COSMO 08

# Preheating after Multi-Field Inflation

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Why is preheating important?

# What do we know about preheating?

- Old Theory of Preheating (additional friction factor)
  Abbot et. al (82), Dolgov and Linde (82), …

- Parametric Resonance:  explosive particle production
  Brandenberger, Traschen (90), Dolgov and Kirilova (90), Kofman, Linde, Starobinsky (98), …

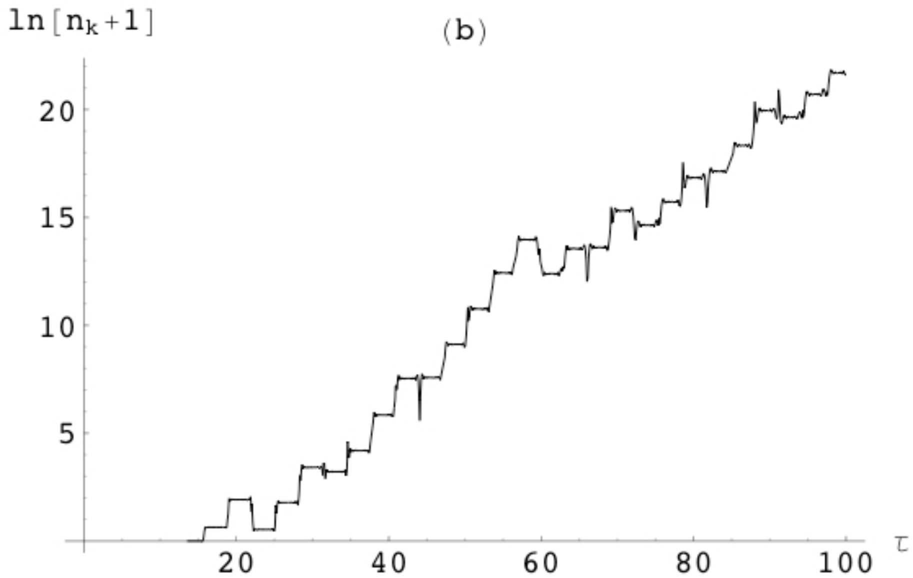
Kofman, Linde, Starobinsky (97)

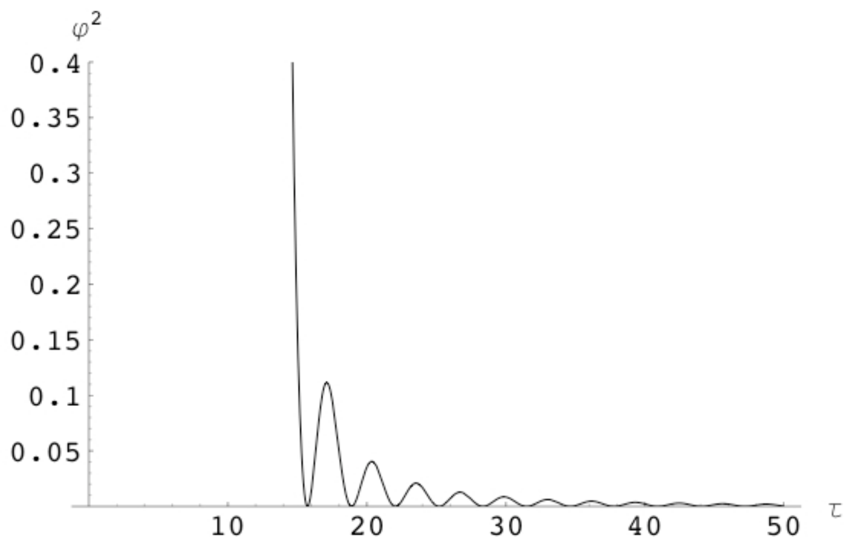
# Parametric Resonance: single-field

- Periodic variation of effective mass $\ddot{\chi}_k + 3H\dot{\chi}_k + \left(\frac{k^2}{a^2} + g^2\varphi^2\right)\chi_k = 0$

Oscillating term

- Leads to resonances (narrow, broad, stochastic)
- Explosive particle production:



Bassett et. al (06)

# Cantor Preheating: two inflaton fields

- Numerical study involving two inflaton fields, one matter field
- Analytic tool: spectral theory
- Possible amplification  of almost all modes, enhanced particle production

Review: Wands (07)

## Why consider multiple inflatons?

- "Natural" in string theory (presence of many moduli fields etc.)

- Examples are N-flation (Dimopolus, Kachru, McGreevy, Wacker 05), Inflation from multiple M5-branes (Becker, Becker, Krause 06), Inflation from tachyons (Majumdar, Davis 03)…

## Challenges of multi-field inflation

- Is Parametric resonance still possible?

- Do we reheat standard model particles? We could be reheating hidden sectors. This reveals additional fine-tuning, a problem for many string motivated models (D. Green 08).

- Better understanding of the end of inflation - what are the inflaton fields?

# Preheating Model:
## Multiple-fields having the same mass

Consider

$$\mathcal{L} = -\frac{1}{2}\sum_{i=1}^{\tilde{\mathcal{N}}}\left(g^{\mu\nu}\nabla_\mu\varphi_i\nabla_\nu\varphi_i + m_i^2\varphi_i^2 + g^2\varphi_i^2\chi^2\right) - \frac{1}{2}g^{\mu\nu}\nabla_\mu\chi\nabla_\nu\chi$$

with $\tilde{\mathcal{N}} = 150$ (arises in N-flation.)

Ignoring back reaction, the equations of motion become

$$\ddot{\varphi}_i + 3H\dot{\varphi}_i + m_i^2\varphi_i = 0,$$

$$\ddot{\chi}_k + 3H\dot{\chi}_k + \left(\frac{k^2}{a^2} + g^2\sum_i \varphi_i^2\right)\chi_k = 0,$$

$$6H^2 = \sum_i \dot{\varphi}_i^2 + \sum_i m_i^2\varphi_i^2$$

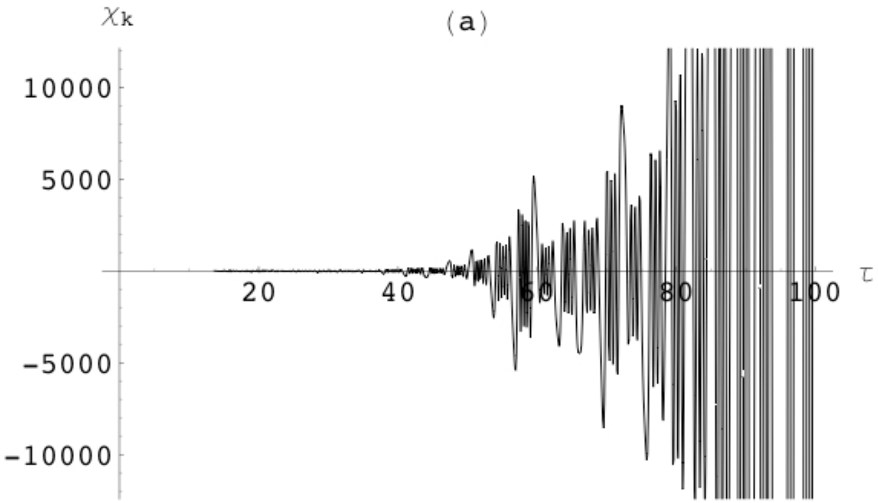
# Multiple fields with equal masses

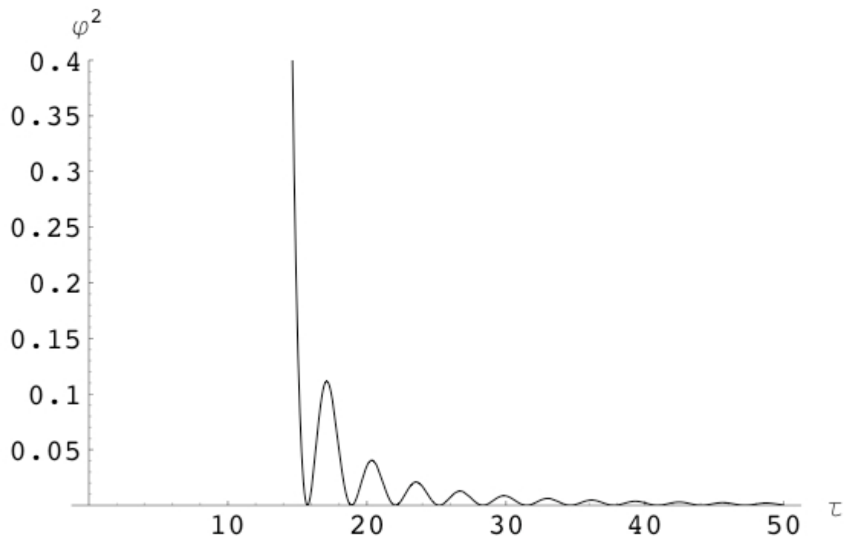
The fields' collective behavior is coherent; the model becomes indistinguishable from a single field one:

$$\varphi = \sqrt{\tilde{N}}\varphi_i$$

$$\ddot{\chi}_k + 3H\dot{\chi}_k + \left(\frac{k^2}{a^2} + g^2\varphi^2\right)\chi_k = 0$$

System exhibits parametric resonance:



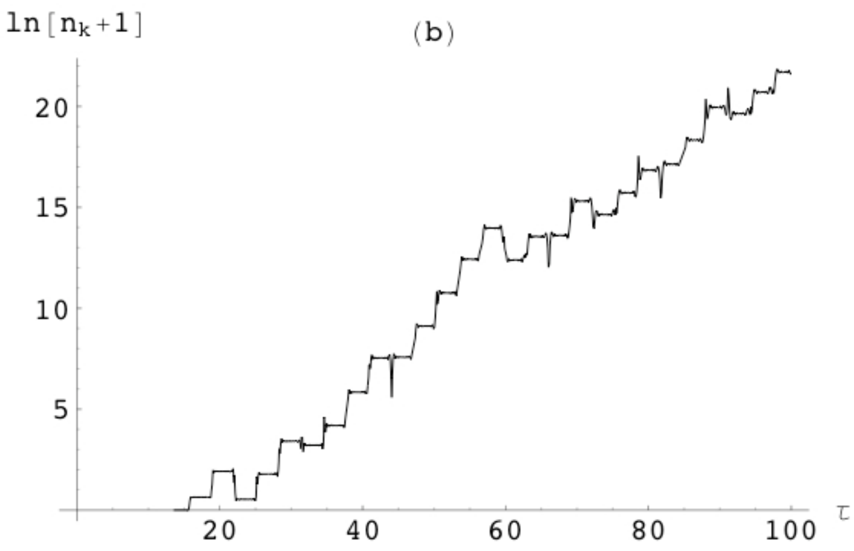
# Particle number:

$$n_k = \frac{1}{2}\left(\frac{|\dot{X}_k|^2}{\omega_k} + \omega_k |X_k|^2\right) - \frac{1}{2}$$

Where $X_k = a^{3/2}\chi_k$ and $\omega_k = \sqrt{\frac{k^2}{a^2} + g^2\varphi^2}$

The oscillating part of the mass term shows that an increase in the number of inflatons does not change the resonance effect since it is equivalent to the single field model.

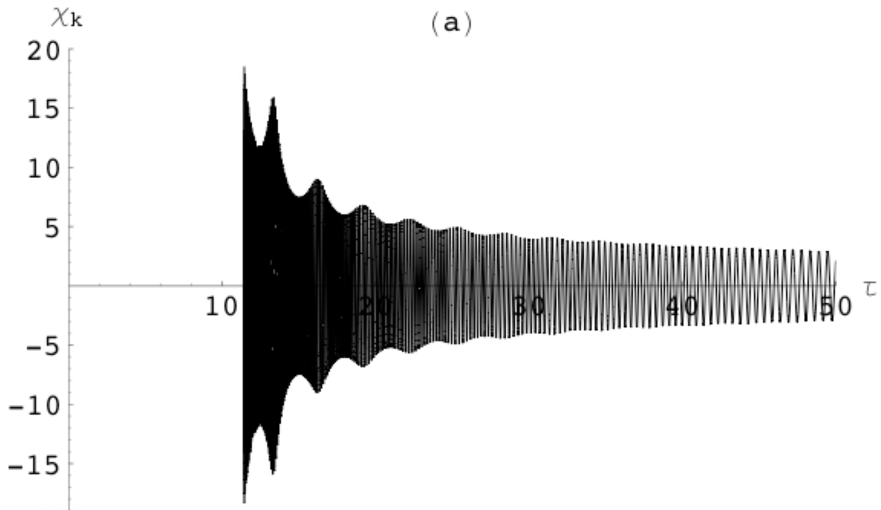
System exhibits explosive particle production:

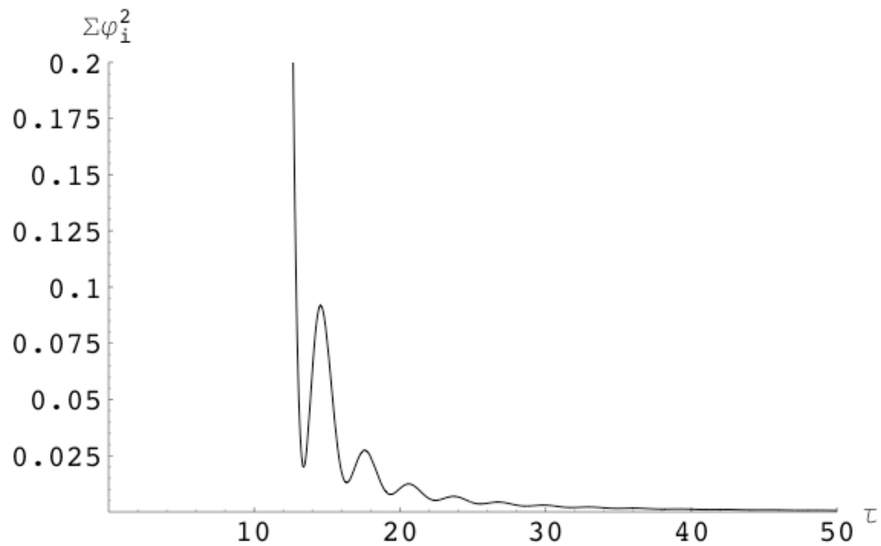


# Main Result: multiple fields with a mass distribution – parametric resonance is suppressed

The inflatons' collective behavior is not coherent; the dephasing of the fields is due to the mass differences.

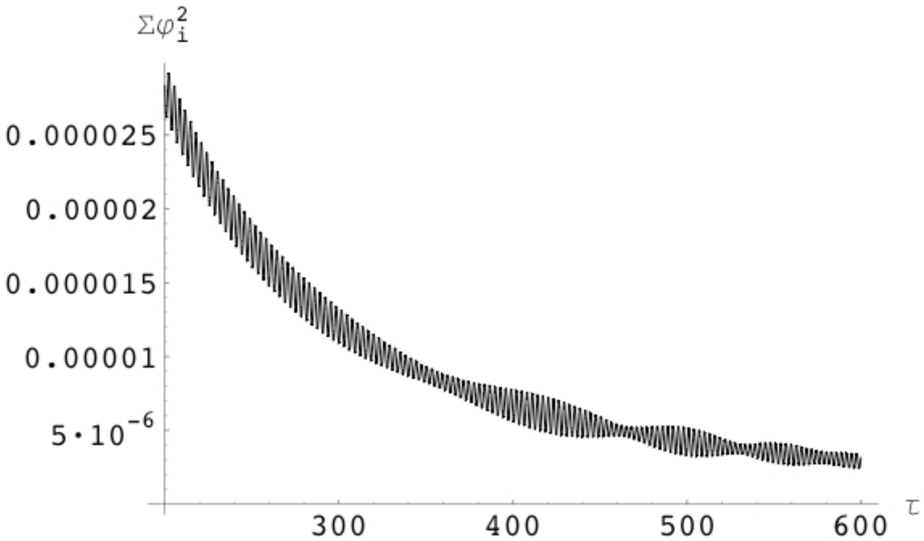
On short-time scales:

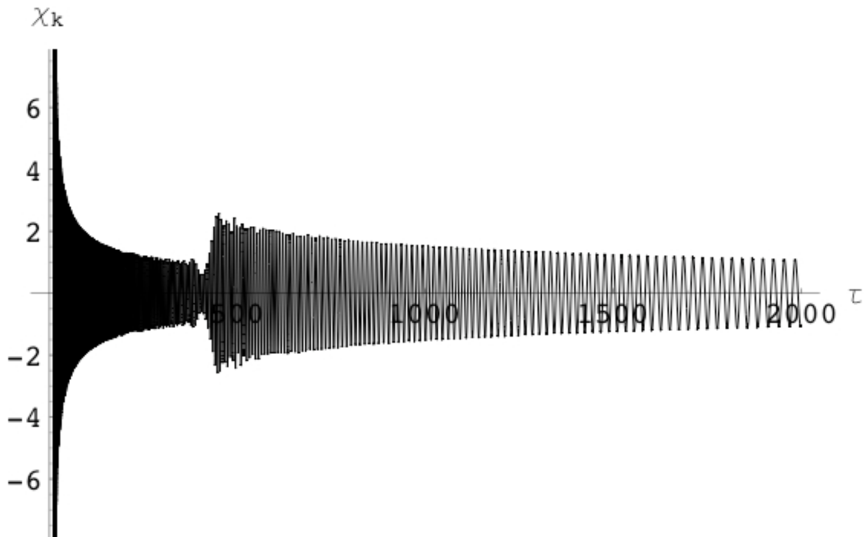


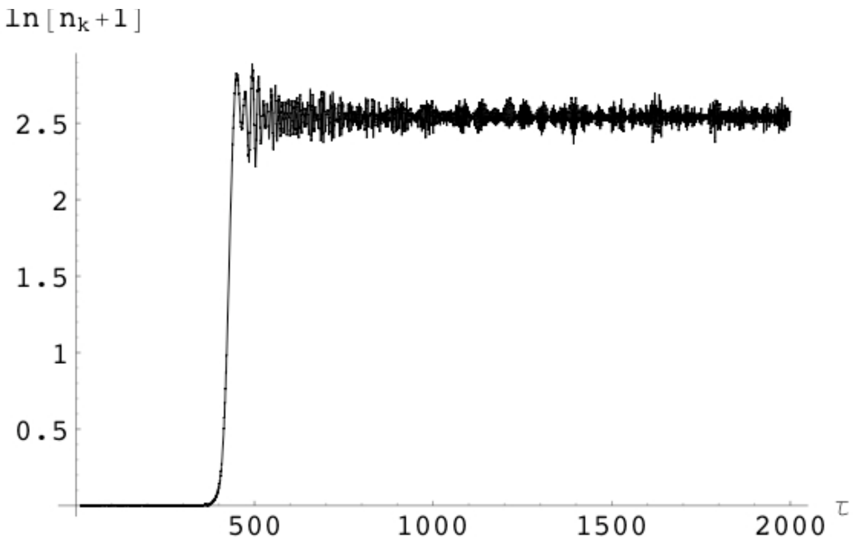



# Main Result: multiple fields with a mass distribution – parametric resonance is suppressed

On long-time scales: short burst of PR due to beats



# Summary of Results

Parametric resonance is suppressed in generic multi-field models of inflation.

Our results show that the resonance effect is weak on short time scales and infrequent on long time scales. As a result, the old theory of preheating is applicable when considering a large number of fields

# Possible follow-ups

- Reconsider existing multi-field models

- Investigate how Cantor preheating gets suppressed by successively increasing the number of fields.

- Investigate different coupling constants and more matter fields.