Self-similar Bumps and Wiggles: Isolating the Evolution of the BAO Peak with Power-law Initial Conditions

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with

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Background

Early Universe

Late Universe

Advantages:

Distance scale anchored to CMB (not LMC!)
Very useful for constraining Dark Energy

Theoretical Challenges:

BAO feature changes over time
Need <1% accurate theory for any w(z)!
Initial Conditions

Clustering

$\xi(\frac{r}{r_{BAO}}) \sim r^{-(n+5)}$

Fourier Transform

$P_L(k) \sim (k_{BAO}^2)^{-3}$

Linear regime

$\xi(t) = 1$

Strongly non-linear regime

Time

Scale

Scale$^{-1}$

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Non-linear structure formation
Simplifying the Problem

**Bump evolves like an ordinary 1-D diffusion process!**

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Self-similar Bumps!

\[
\frac{r_{bao}}{L_{box}} = \frac{1}{10}, \quad \frac{r_{bao}}{n_p^{-\frac{1}{3}}} = 50
\]

Self-similarity =

evolution only depends on \( R_{NL}/r_{bao} \)

Departures from this scaling indicates numerical problems

Can’t do this with LCDM!

Conclusions:

\[
\frac{r_{bao}}{L_{box}} > \frac{1}{10}, \quad \frac{r_{bao}}{n_p^{-\frac{1}{3}}} > 25
\]

seems to always pass this test
Fourier-space phenomenology

\[ P_{NL}(k) = \exp(-\Sigma^2k^2/2) P_L(k/\alpha) + A(k) \]

Non-linear spectrum

Damping

Small-scale model

Initial spectrum

shift!
Beyond linear-order

PT breaks down

PT valid

• Powerlaw x bump setup is a challenge for PT schemes
• Factors of $\Sigma^2 = \frac{1}{3\pi^2} \int_0^\infty P_L(q) \, dq$ typically diverge
• Pat McDonald’s SimpleRG scheme avoids this factor

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Conclusions

• New LCDM-ish model for testing PT schemes checking numerical accuracy!
• Bump evolves like a 1-D diffusion process
• Huge shift for case with steepest power spectrum!
• Self-similar tests recommend $r_{bao} / L_{box} > 1/10$, $r_{bao} / n_p^{-1/3} > 25$
• McDonald’s SimpleRG predictions provide good match to results

To do:

• Post matter-clustering results on arXiv this summer!
• Halo clustering / scale-dependent bias
• Explore Sirko 2005 approach to running ensembles of simulations