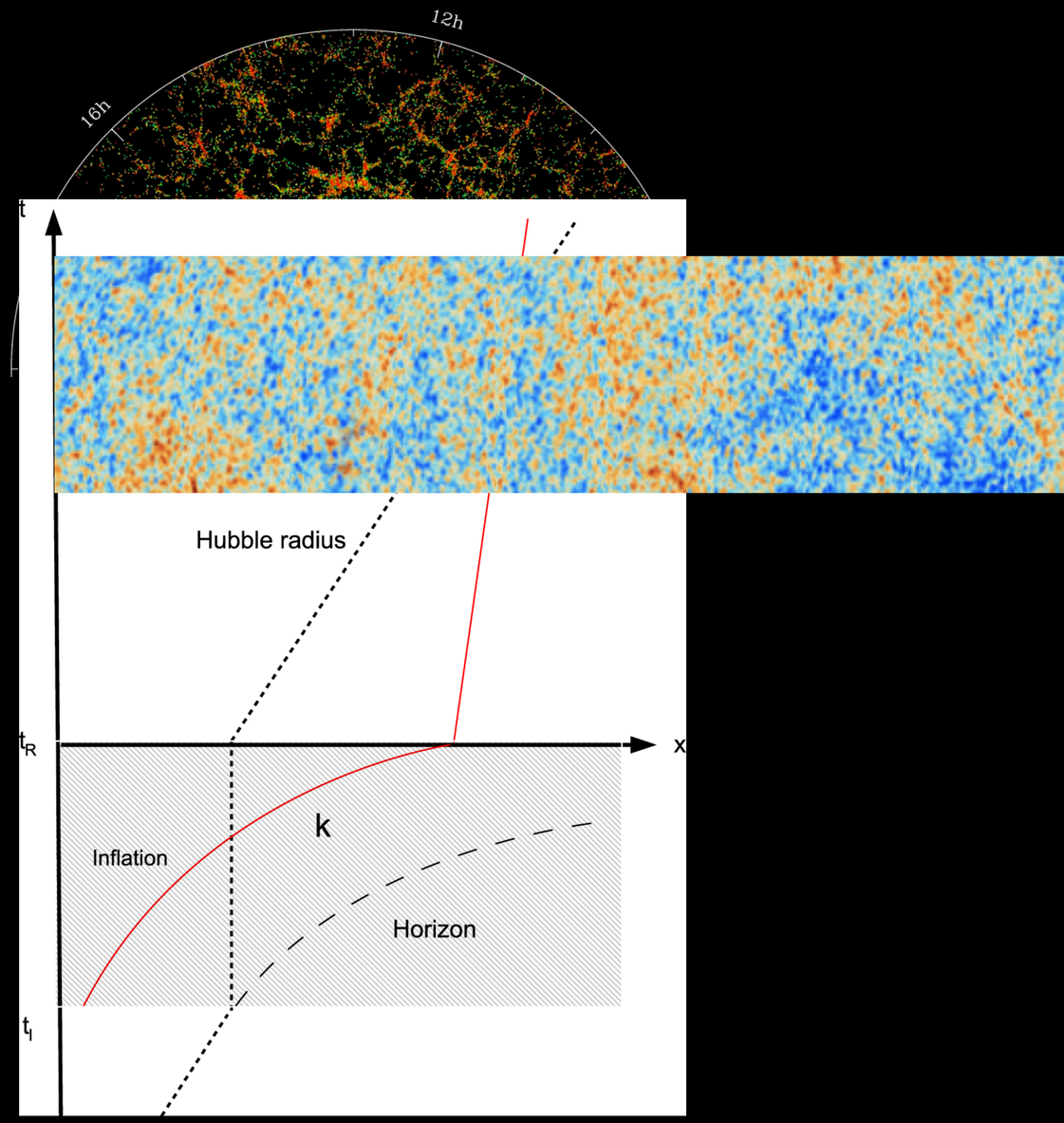

Cosmic Inflation as Particle Factory

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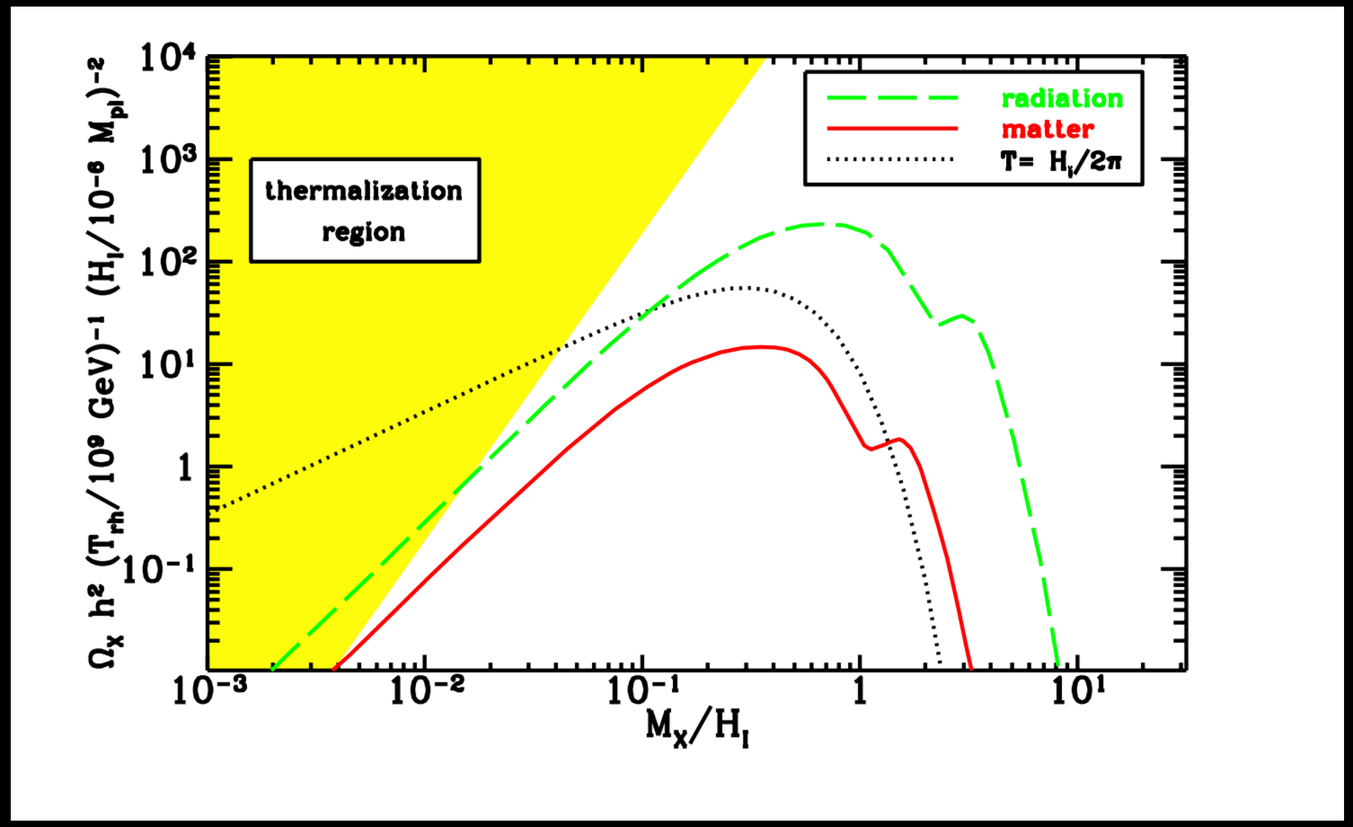
[Submitted on 14 Oct 1998]

WIMPZILLAS!

Edward W. Kolb, Daniel J. H. Chung, Antonio Riotto



“Particle Production” in Quantum Mechanics

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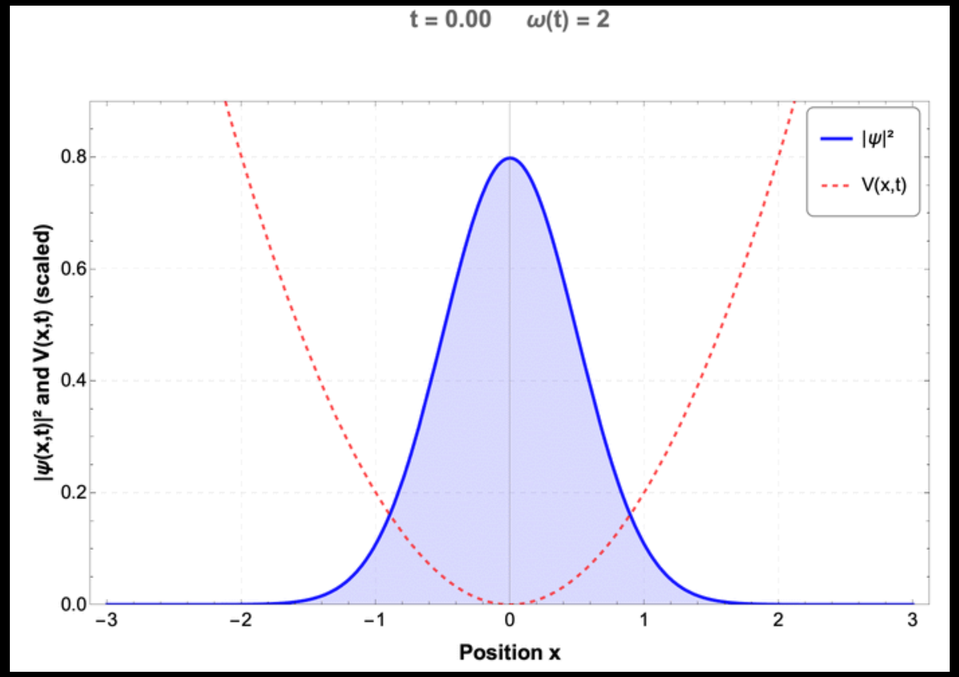
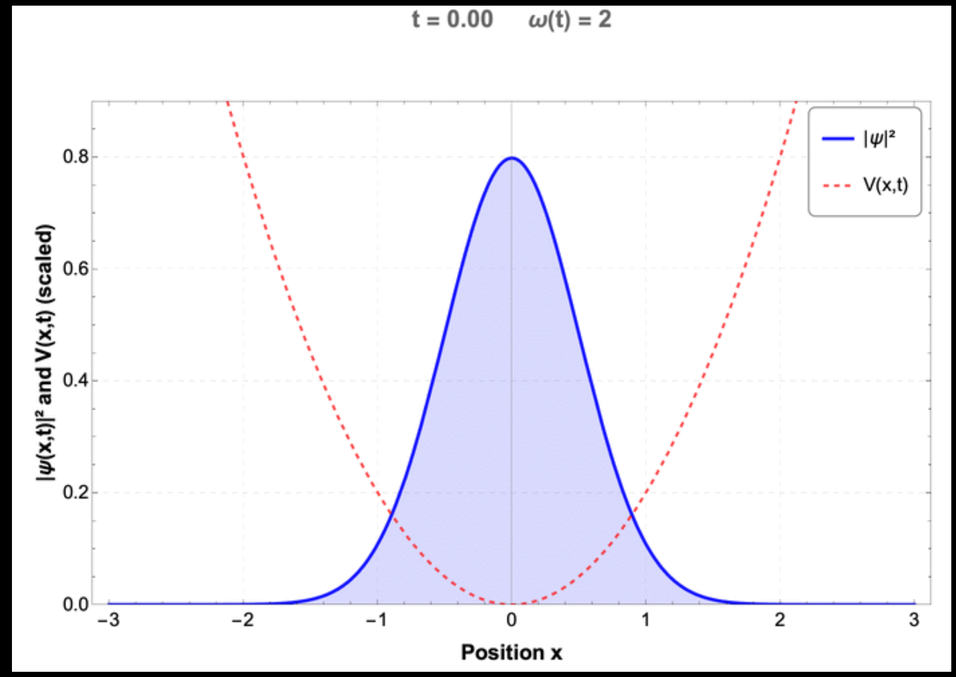
$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + \frac{1}{2}m\omega(t)^2x^2$$





Application to inflation: Scalar Field

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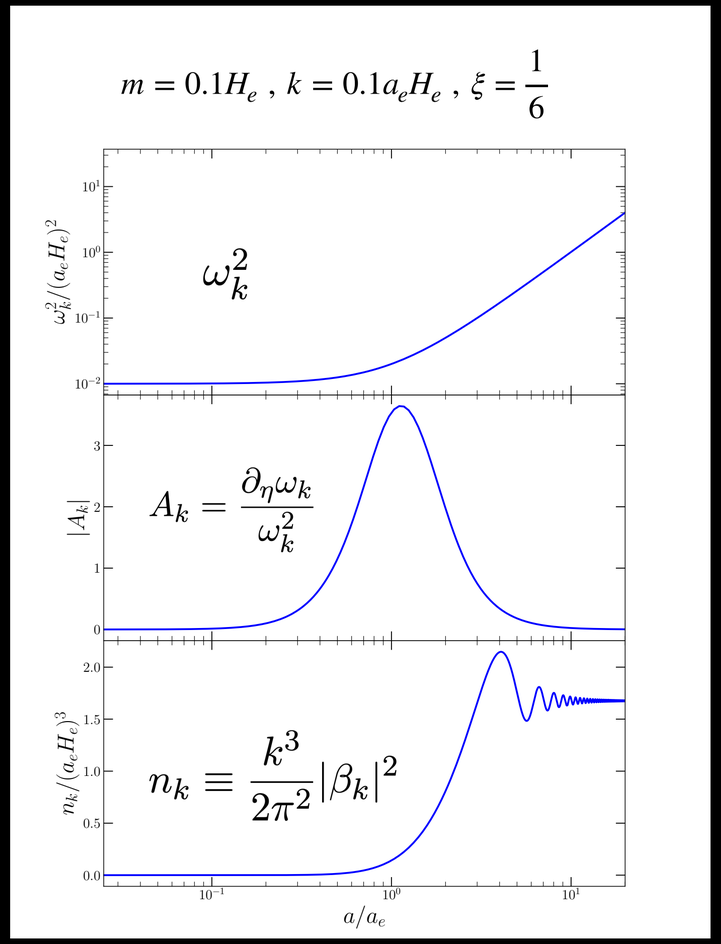
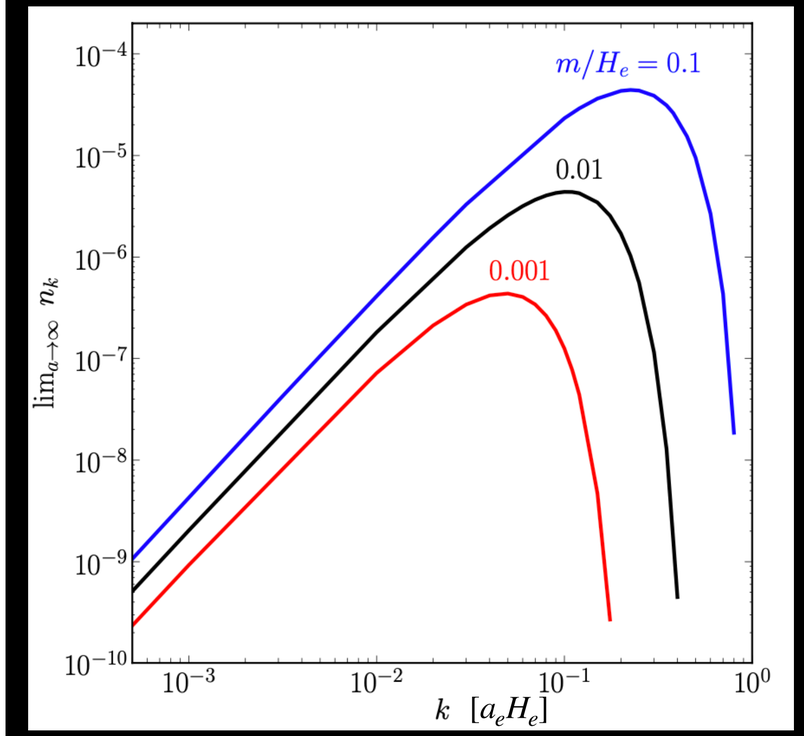
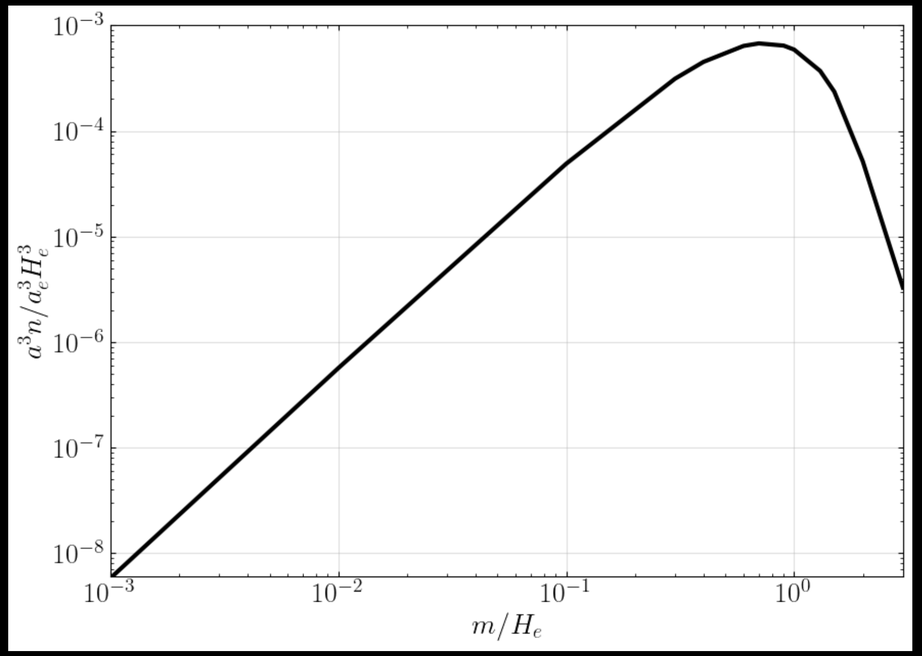
Kolb, Riotto, Chung, +…

$$\omega_k^2 = k^2 + m^2 a^2 + (\frac{1}{6} - \xi) a^2 R$$







Inflation: idea in search of a particle

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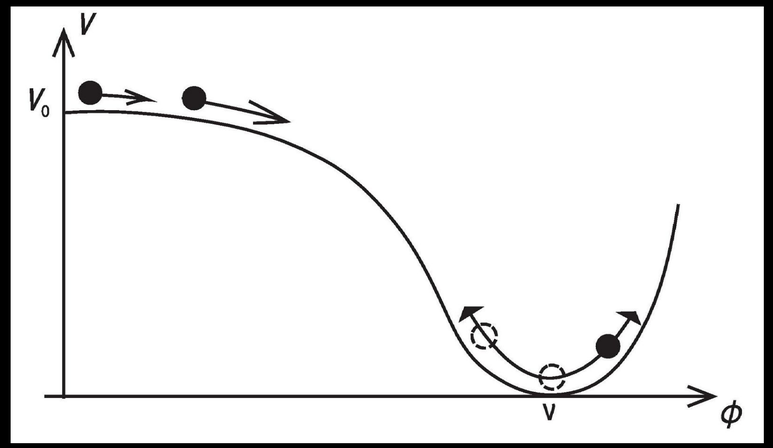
— Many models. Most common: scalar field with $V(\phi)$
—Many are now ruled out, e.g.
$V = \phi^2$, ϕ^4 : potential is too steep (V'/V)



Challenges:
— How connected to SM?
— Needs Quantum Gravity?

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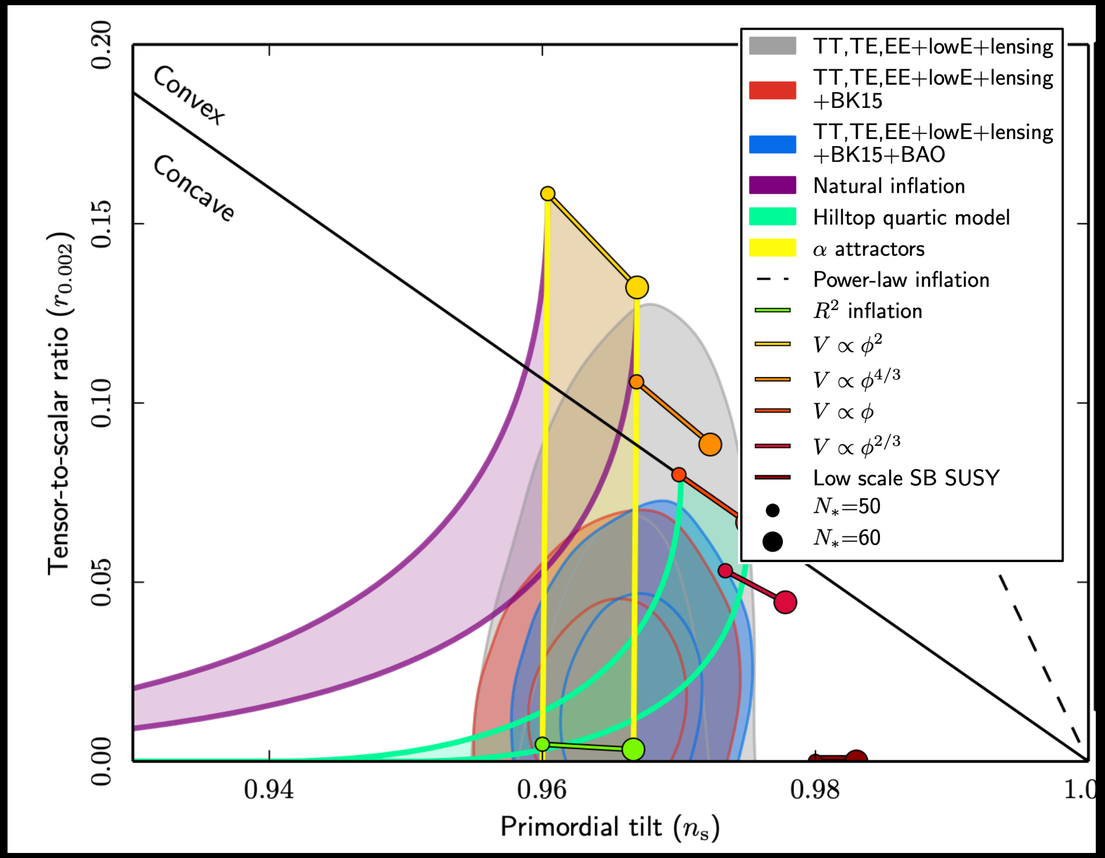

Higgs Inflation

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$$\mathscr{L} = \frac{1}{2}M_{pl}^2 R + \frac{1}{2}|D_\mu \Phi|^2 - \underbrace{\frac{\lambda}{4}\left(|\Phi|^2 - v^2\right)^2}_{\text{Too steep}} + \xi|\Phi|^2 R$$

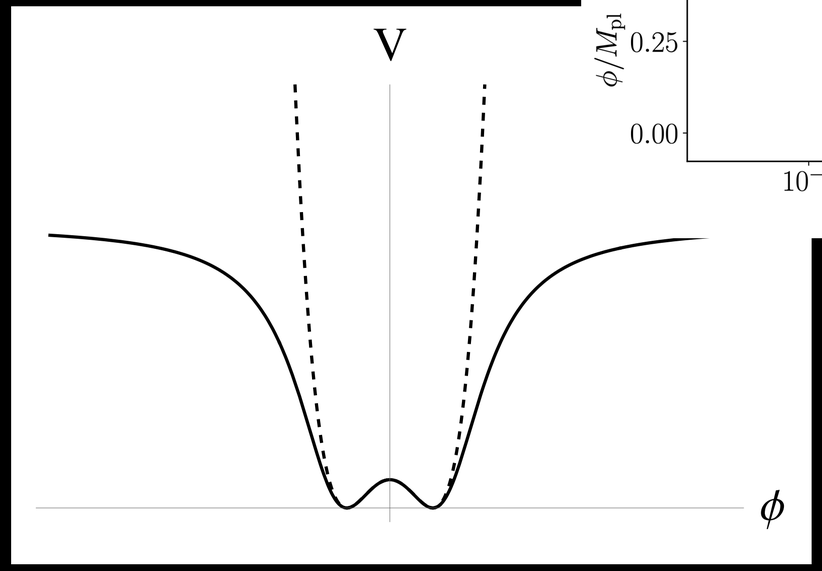
"Nonminimal coupling"

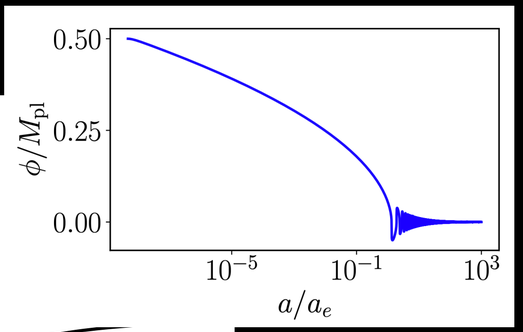
1970's: Coleman, Parker, +…
Required by renormalization

During inflation, ξ acts like a *stretching* of the potential.

Transform to "Einstein Frame"

$$g_{\mu\nu} \to e^{\Omega(\phi)} g_{\mu\nu} \Rightarrow V \to \frac{V}{(M_{pl}^2 + \xi|H|^2)^2}$$





$$\Phi = \begin{pmatrix} v+\phi \\ 0 \end{pmatrix}$$

Cosmological Observables

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Spectrum of scalar fluctuations:

$$\mathscr{P}(k) = A_s \left(\frac{k}{k_0}\right)^{n_s - 1}$$

$$A_s \sim \frac{\lambda}{\xi^2} \sim 10^{-10} \Rightarrow \quad \boxed{\xi \sim 10^5 \sqrt{\lambda(E_{\rm inf})}}$$

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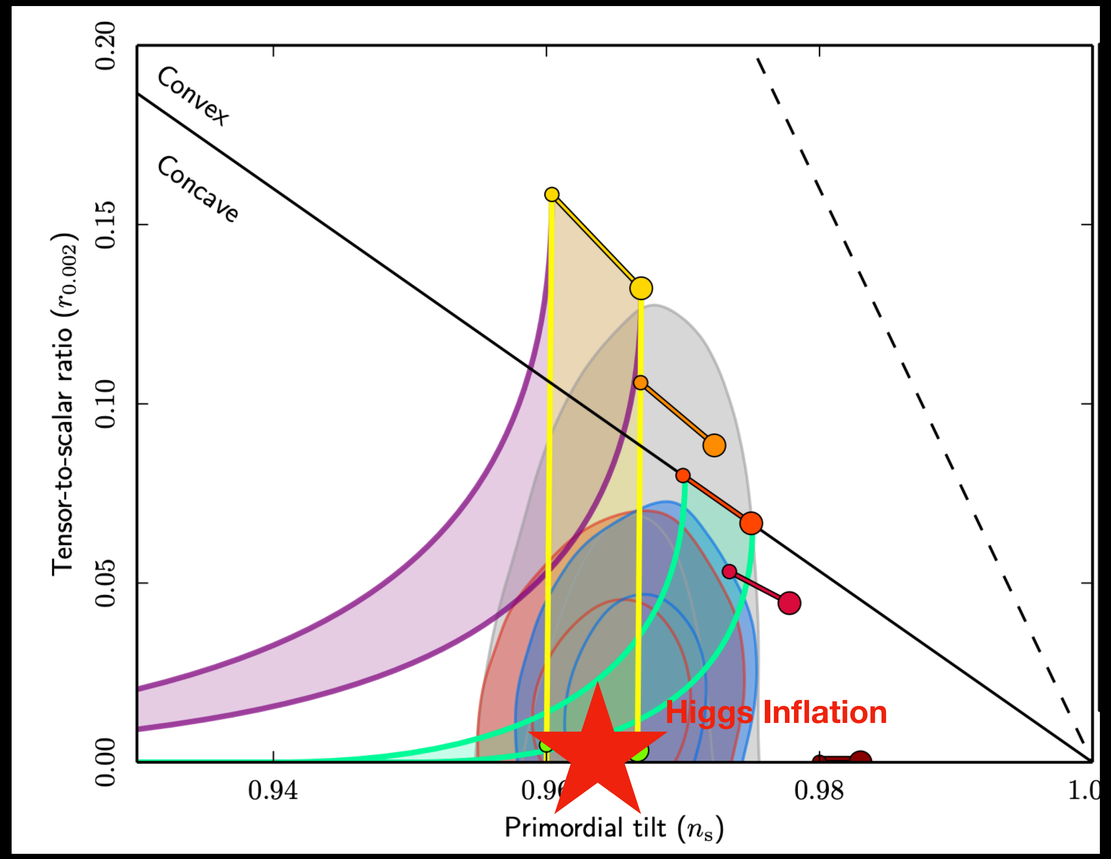

The Planck "Sweet Spot"

The Higgs Self-Coupling: Instability!

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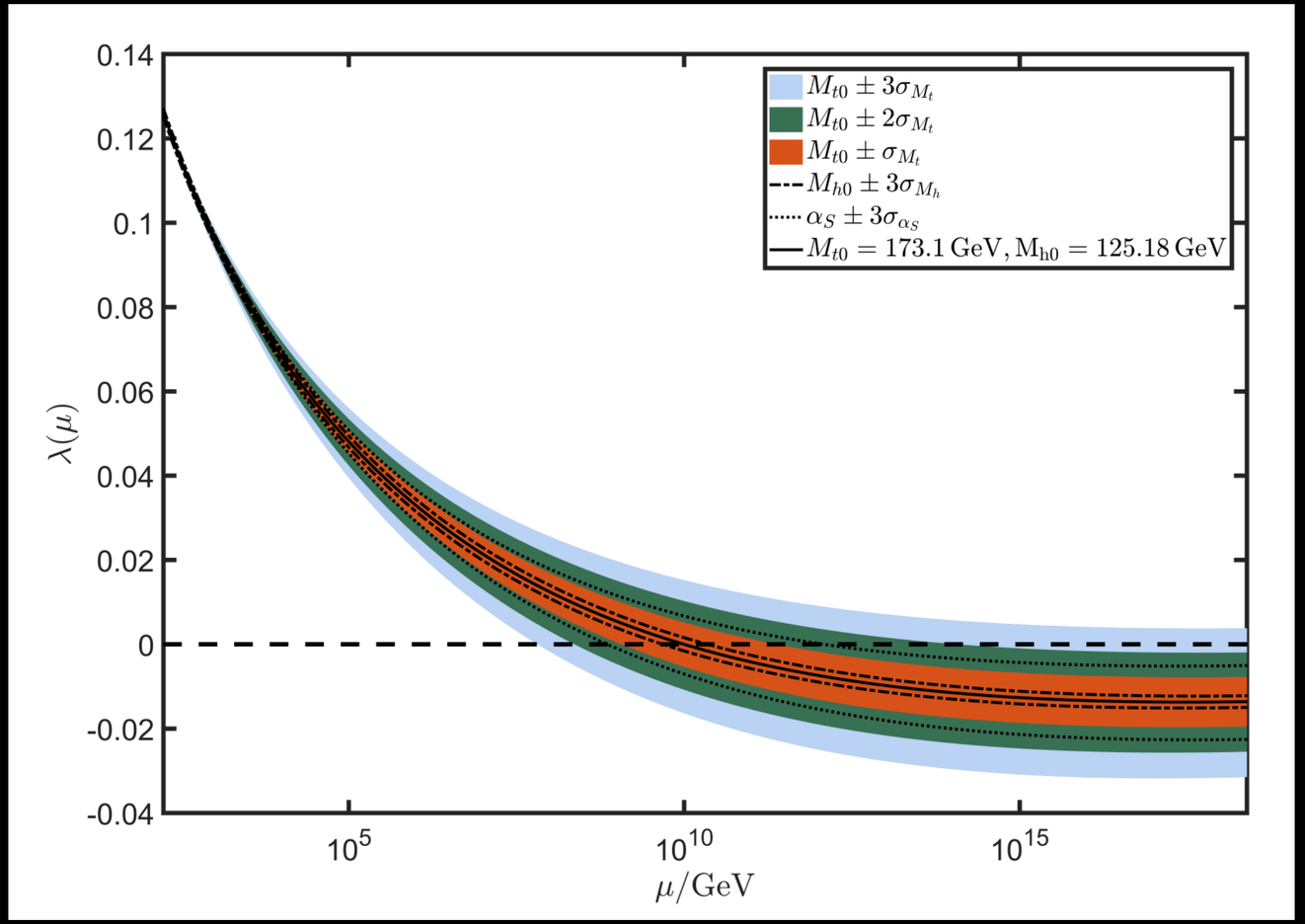
Energy scale of Higgs Inflation is $\sim 10^{12}\mathrm{GeV}$.



Markkanen, Rajantie, Stopyra '18

The Higgs Self-Coupling: Instability!

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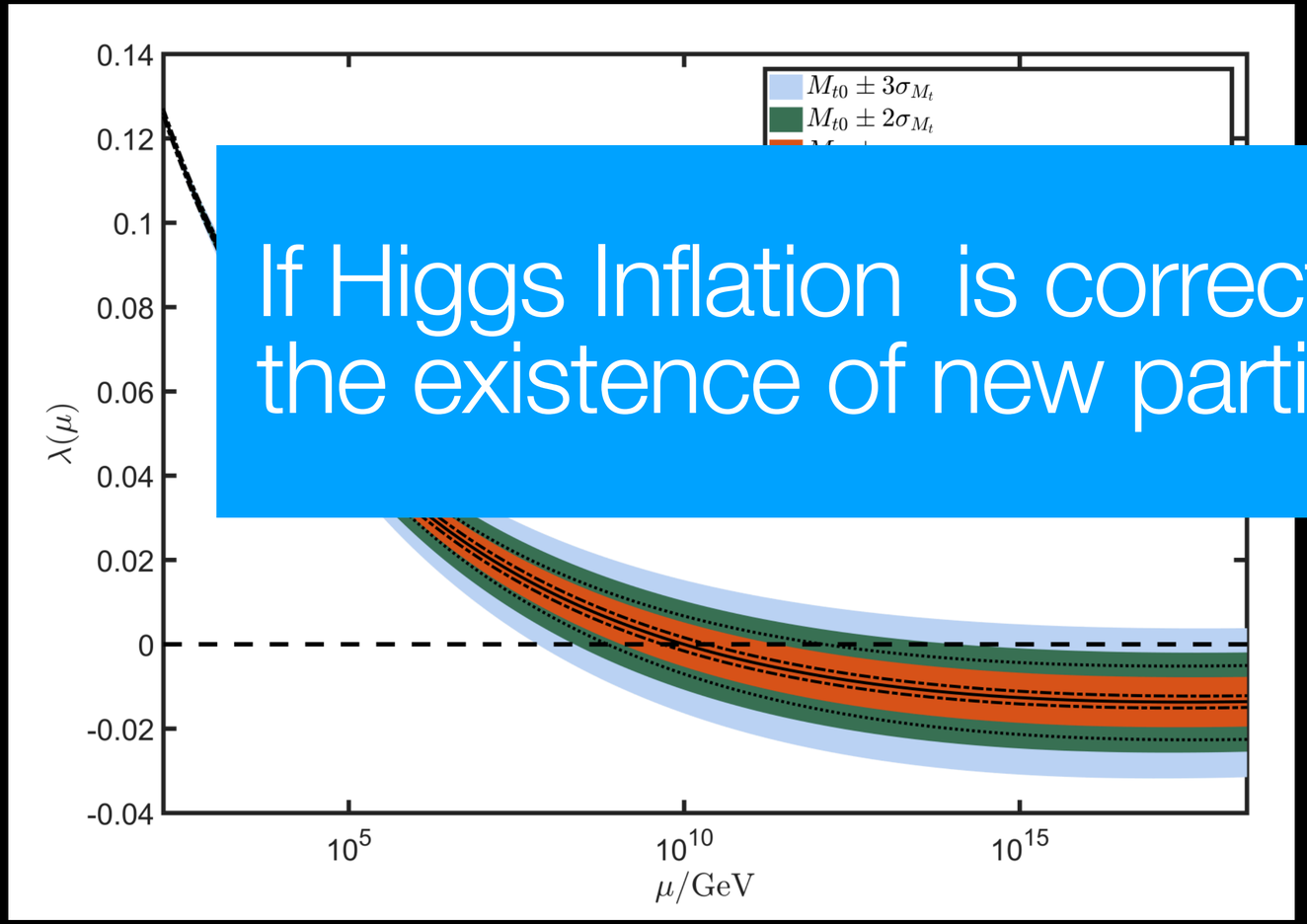

If Higgs Inflation is correct, it implies the existence of new particles!

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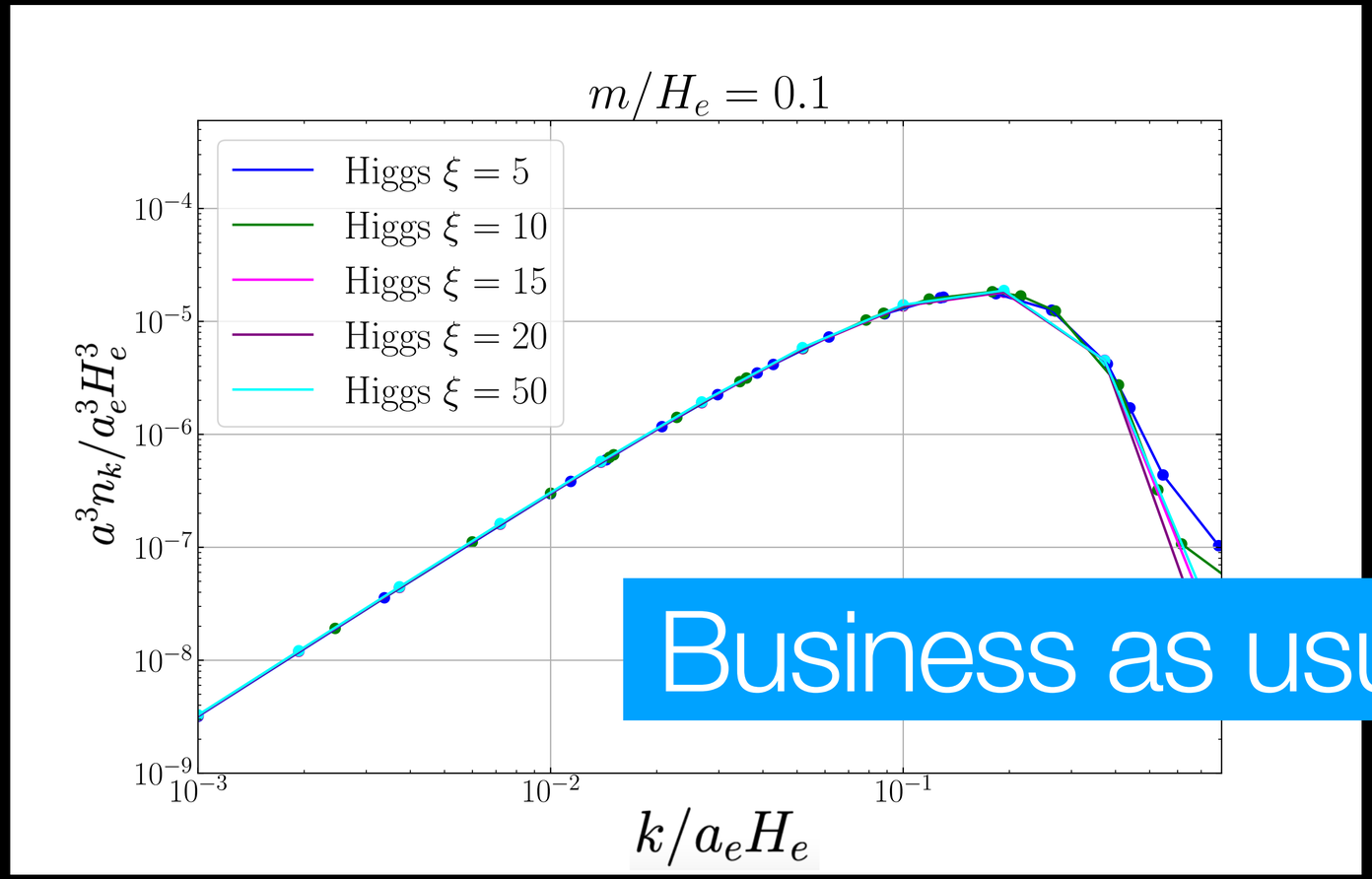
WIMPZillas in Higgs Inflation



Business as usual?

Higgs Inflation: A new peak emerges!

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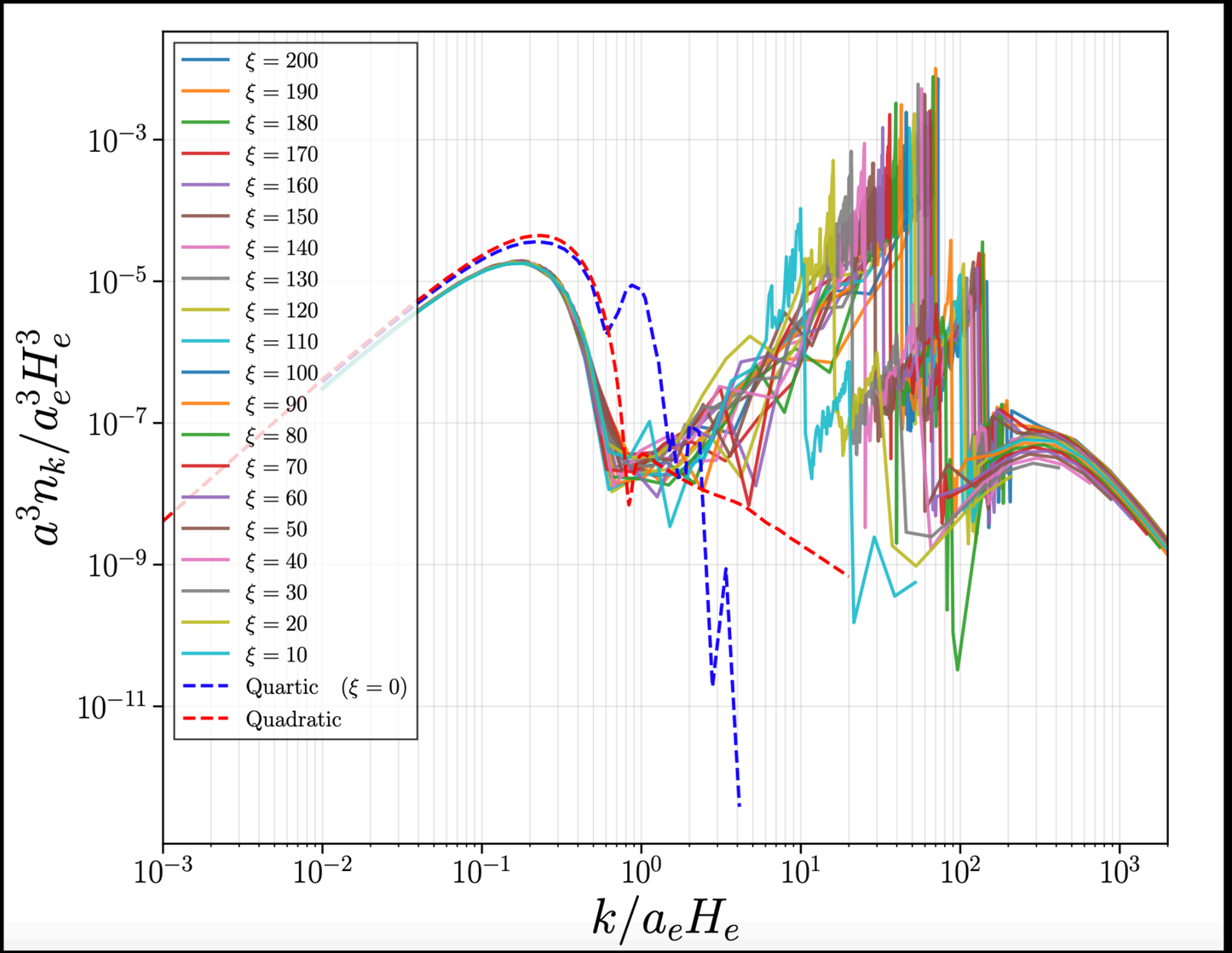
Chowdhury, Kolb, Jenks, EM
JHEP '26



Resonance

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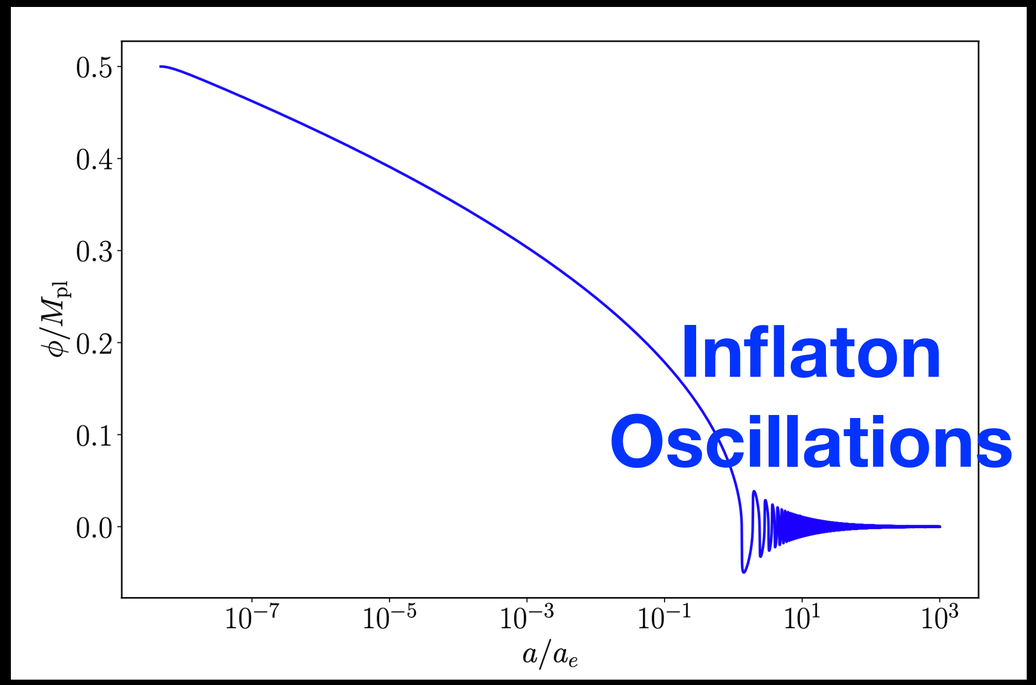
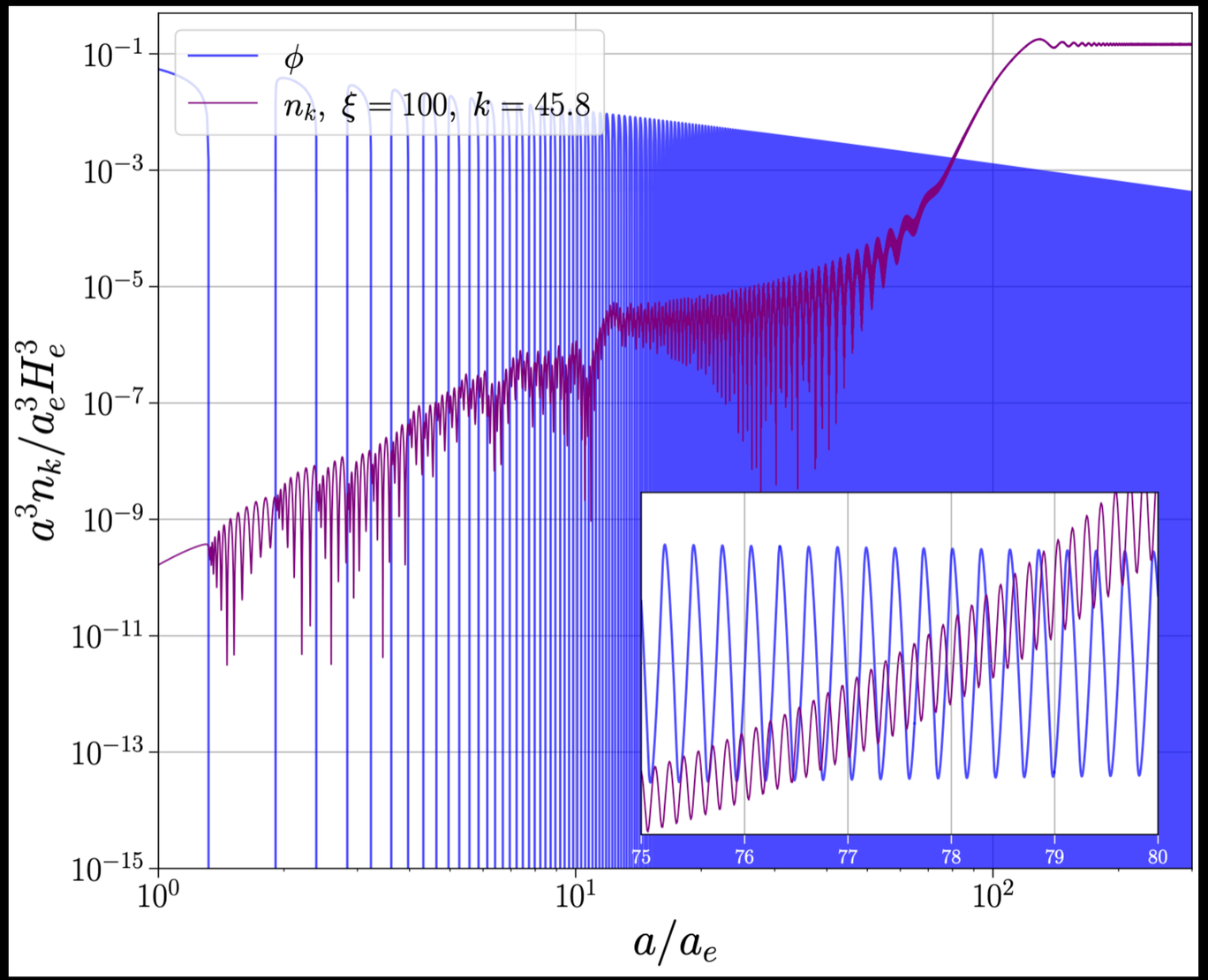


Particle Number Density



Scaling symmetry

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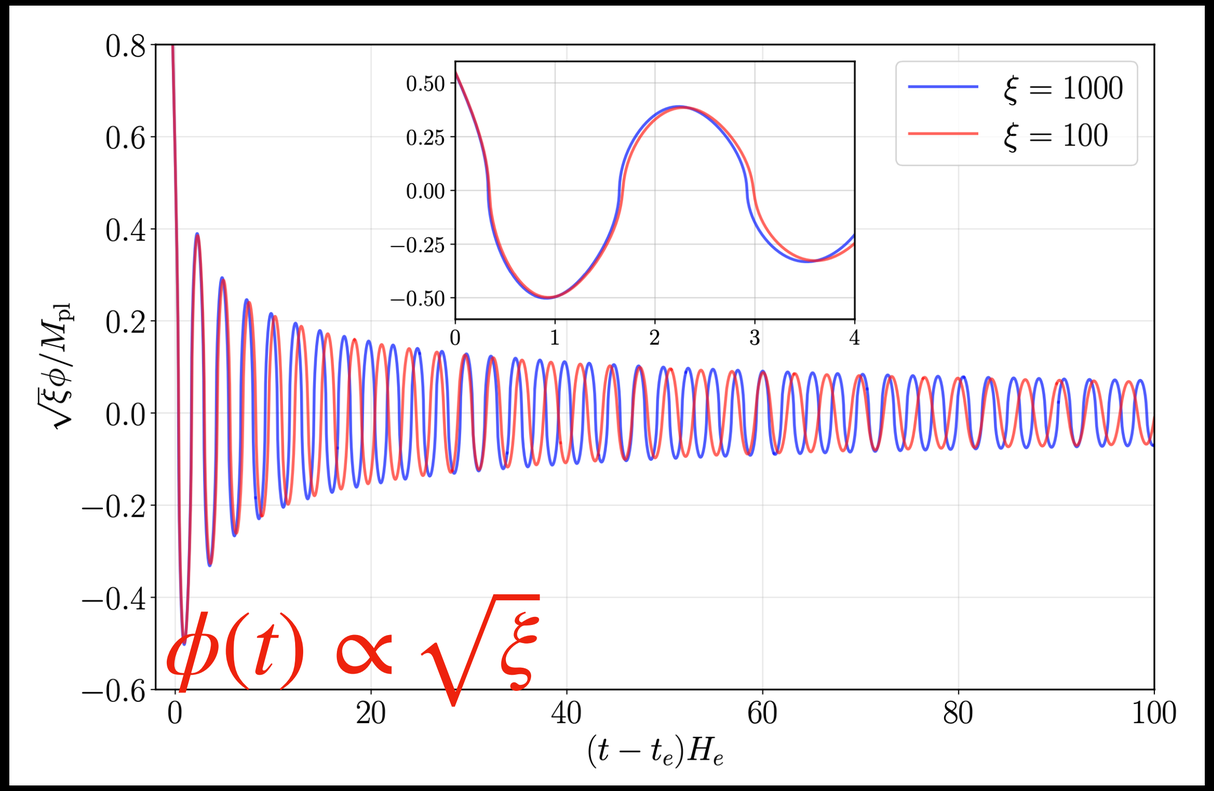
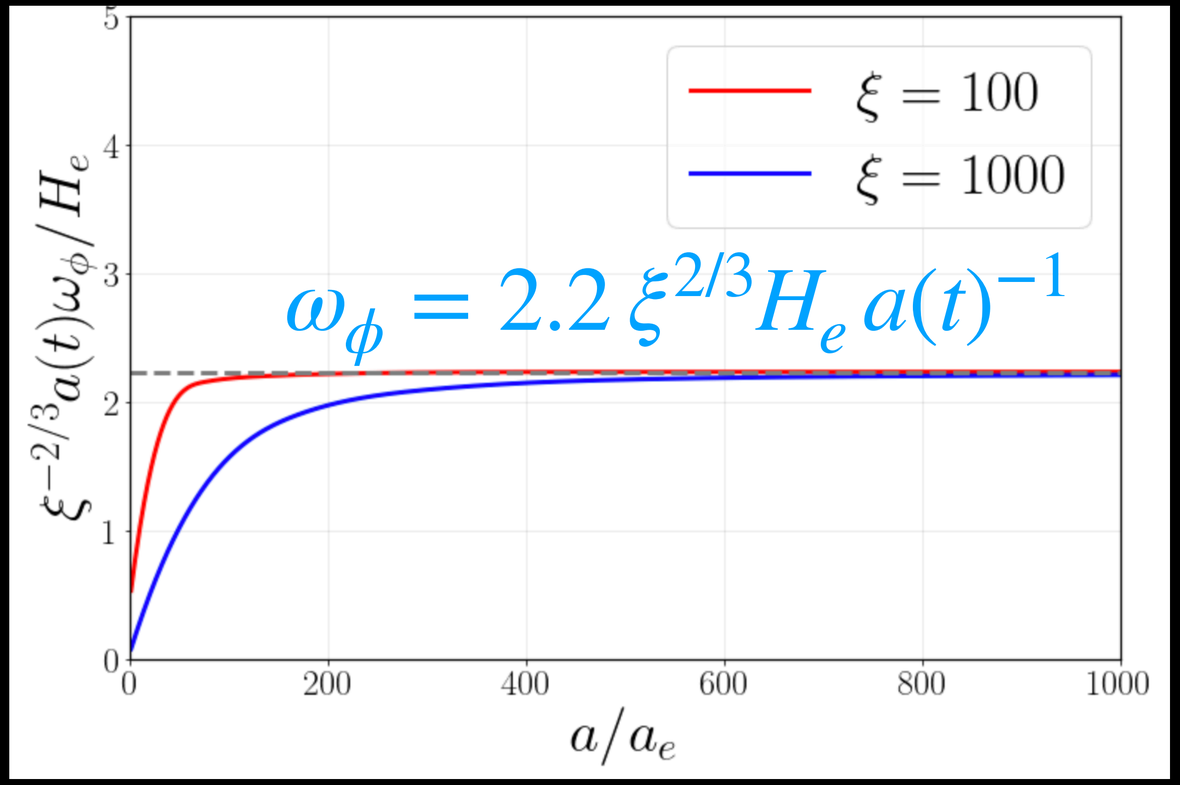
Early Times:
Universal $\sqrt{\xi}\phi(t)$



Late times:
Universal *frequency*



Particle Production: Universal Structure

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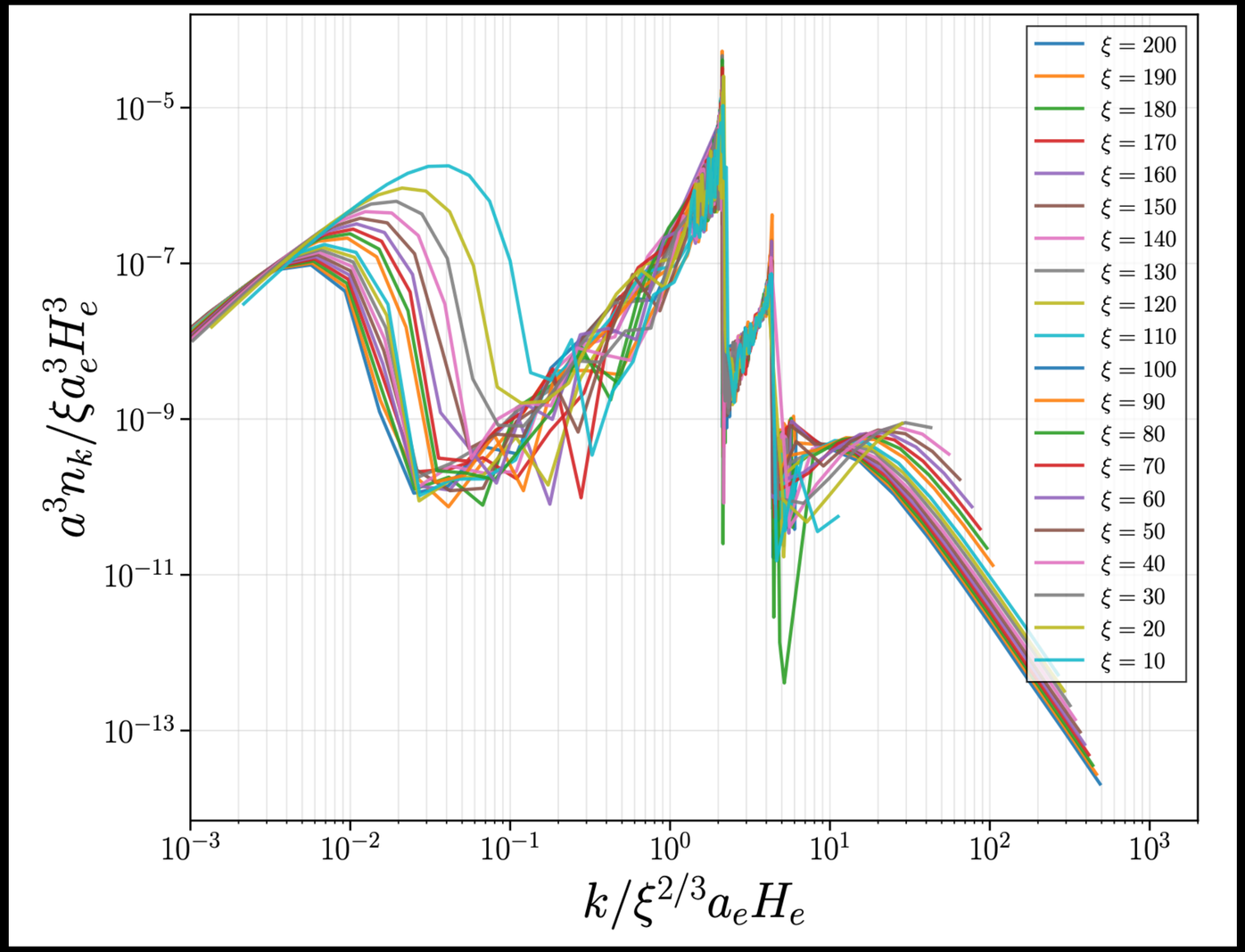
$$k_{\text{peak}} \approx 2\,\xi^{2/3} H_e$$

Chowdhury, Kolb, Jenks, EM
JHEP '26



Dark Matter

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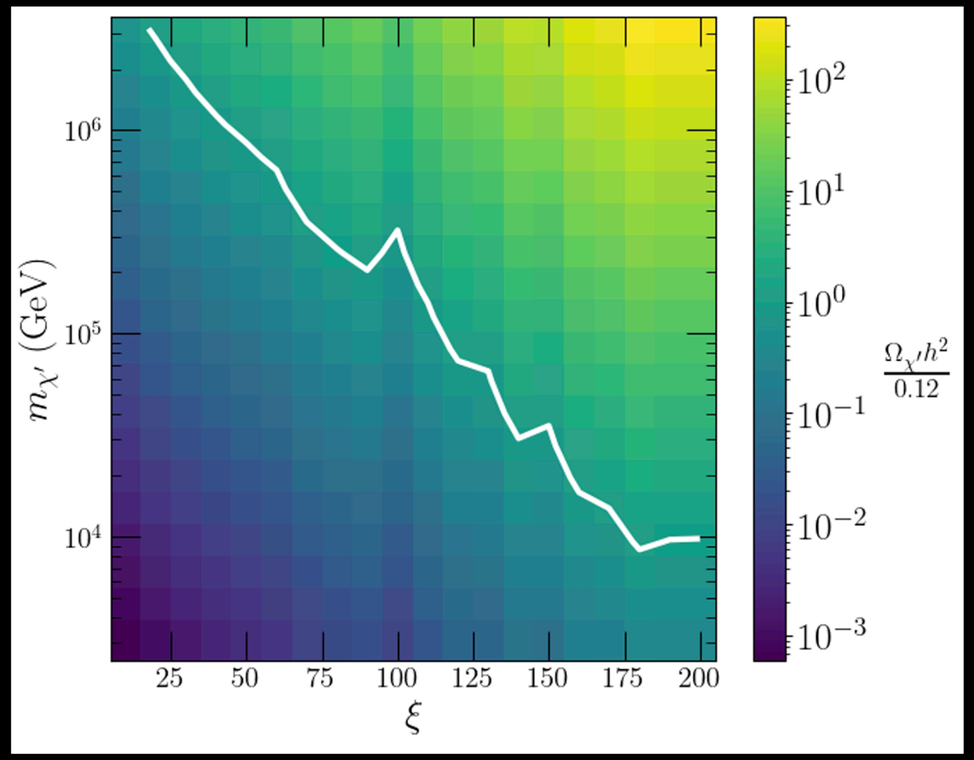
Dark matter mass fixes ξ!

$$\frac{\Omega_\chi h^2}{0.12} = \frac{m_\chi}{H_e}\left(\frac{H_e}{10^{12}\mathrm{GeV}}\right)^2\left[\frac{T_{\mathrm{RH}}(\xi)}{10^9\mathrm{GeV}}\right]\frac{a^3 n}{10^{-5}},$$

+ CMB fixes $\lambda(E_{\mathrm{inf}})$

$$A_s \sim \frac{\lambda}{\xi^2} \sim 10^{-10} \Rightarrow \quad \boxed{\xi \sim 10^5\sqrt{\lambda(E_{\mathrm{inf}})}}$$



Strongly restricts new physics!

Summary

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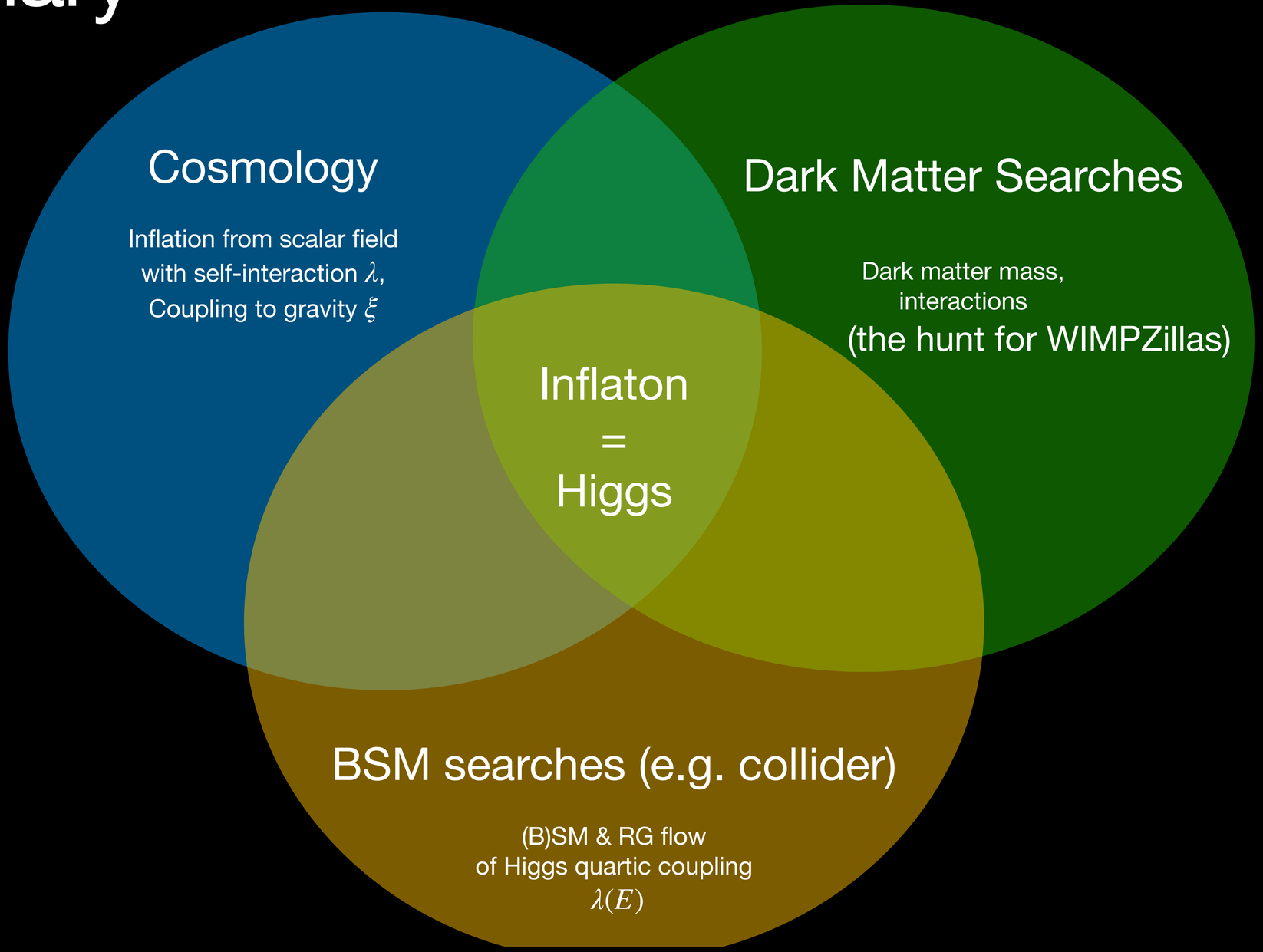

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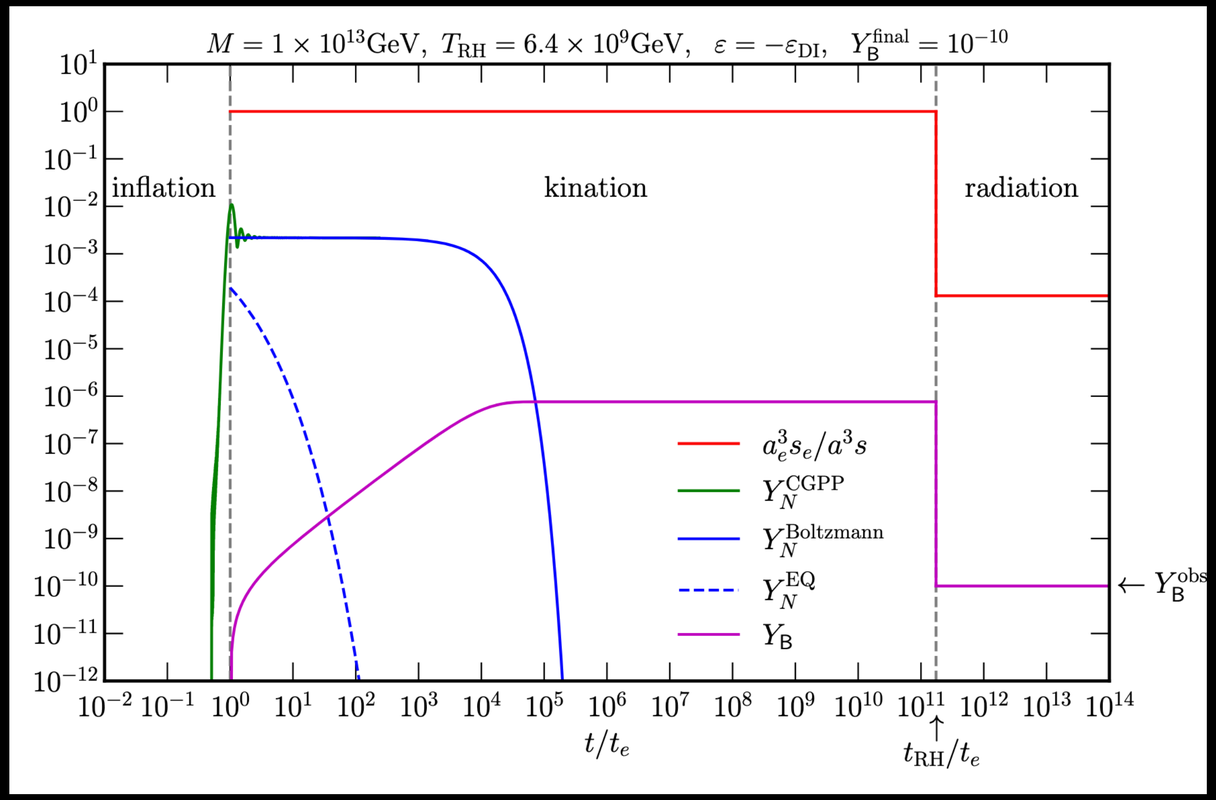
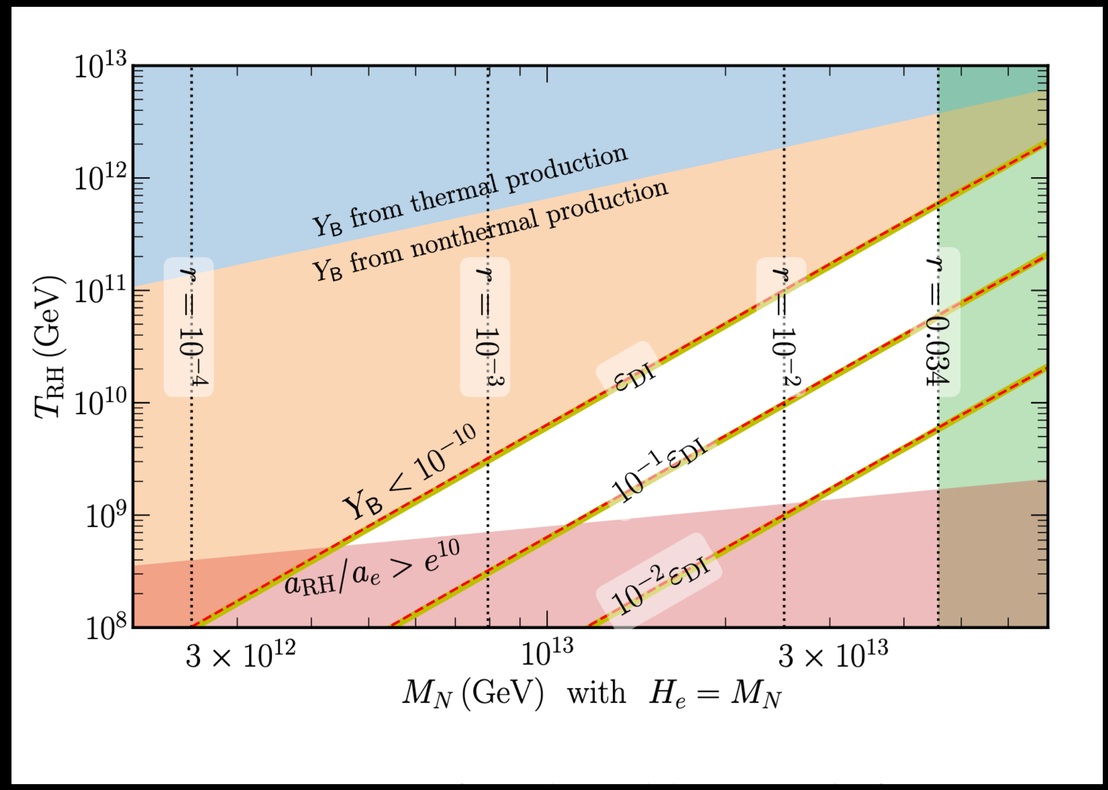
Hot off the press: *Non-Thermal Leptogenesis*

With Chowdhury, Jenks, Kolb, Long





Thanks!

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NSERC CRSNG

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Research Manitoba

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