Fermion (non)reheating in a Quartic Inflaton Potential

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Based on hep-ph 2512.16203 (Accepted in JCAP): **NB°**, E. Chavez*, M. A. G. Garcia*, A. Menkara°, M. Pierre°

GOALS

- Determine the range of perturbative validity
- Perform a complete non-perturbative analysis to comment on whether reheating is realistically achievable before fragmentation
- Discuss post-fragmentation particle production in this setup

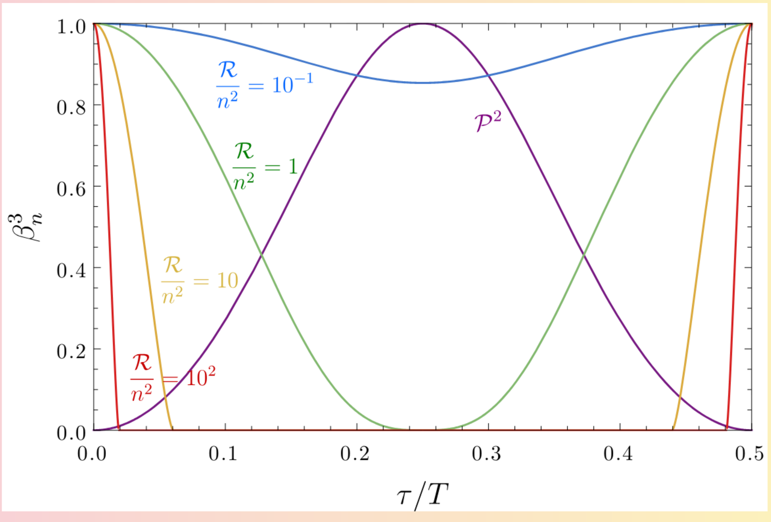
Reheating: A post-inflationary period where the Universe exits inflation and bridges to a stage of radiation domination.

Our setup: We consider an inflaton potential with a **quartic minimum** $V(\phi) = \lambda M_P^4\left(\sqrt{6}\tanh\left(\frac{\phi}{\sqrt{6}M_P}\right)\right)^k$, with k=4, and a Yukawa coupling y, between inflaton and fermion $\mathcal{L}_{\rm int} = y\phi\bar{\psi}\psi$.

Perturbative

Inflaton condensate decay via : $\left|\overline{\mathcal{M}_n}\right|^2 = \dfrac{2n^2\omega_\phi^2}{g_\psi}\bar{y}_n^2\beta_n^2\phi_0^2\,|\mathcal{P}_n|^2$

- Includes kinematic blocking
- NO PAULI-BLOCKING
- Only sub-horizon modes
- Solve Boltzmann equations



Non-perturbative

Energy density: $\rho_\psi = \frac{1}{(2\pi)^3a^4}\int d^3\boldsymbol{p}\,\omega_p n_p$

where the occupation number is $n_p = \frac{1}{2}\left|\left(1+\frac{am_\psi}{\omega_p}\right)^{1/2}U_2 - \left(1-\frac{am_\psi}{\omega_p}\right)^{1/2}U_1\right|^2$

and the spinor mode equations can be recast as:

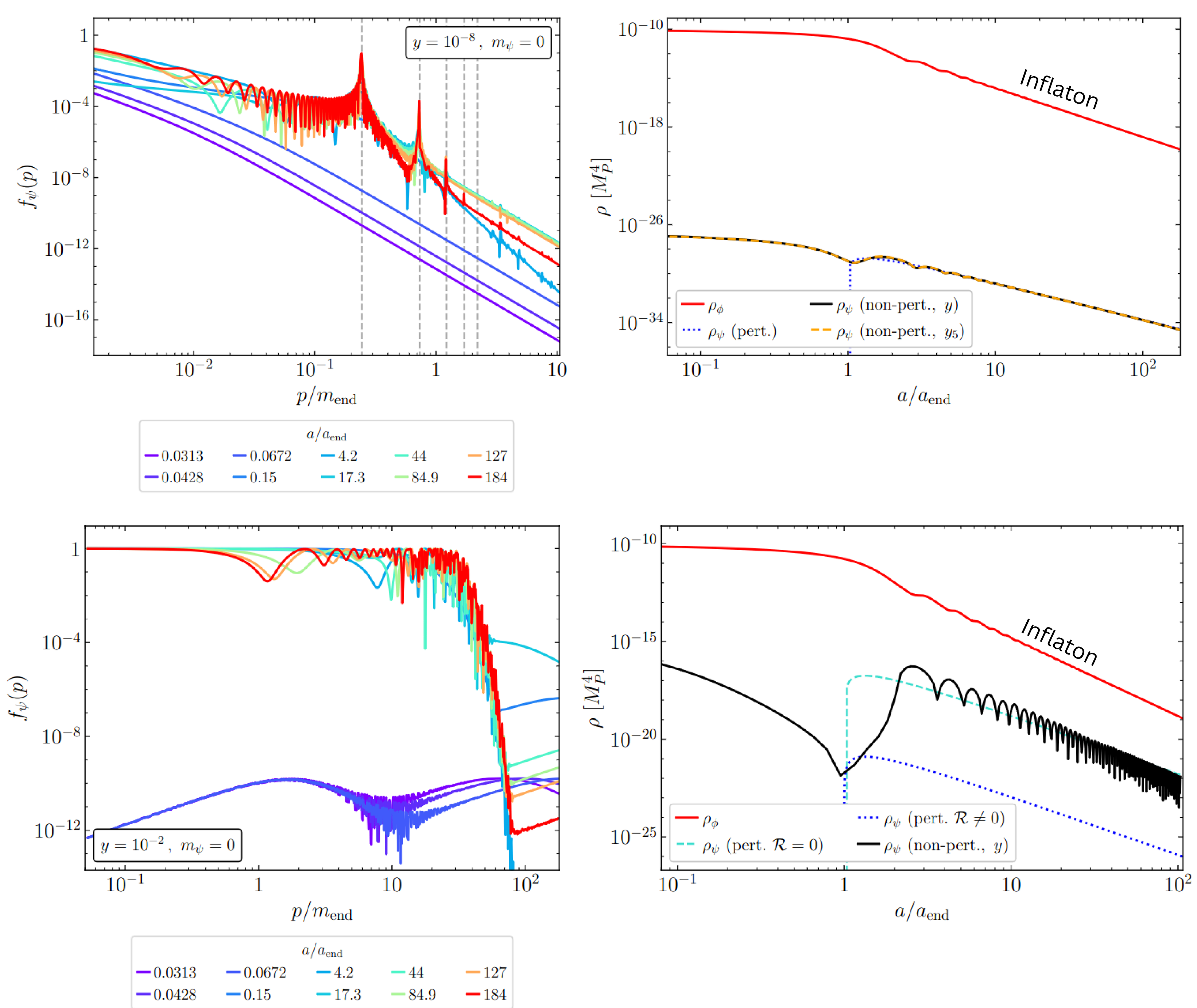
$$\begin{aligned} U_1'(\eta) &= -ipU_2(\eta) + iam_\psi U_1(\eta),\\ U_2'(\eta) &= -ipU_1(\eta) - iam_\psi U_2(\eta). \end{aligned}$$

Includes all effects and modes of all wavelengths (even superhorizon)

Inflaton fragmentation

- Break down of the homogeneous inflaton condensate
- Occurs at $\sim 180\, a/a_{end}$ for quartic inflation [See JCAP 11 (2024) 004]
- Quantum fluctuations are enhanced by quartic self coupling
- Dominant fermion production channel changes

Pre-Fragmentation
Phase-Space Distribution (PSD) and energy densities

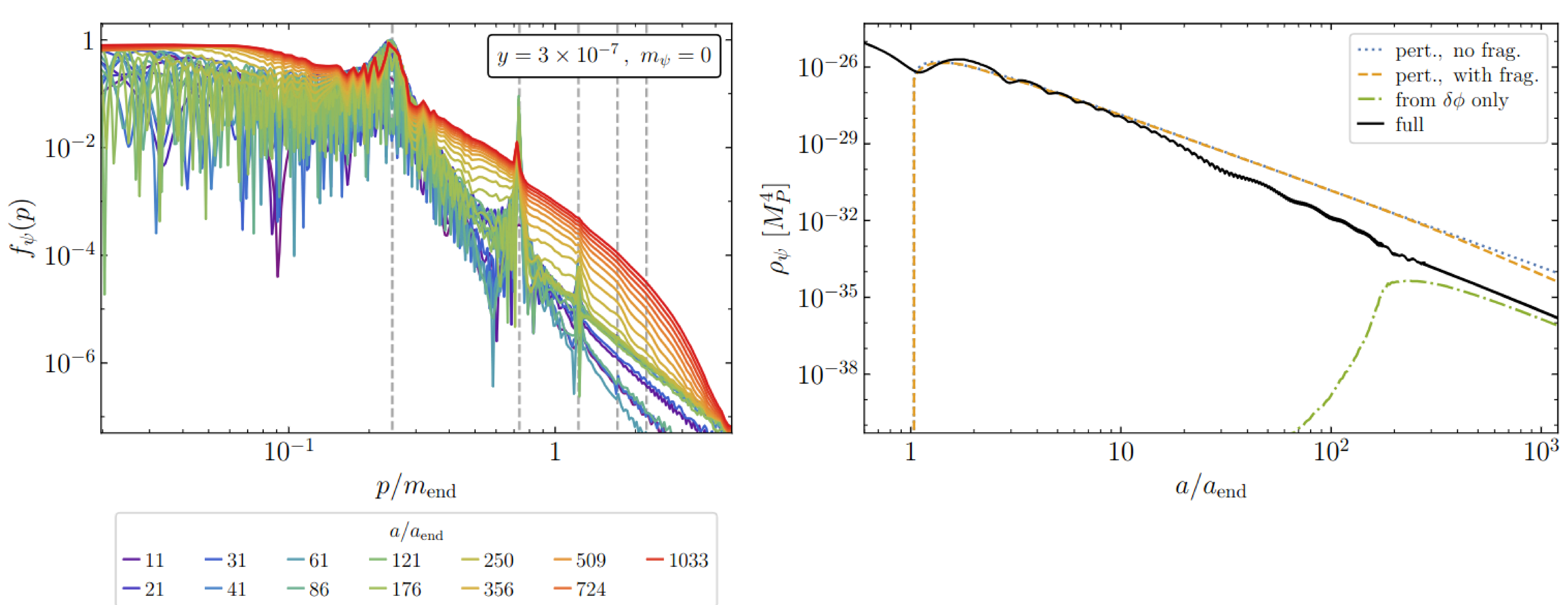


Prior to fragmentation:

- Perturbative particle production or the 'Boltzmann approach' is valid for very small couplings [$y \lesssim 10^{-8}$].
  → These couplings do **NOT** lead to reheating (BBN bounds).
- Necessary to be in the **'non-perturbative'** or large Yukawa limit.
  → Deviation from perturbative estimate.
  → Radiative corrections kill flatness for $y \gtrsim 10^{-2}$.

NEED TO CONSIDER POST-FRAGMENTATION PRODUCTION

Post-Fragmentation
Phase-Space Distribution (PSD) and energy densities



Post-fragmentation:

- Condensate replaced by inflaton quanta
  → Treated as perburbative decays to fermions
  → Includes kinematic effects and Pauli-Blocking
- PSD inherited from Pre-fragmentation, non-pertubative production
  → Occupation numbers are already approaching 1 which leads to blocking soon after fragmentation
- Energy density is suppressed and extrapolation leads to lower reheating temperature than quoted in the literature

My Inspire

TAKEAWAYS

1. Fermions have to be treated non-perturbatively (considering Pauli-blocking) from couplings **as small as** 10^{-7}
2. Reheating to purely fermions in ***quartic*** inflaton potentials is HARD!
3. Need mechanism to de-saturate PSD to maybe achieve reheating

This work

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