Primordial Features and Their Impact on Structure Formation

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Pheno 2026
May 12, 2026

Based on ongoing work with:
Xingang Chen, JiJi Fan, Lingfeng Li (2606.XXXXX);
Yuhsin Tsai, Fengwei Yang, Chris Jungkind (26??.XXXXX)

1 Primordial Features

2 Impact on Structure Formation

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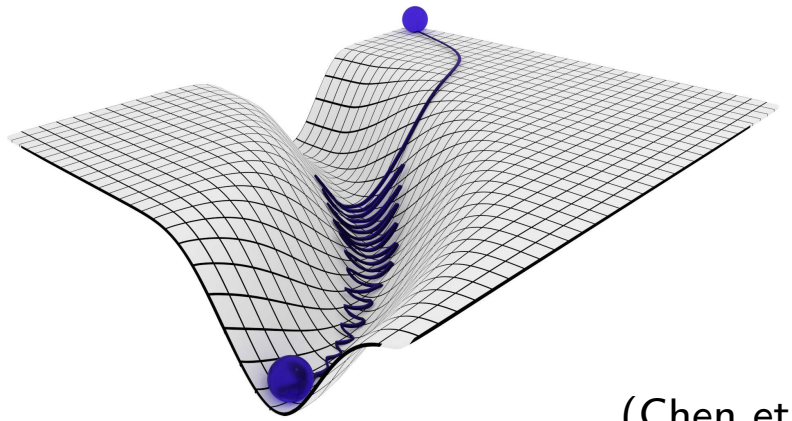
2 Impact on Structure Formation

Features in Inflaton Trajectory

- The presence of other (heavy) fields during inflation may result in features in inflaton potential/trajectory



(Chen et al 2015)

- Motivation:
  - multi-field scenarios are likely (even effective single-field case)
  - gives rise to non-gaussianities
  - **results in features in primordial power spectrum**

(see also Chen 2010-2014++, Chluba et al 2015, Slosar et al 2019, ++)

Features in Primordial Spectrum

- Single-field slow-roll inflation predicts nearly scale invariant primordial spectrum

$$P_{\zeta 0} = A_s \left(\frac{k}{k_0} \right)^{n_s - 1} \quad (1)$$

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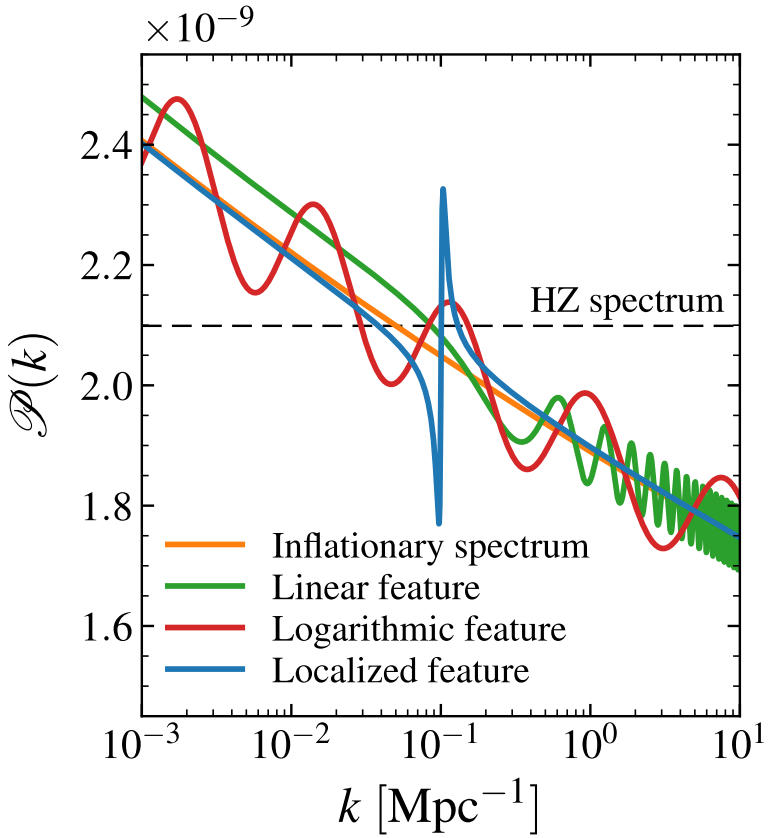
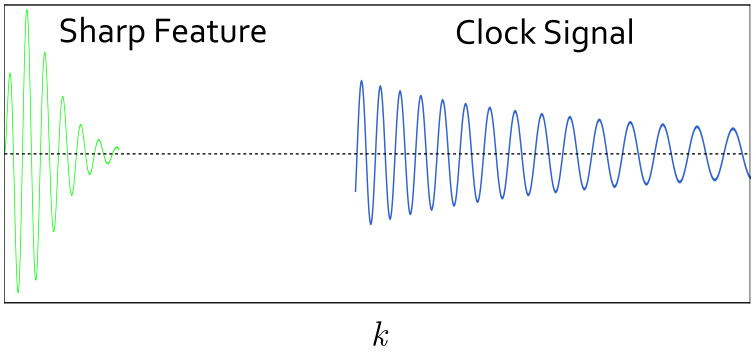


(Slosar et al 2019)

Primordial Clock Signal

- Massive field $\rightarrow$ 2-part signal

Primordial Clock Signal



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- Sharp Feature: excitation of massive field

$$\Delta P_\zeta \sim \text{envelope} \times \cos k/k_0 \quad (3)$$

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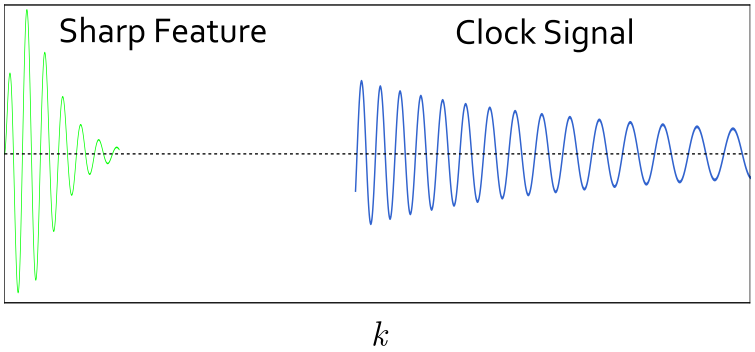

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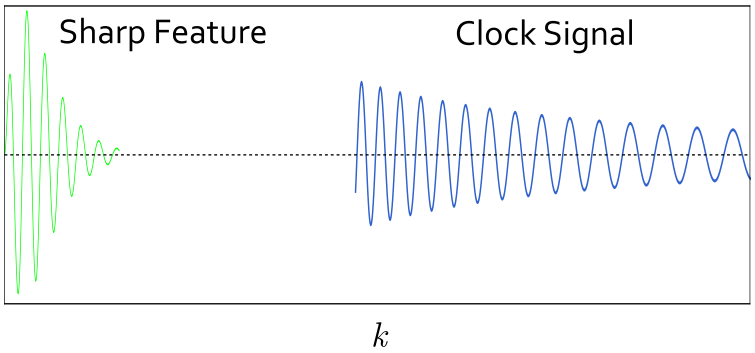

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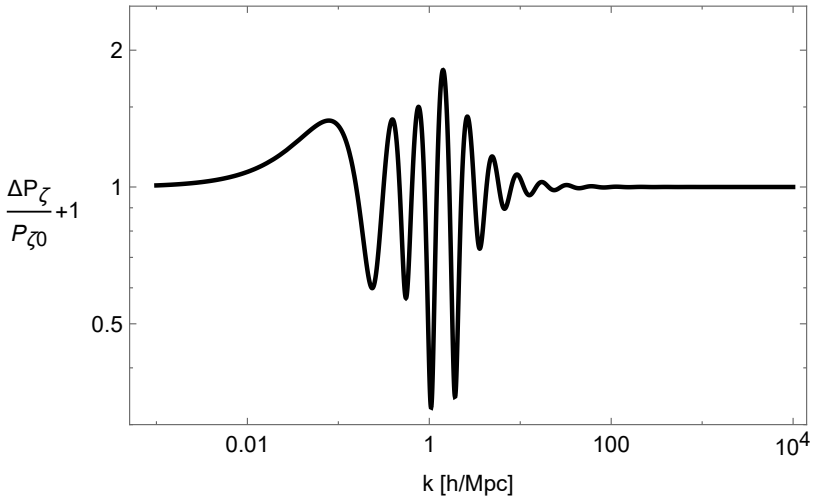

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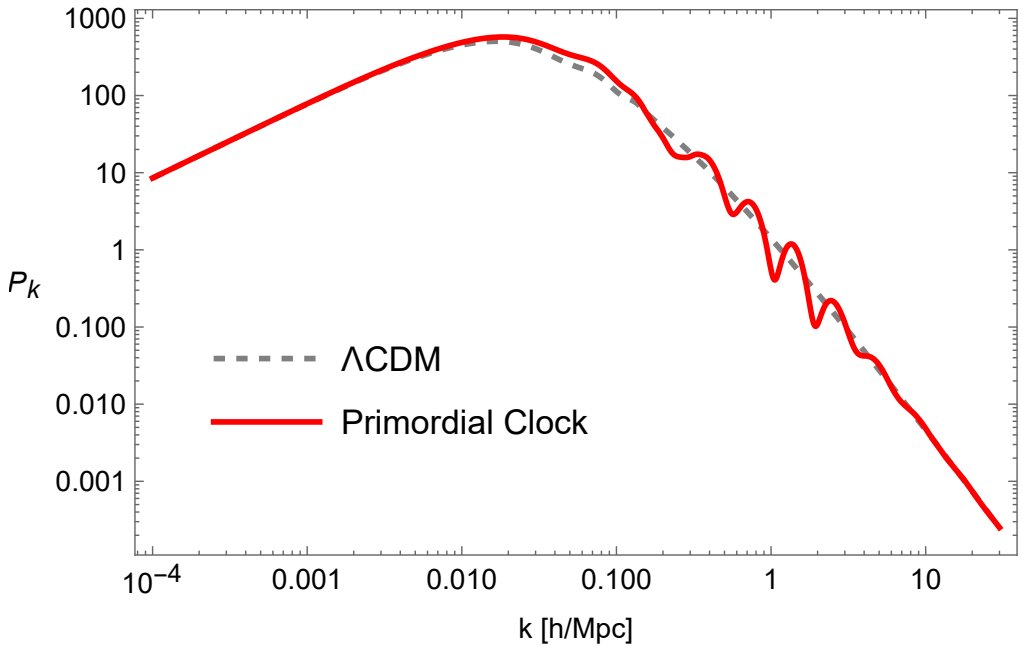

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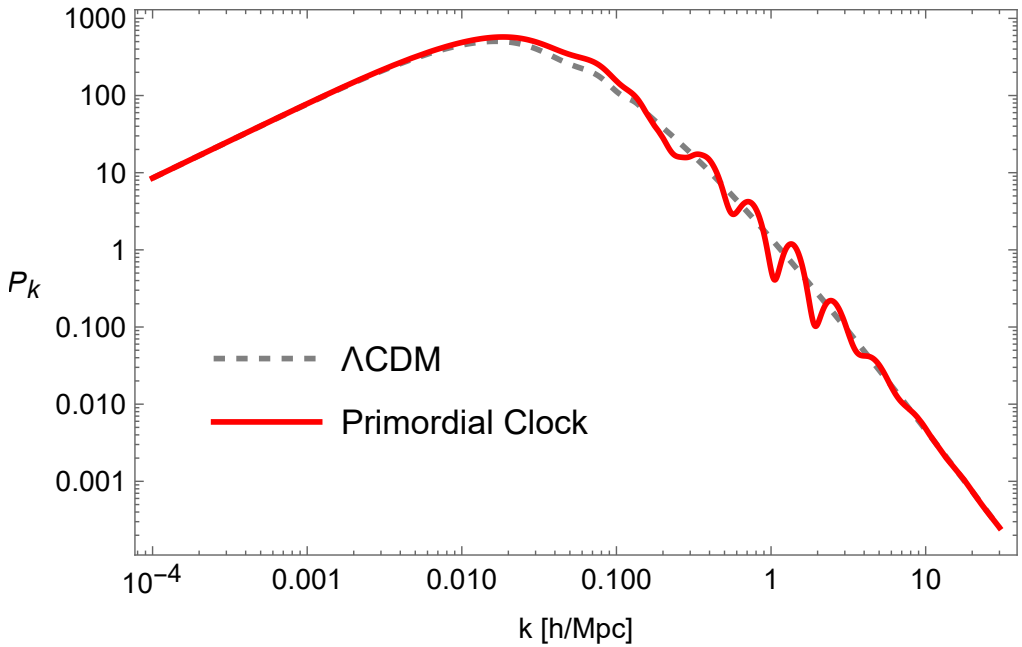

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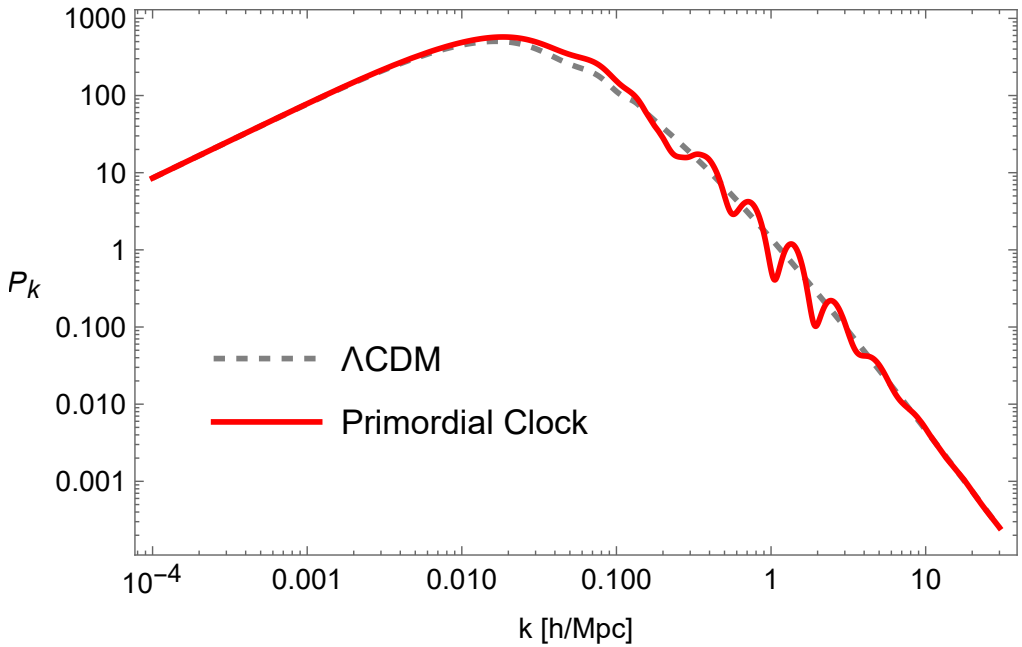

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- Primordial feature signal in scales of structure formation?

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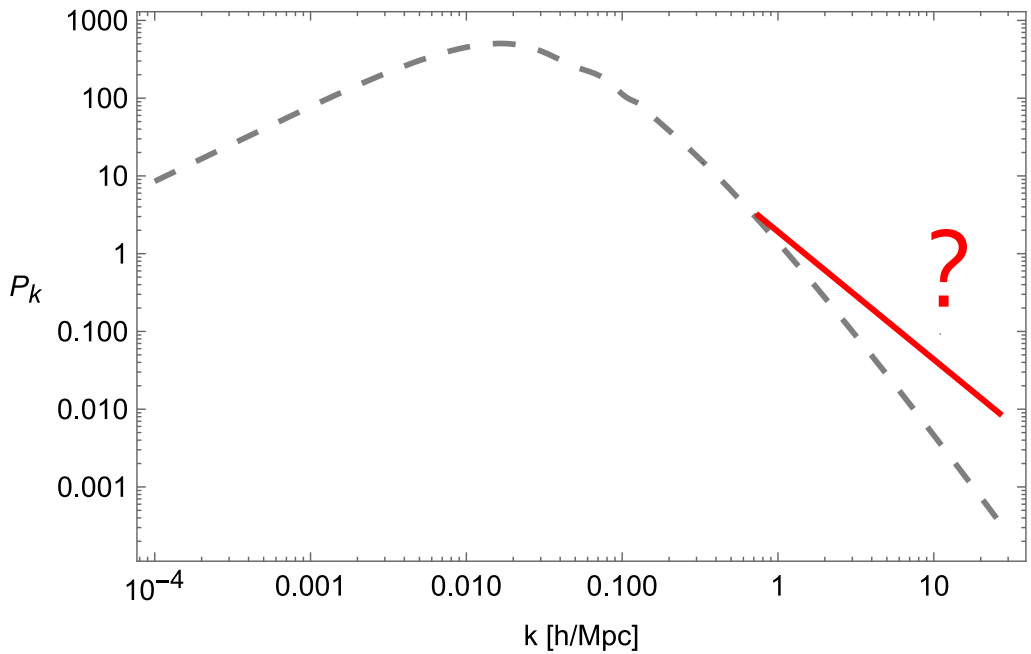
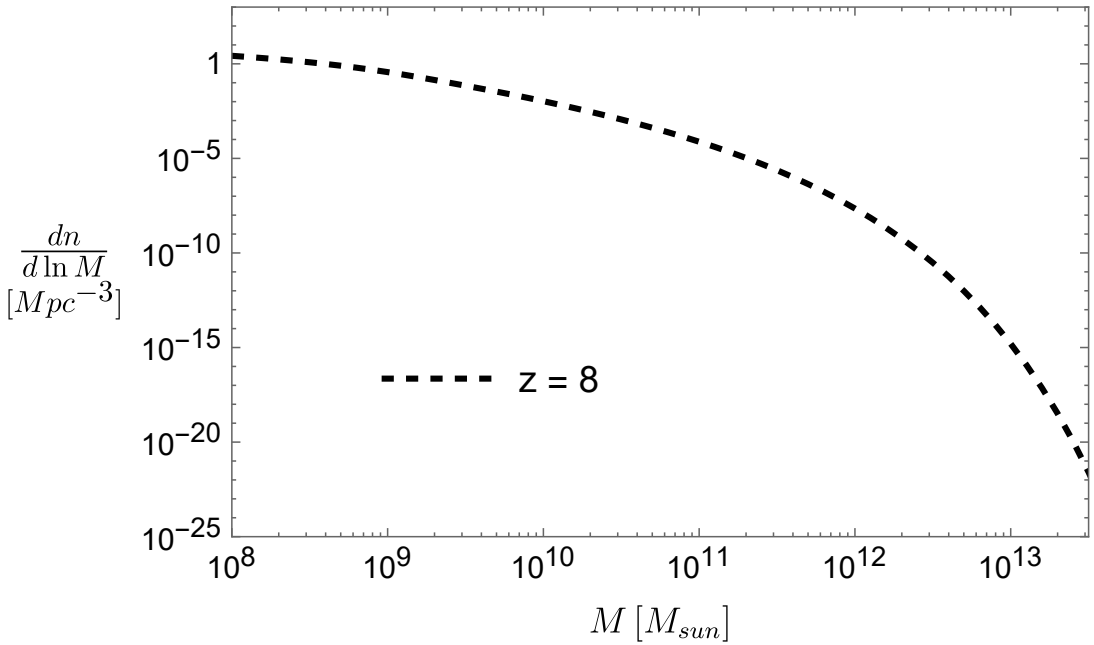


- Interesting new results already in JWST
  - e.g. high redshift galaxies, little red dots
- Emerging picture of more structure at smaller scales

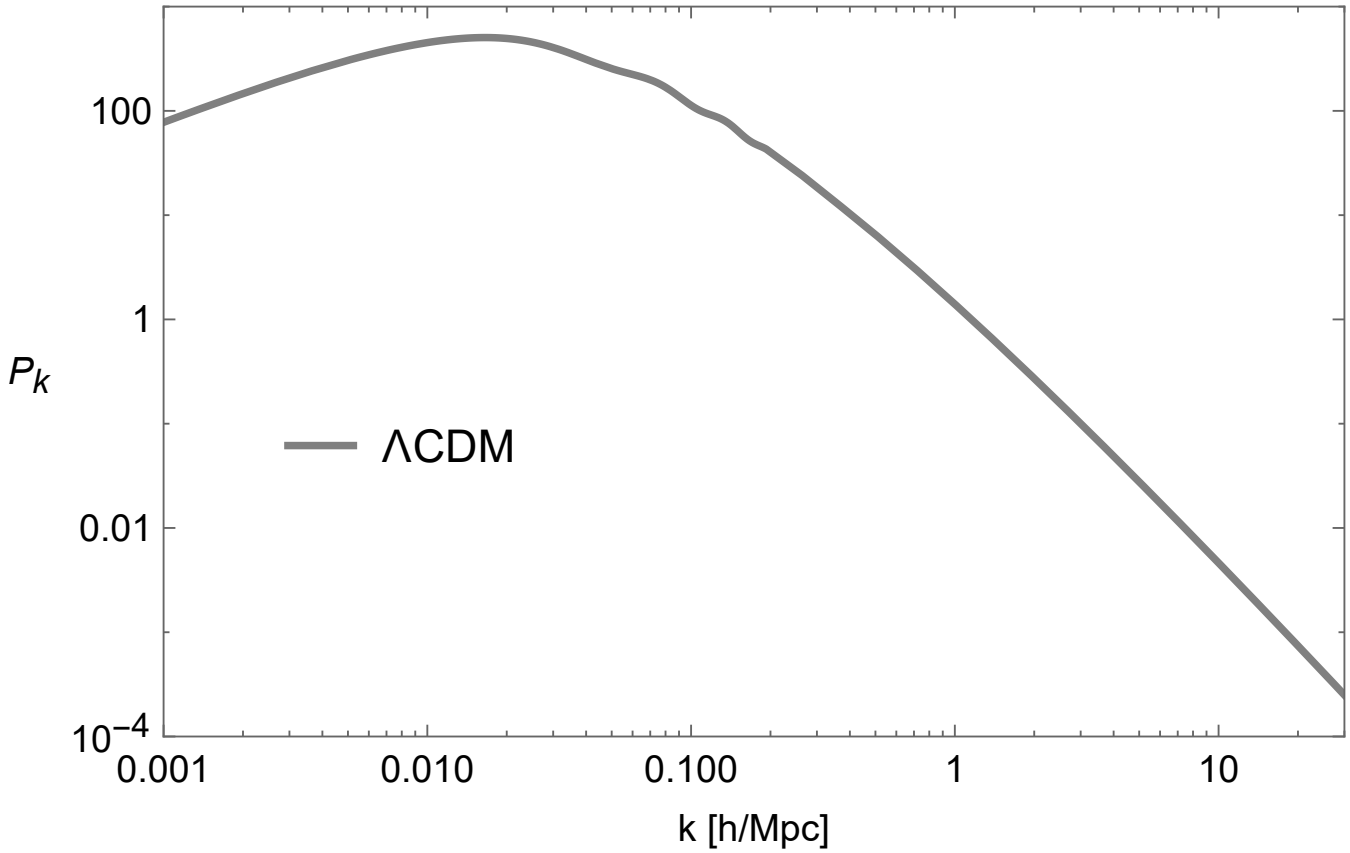
Halo Mass Function (HMF)

- Distribution of haloes predicted using excursion set theory (extended Press-Schechter)
- Using linear matter power spectrum, estimate collapse of structure
- Predict number density of haloes per mass interval $\frac{dn}{d\ln M}$



HMF from Simplified Behaviors

Try simple behaviors in matter power spectrum



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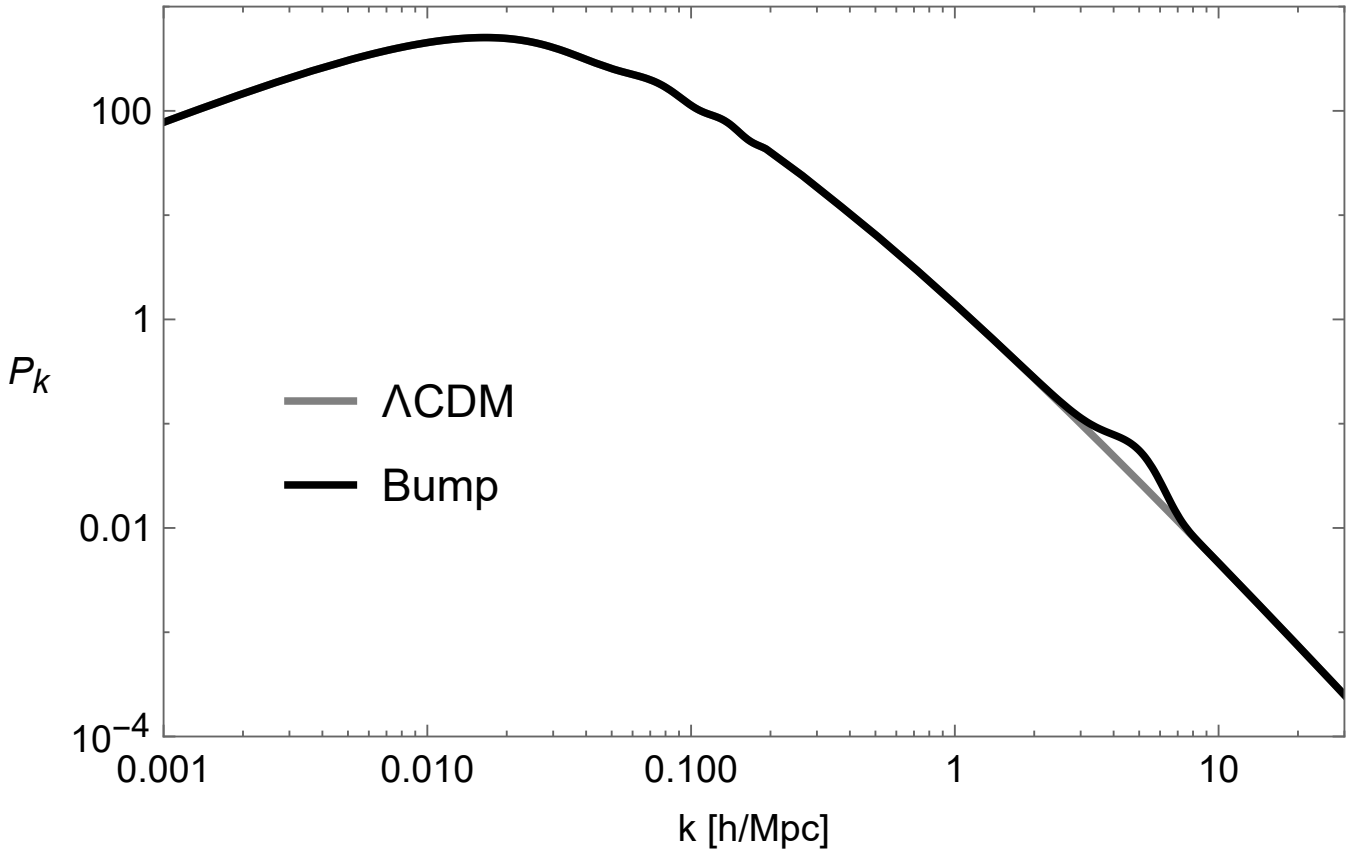

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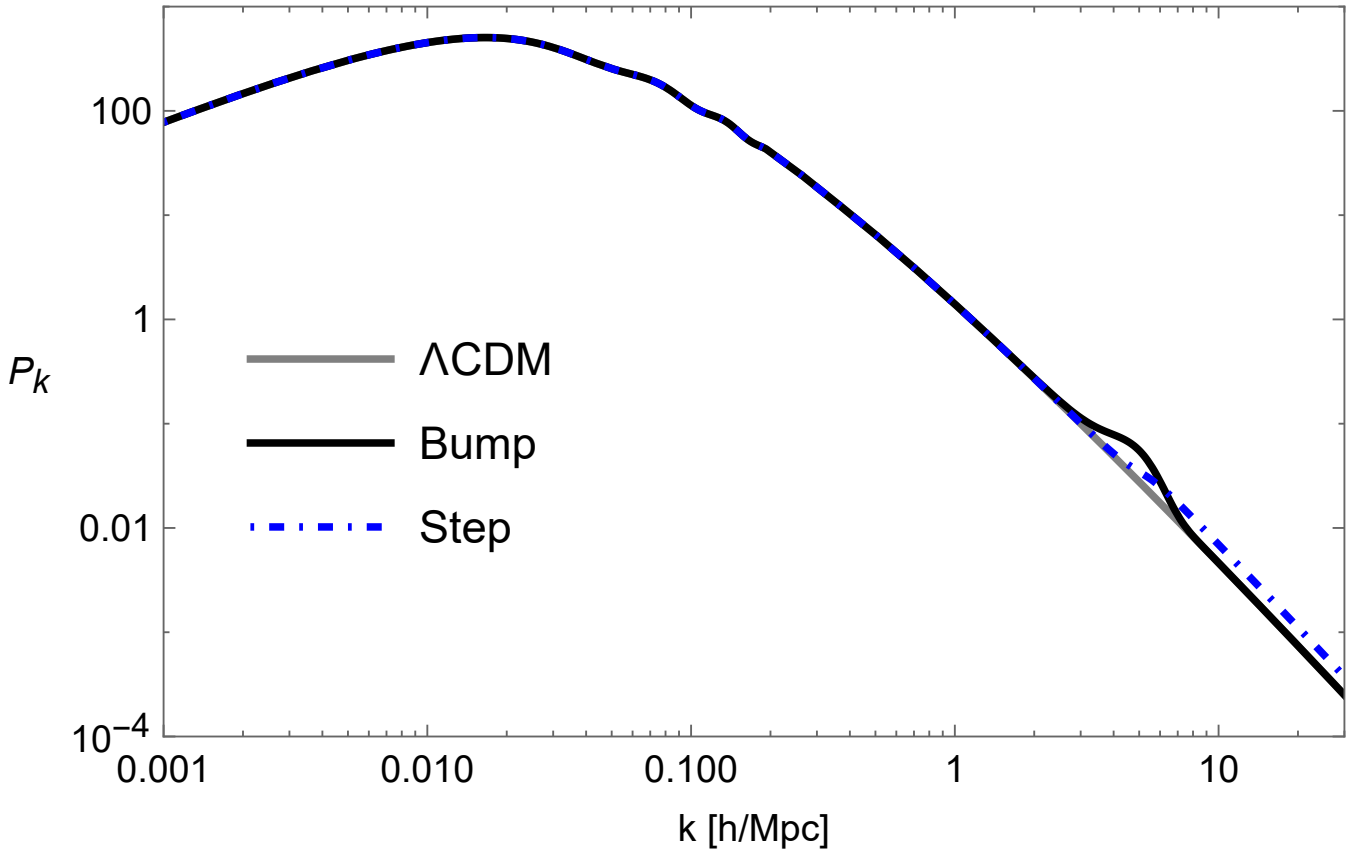

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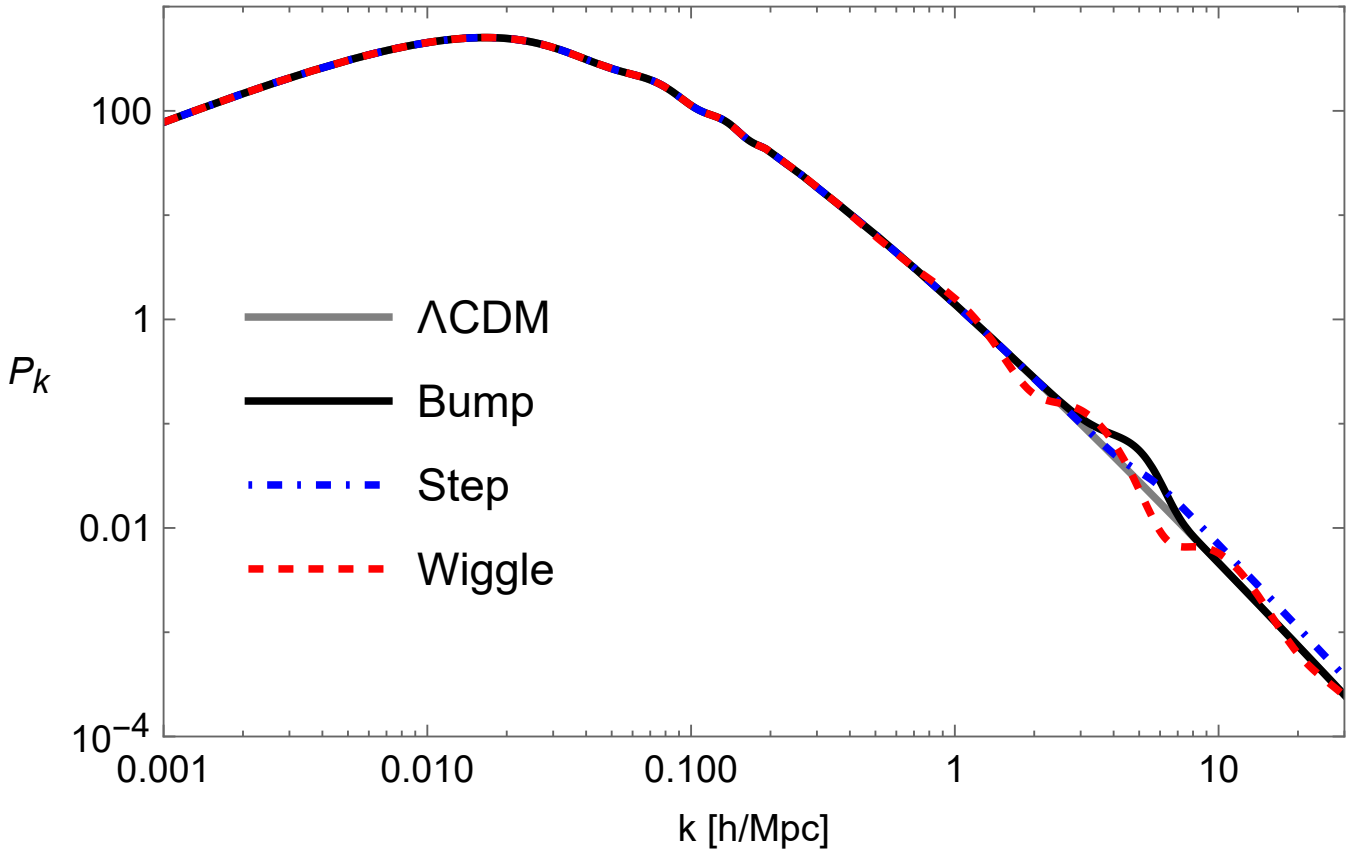

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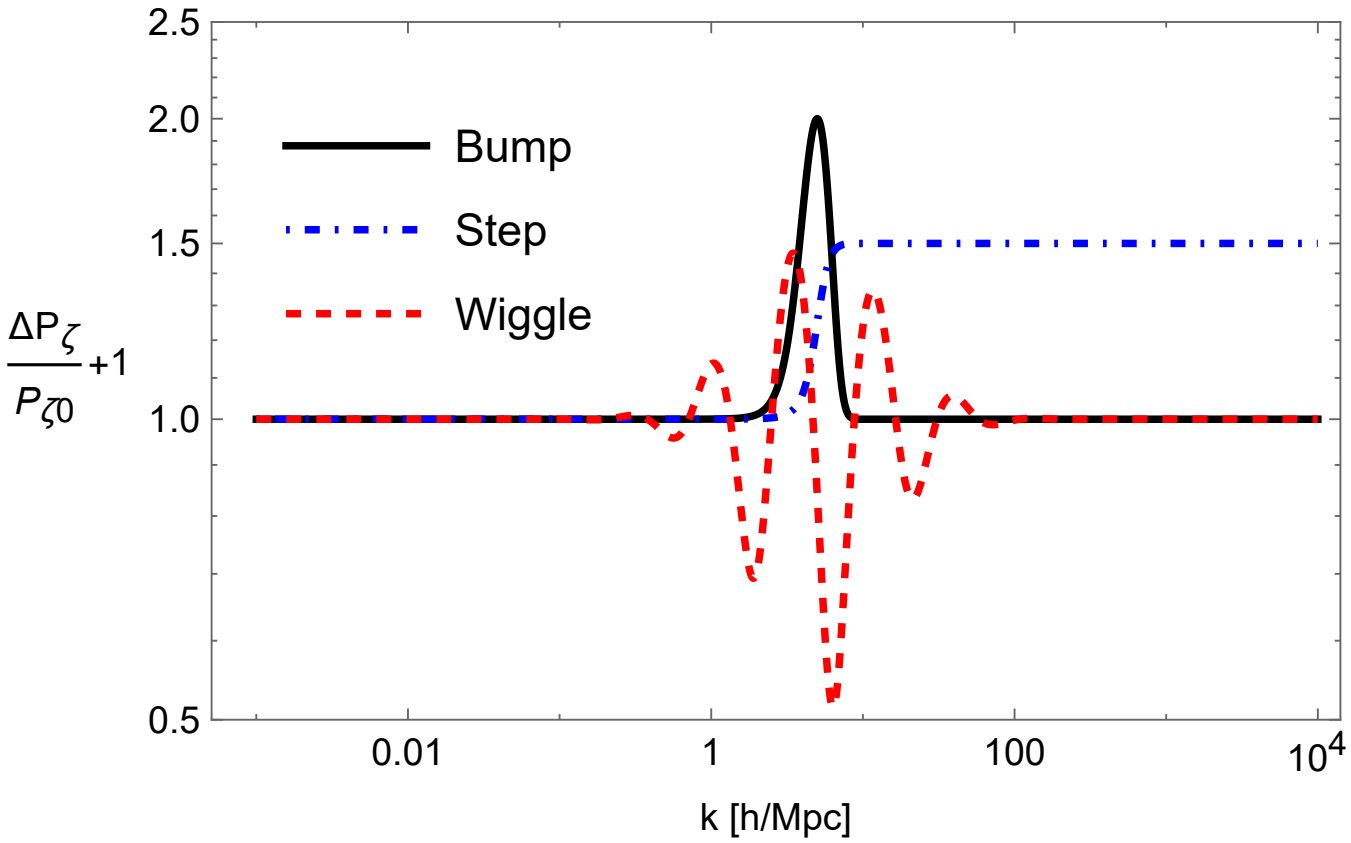

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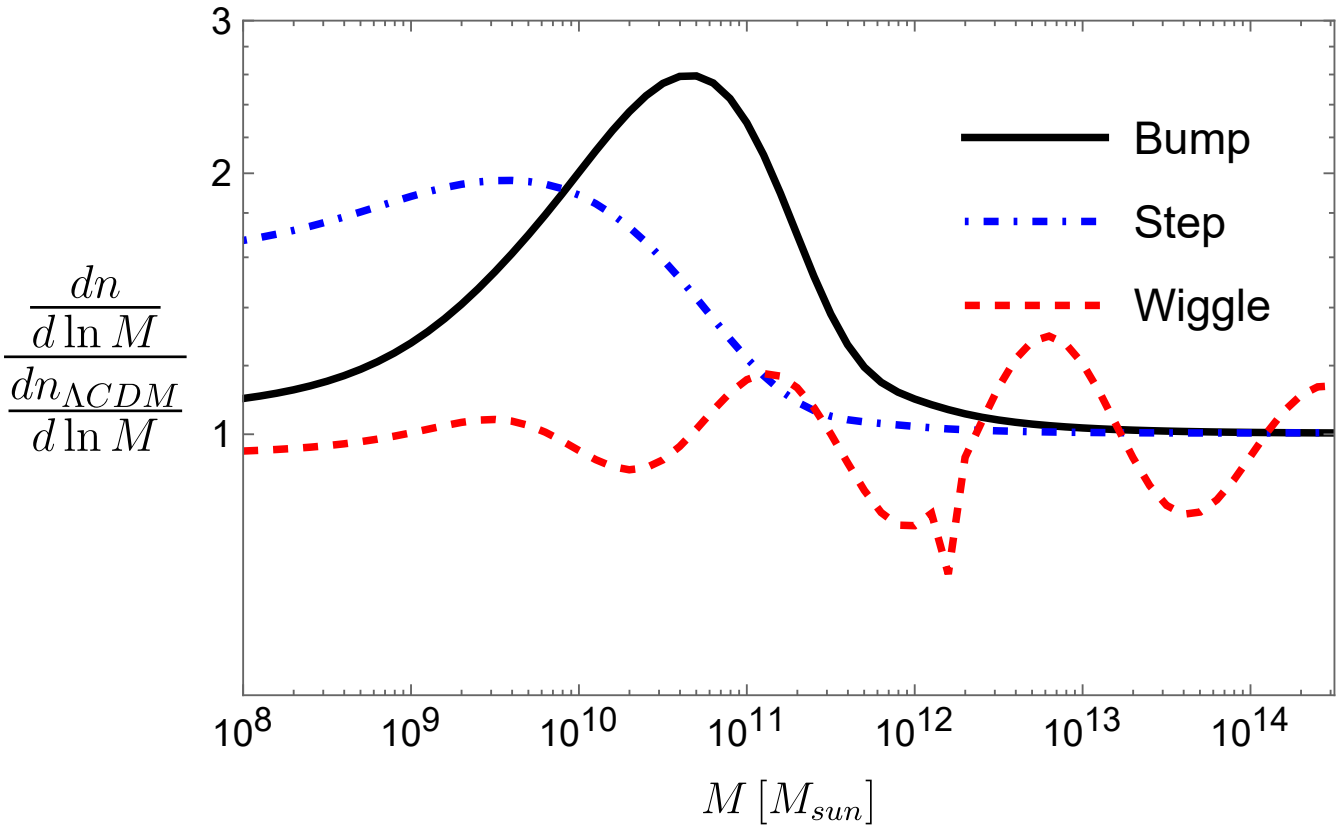

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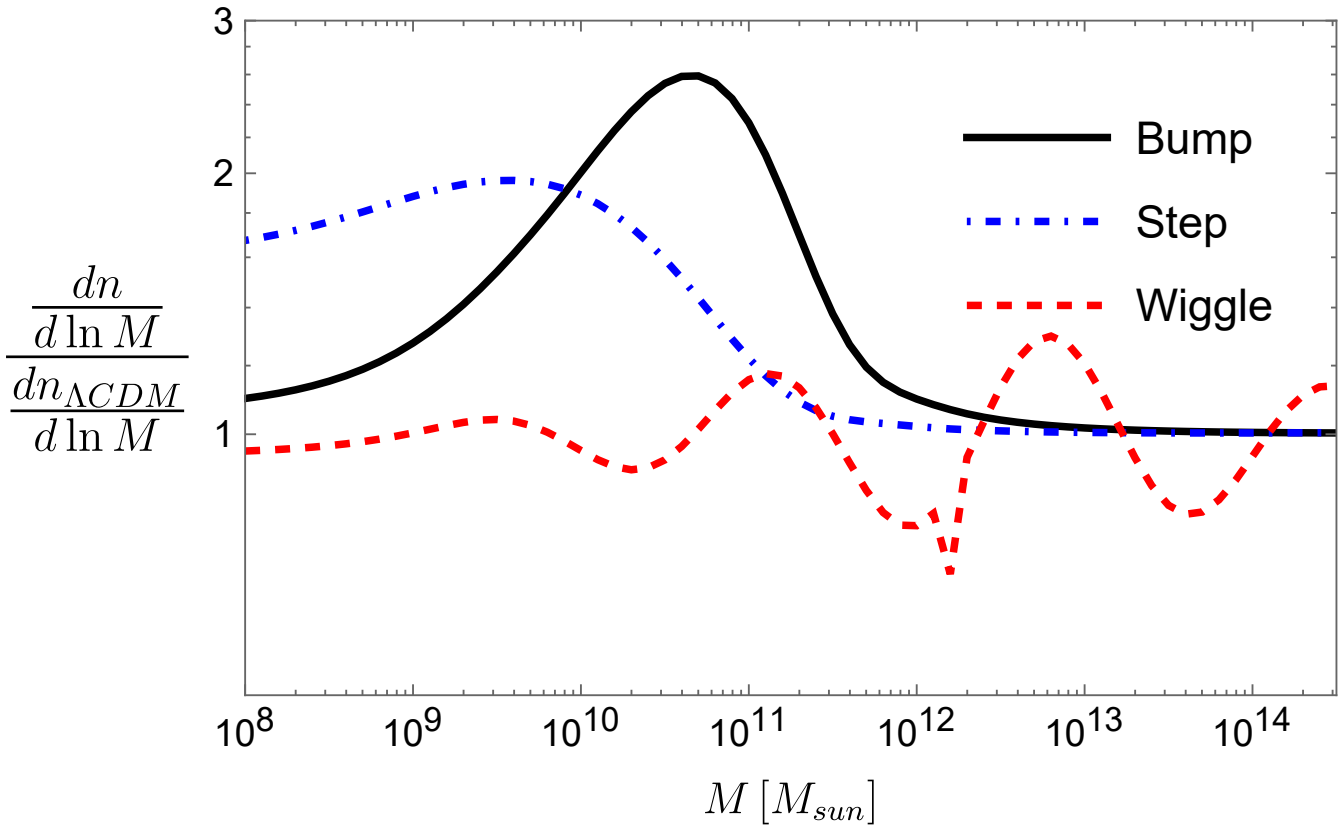
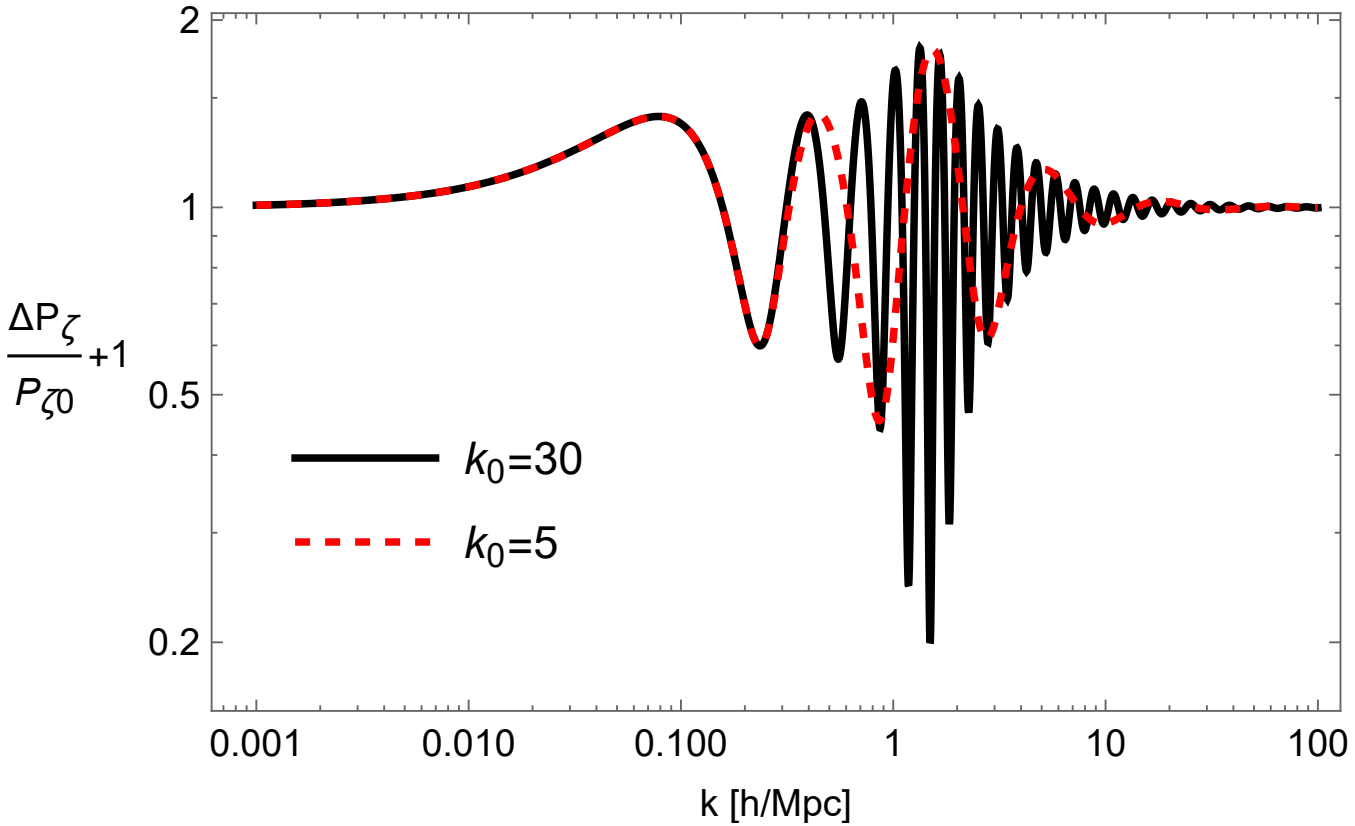


Everything is smeared, BUT oscillations may survive!

HMF from Sharp Feature + Clock

Simplified Sharp Feature + Clock, with different frequencies (mass)



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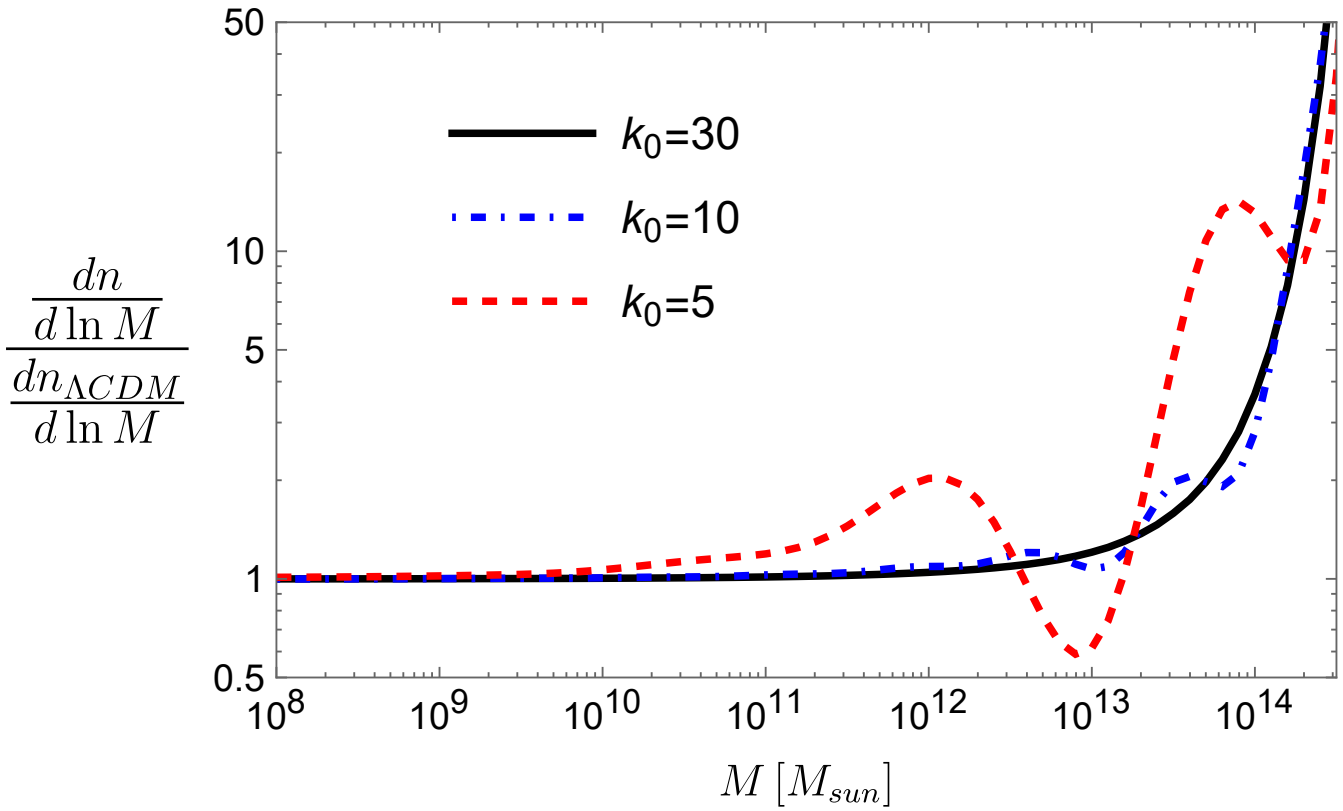

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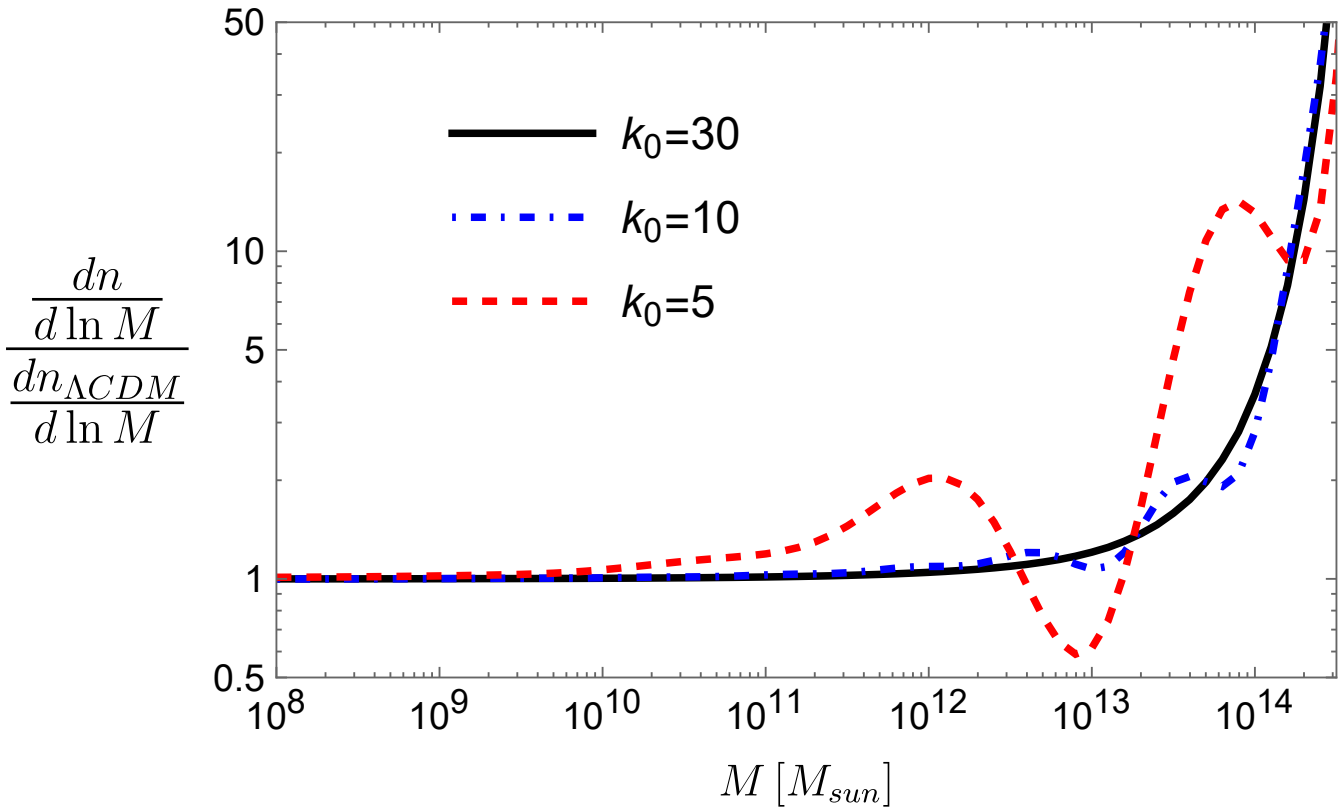
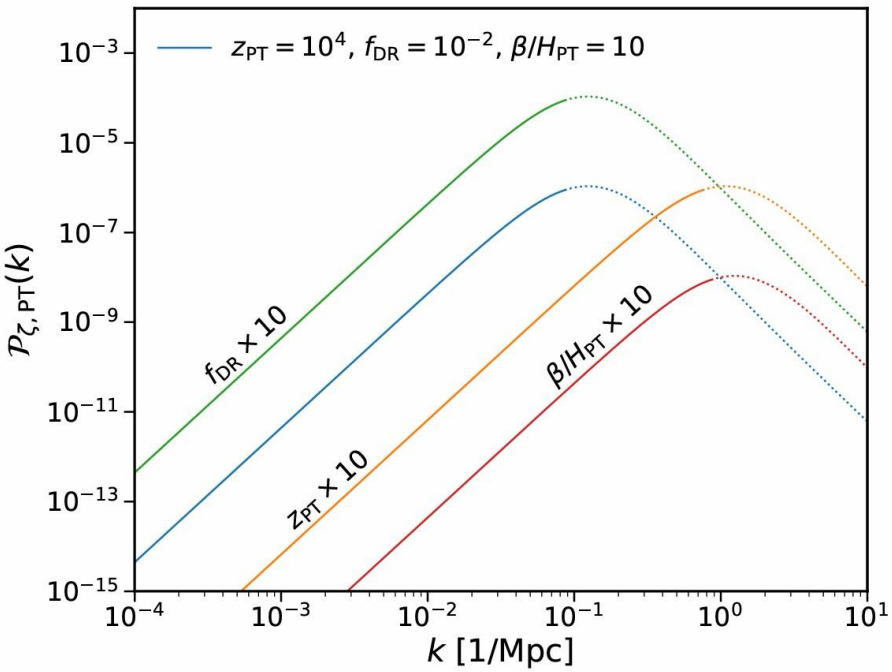


High, low frequency lose oscillations
$\rightarrow$ intermediate frequency oscillations remain!

(see also Acharya 2026)

Bonus: First Order Phase Transitions

(From Daven Ho's Talk yesterday)

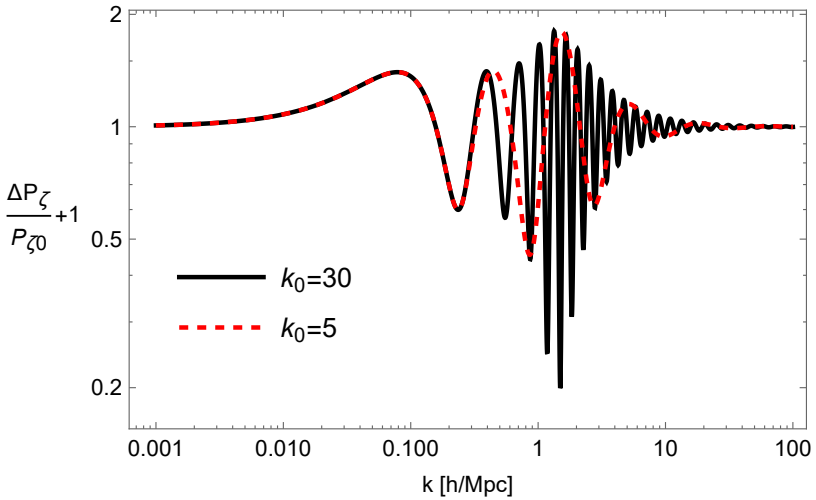


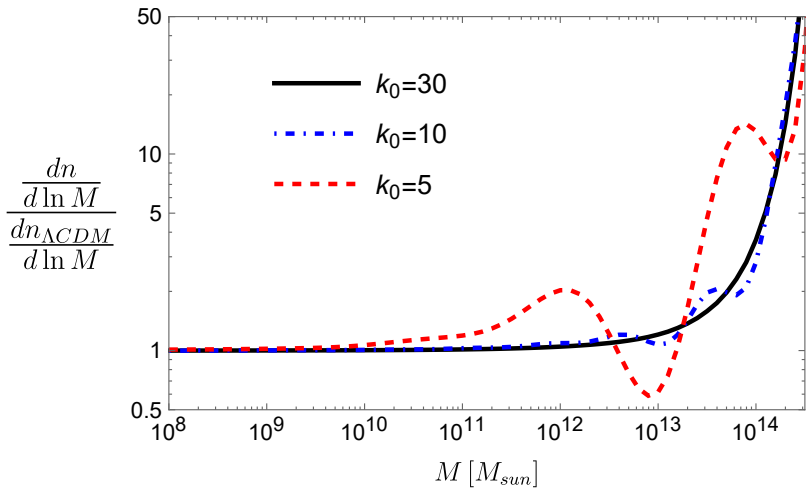
- First order PT modifies spectrum of perturbations
- Impact on *subhalo* mass function

- Ongoing work: understand sensitivity to substructure of pulsar timing arrays

  (based on Dror et al, Ramani et al, Lee et al ++)

Summary





- Oscillatory primordial features $\rightarrow$ maybe oscillations in HMF
- Important questions
  - Constraints from data e.g. UVLF from HST/LWST
  - Do oscillations remain after later galaxy mergers?
- Stay tuned for upcoming results!