Impact of Dark Sector Physics on Large-Scale Structure Topology

Andrew Watts – 18.07.2016

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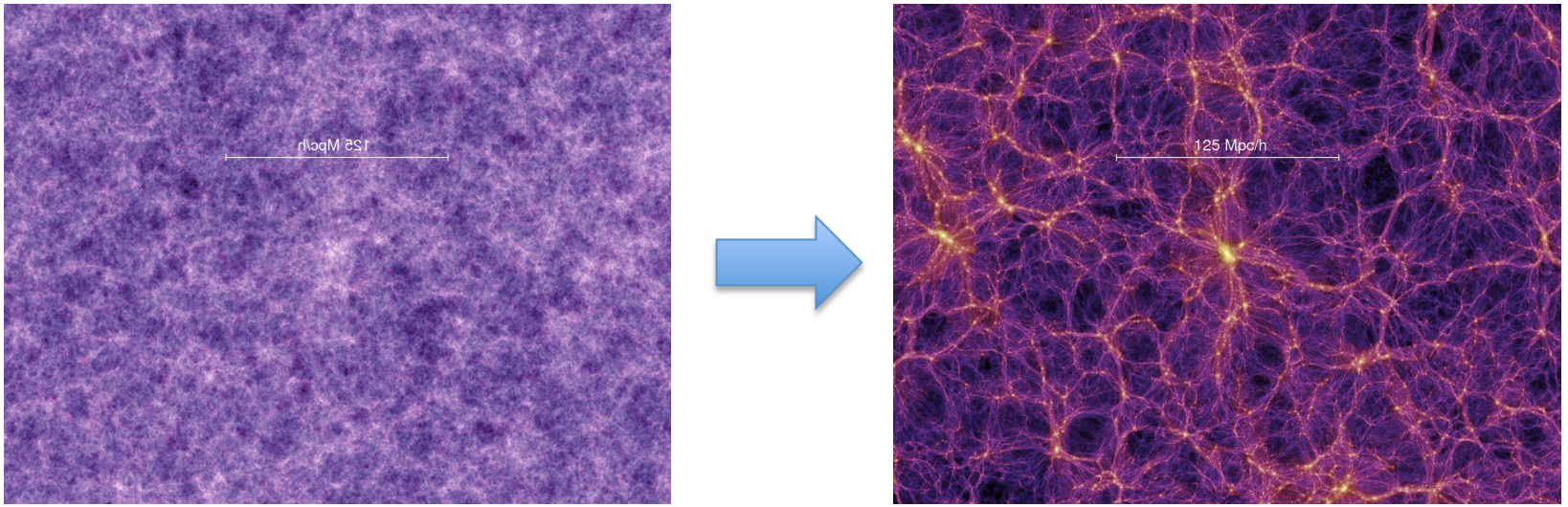
Introduction

$$\Omega_{\mathrm{bm}} + \Omega_{\mathrm{dm}} + \Omega_{\Lambda} = 1$$

- ΛCDM reproduces large-scale structure very well, but with discrepancies at galactic scales.



- In ΛCDM, Λ is constant ≅ 10^{-122} (planck units). This raises a significant fine-tuning problem.

Alternative Models

- ΛWDM: Dark matter particle moves at relativistic speed, structure formation is suppressed below a certain scale. Large-scale structure remains intact.
- Quintessence: dynamical dark energy

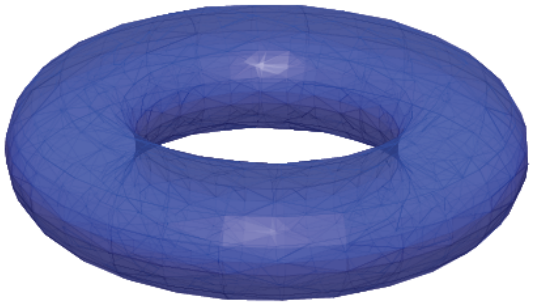
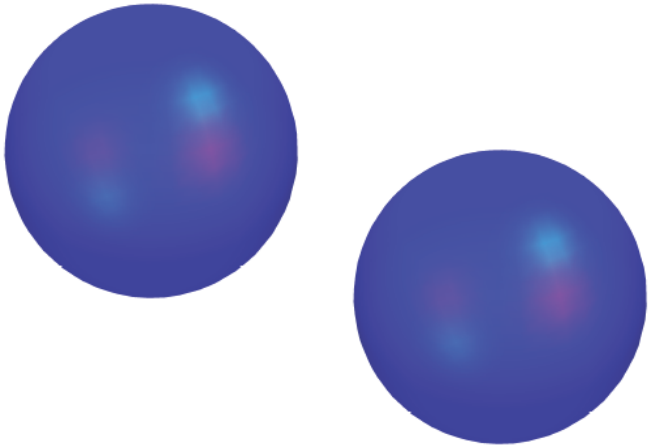
$$L = \int d^4x \sqrt{-g}\left(-\frac{1}{2}\partial_\mu \partial^\mu \phi + V(\phi) + m(\phi)\psi_m \bar{\psi}_m \right)$$

kinetic term potential term interaction term

- Varied parameters: Ω_Λ, σ_8

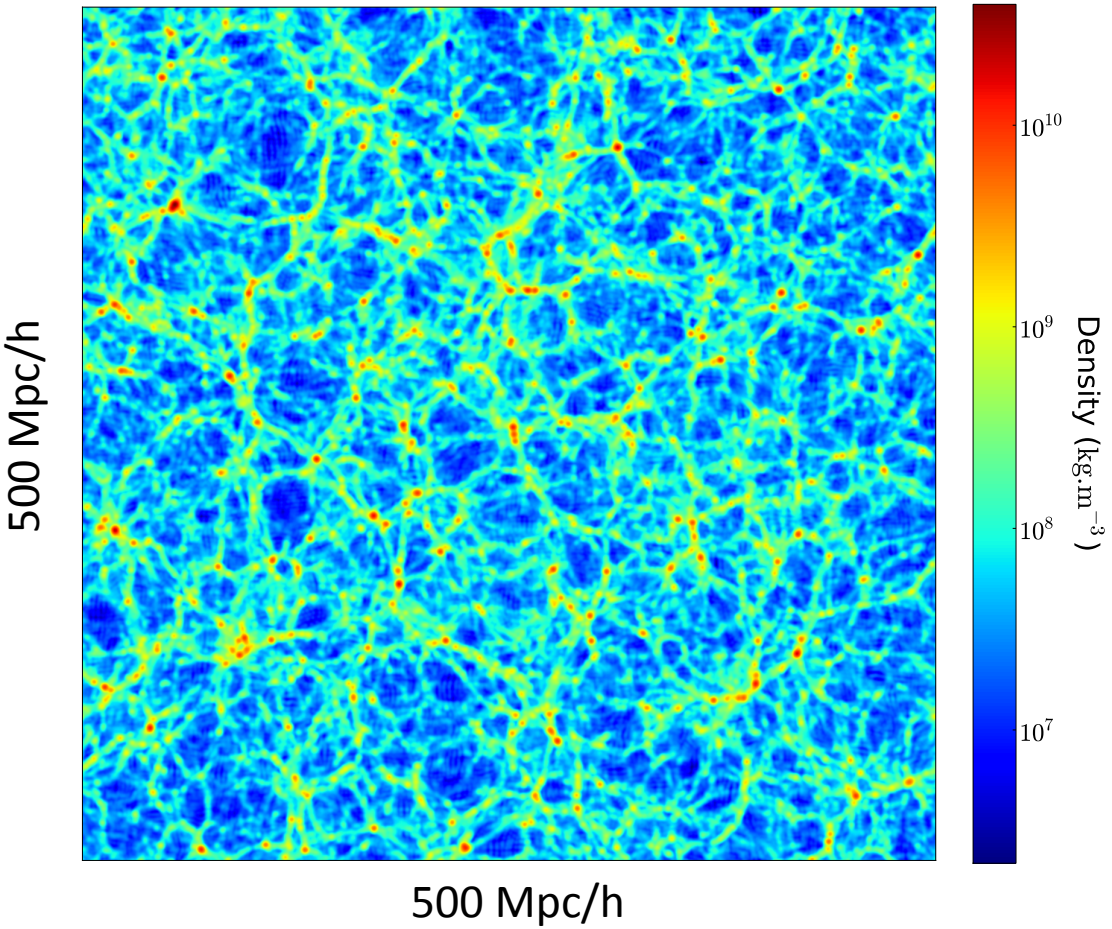
Topology

$$g_s = n_{holes} - n_{\text{surfaces}} + 1$$

		
$g_s = 0$	$g_s = 1$	$g_s = -1$

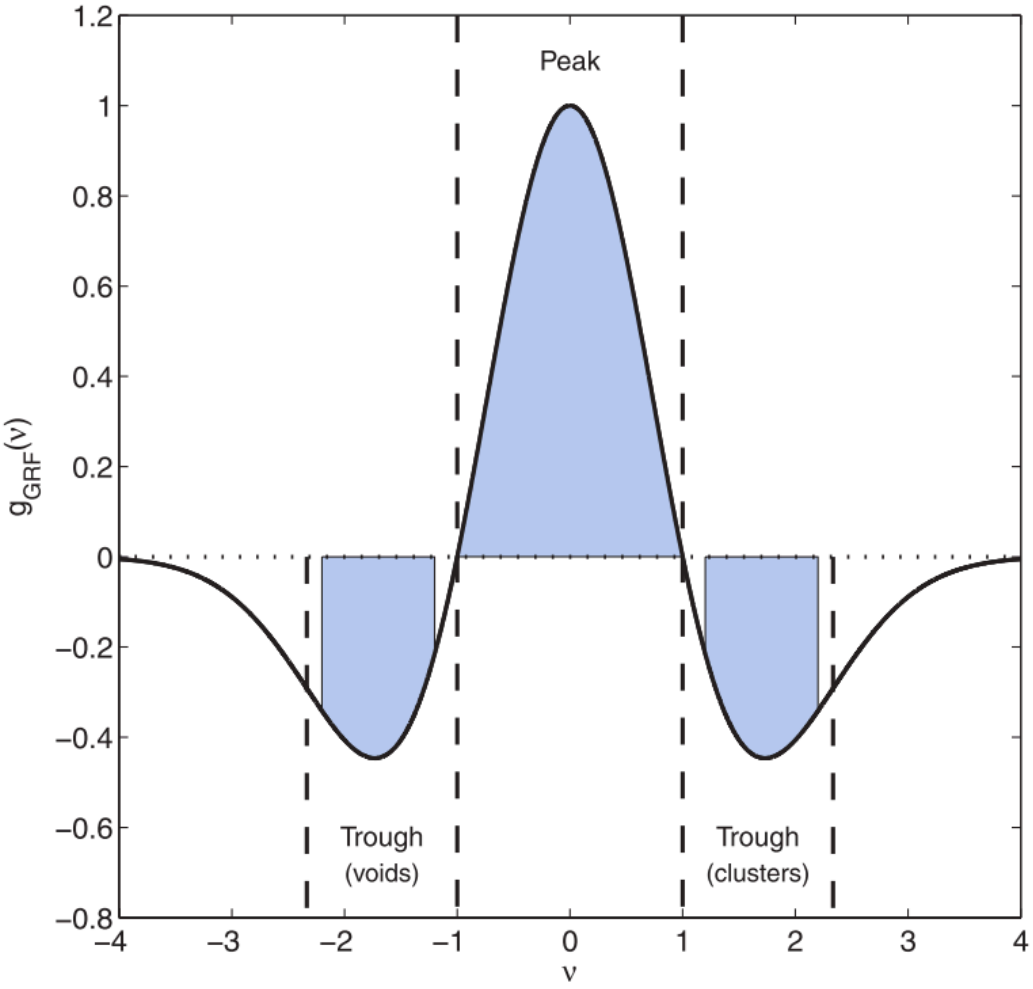
Topology

$$g_s = n_{holes} - n_{\text{surfaces}} + 1$$



$$g_s = ?$$

Hermite functions

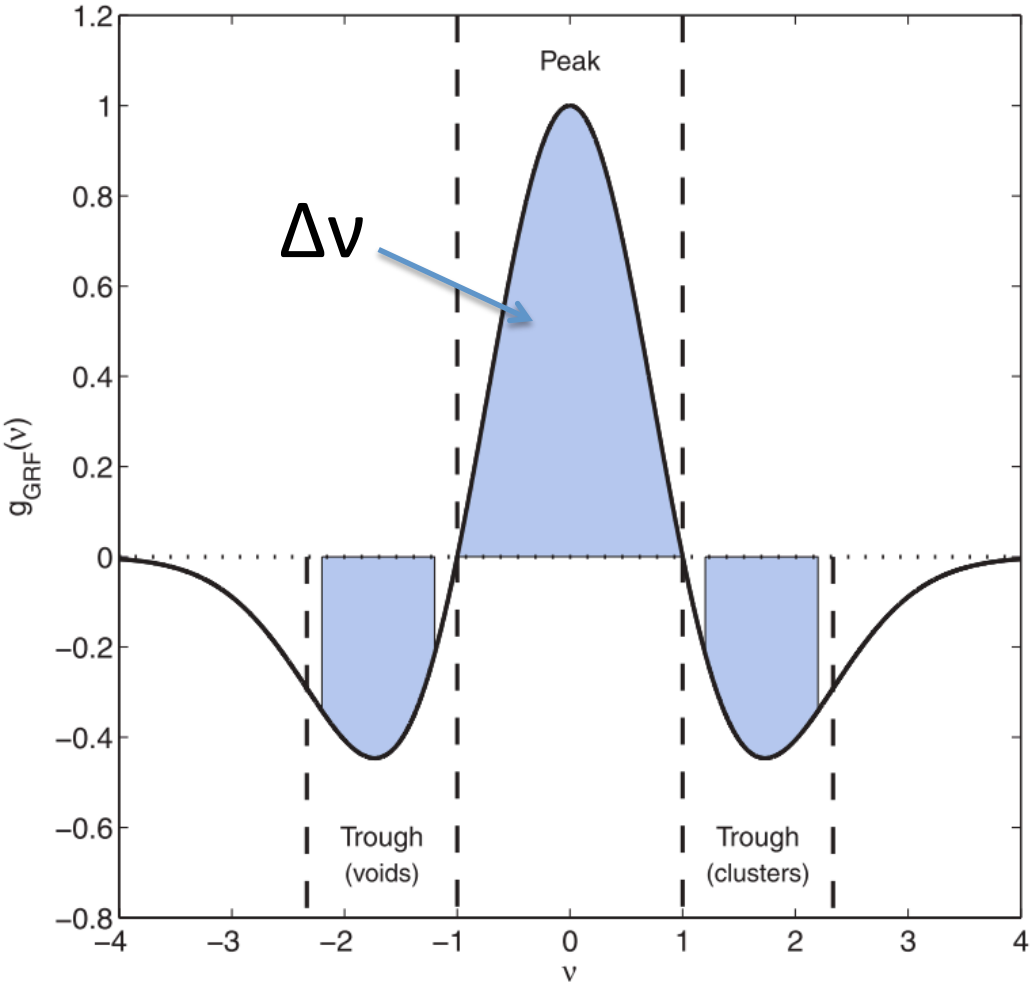


$$g_{\mathrm{GRF}}(\nu) = A(1-\nu^2)\mathrm{e}^{-\nu^2/2}$$

$$g(\nu) = \sum_{n=0}^{\infty} a_n \psi_n(\nu)$$

- Hermite functions form an orthonormal set and produce varied effects on the genus curve.

Hermite functions



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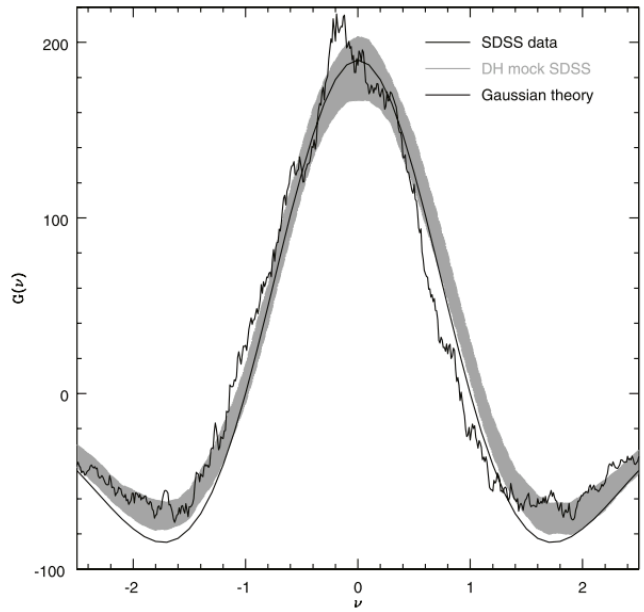

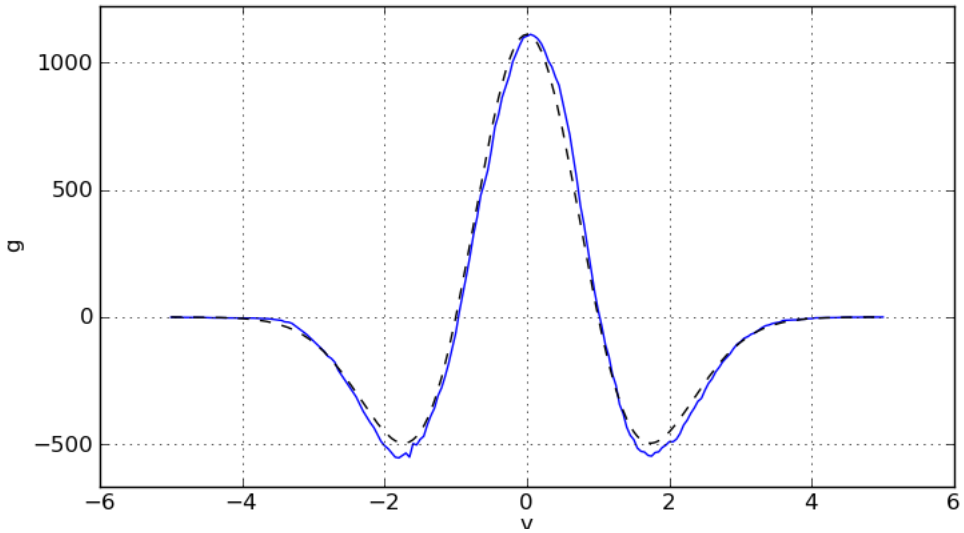

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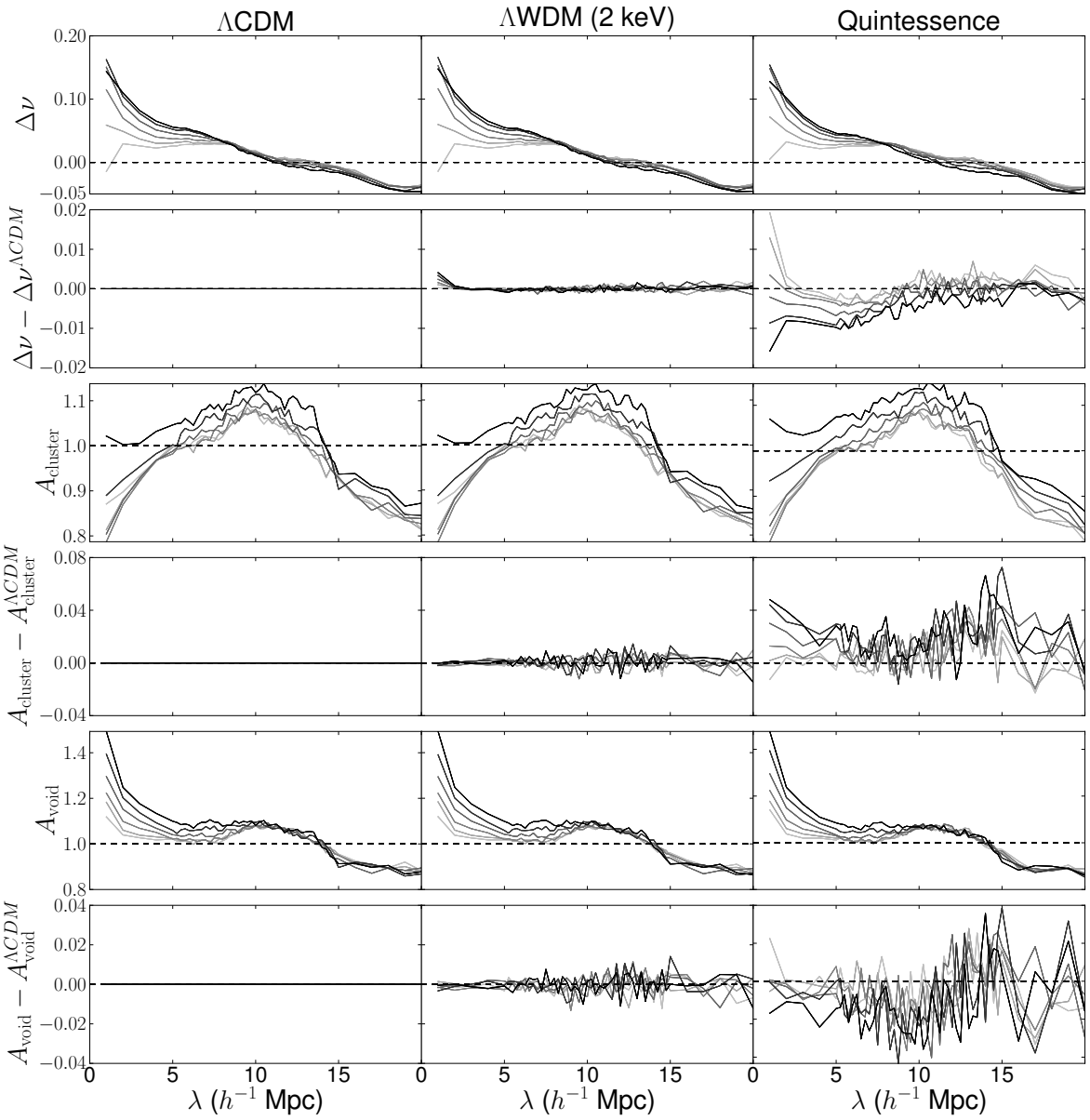
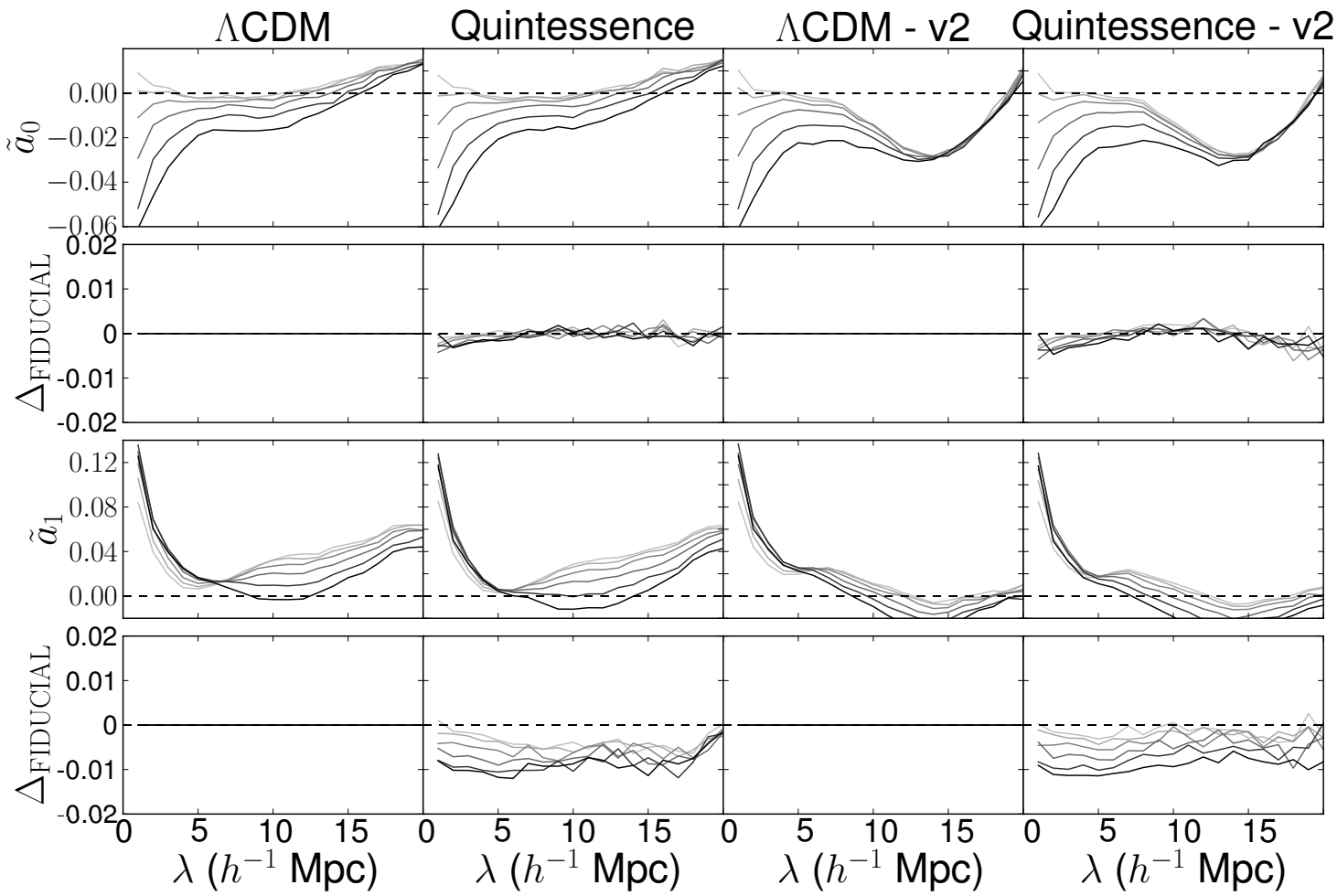
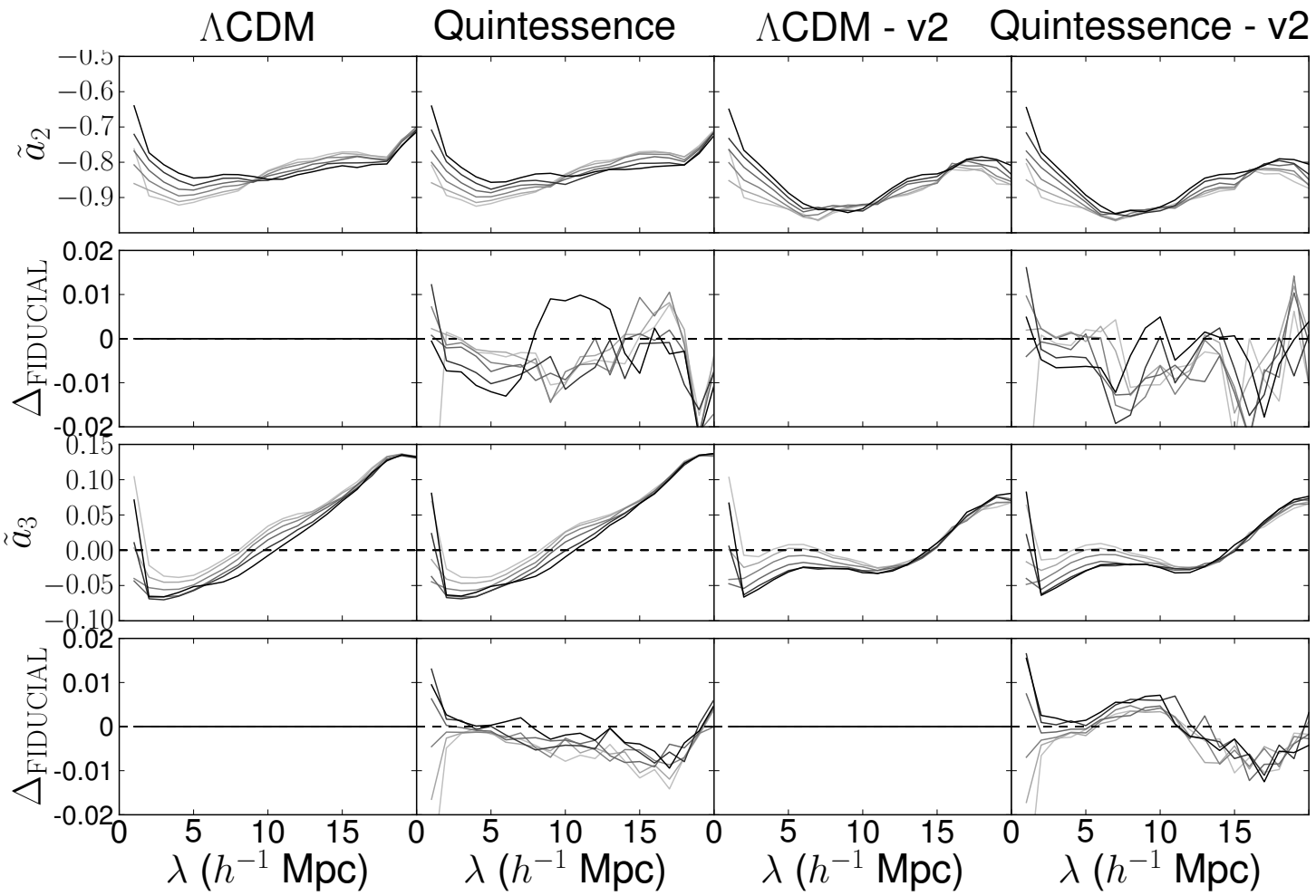


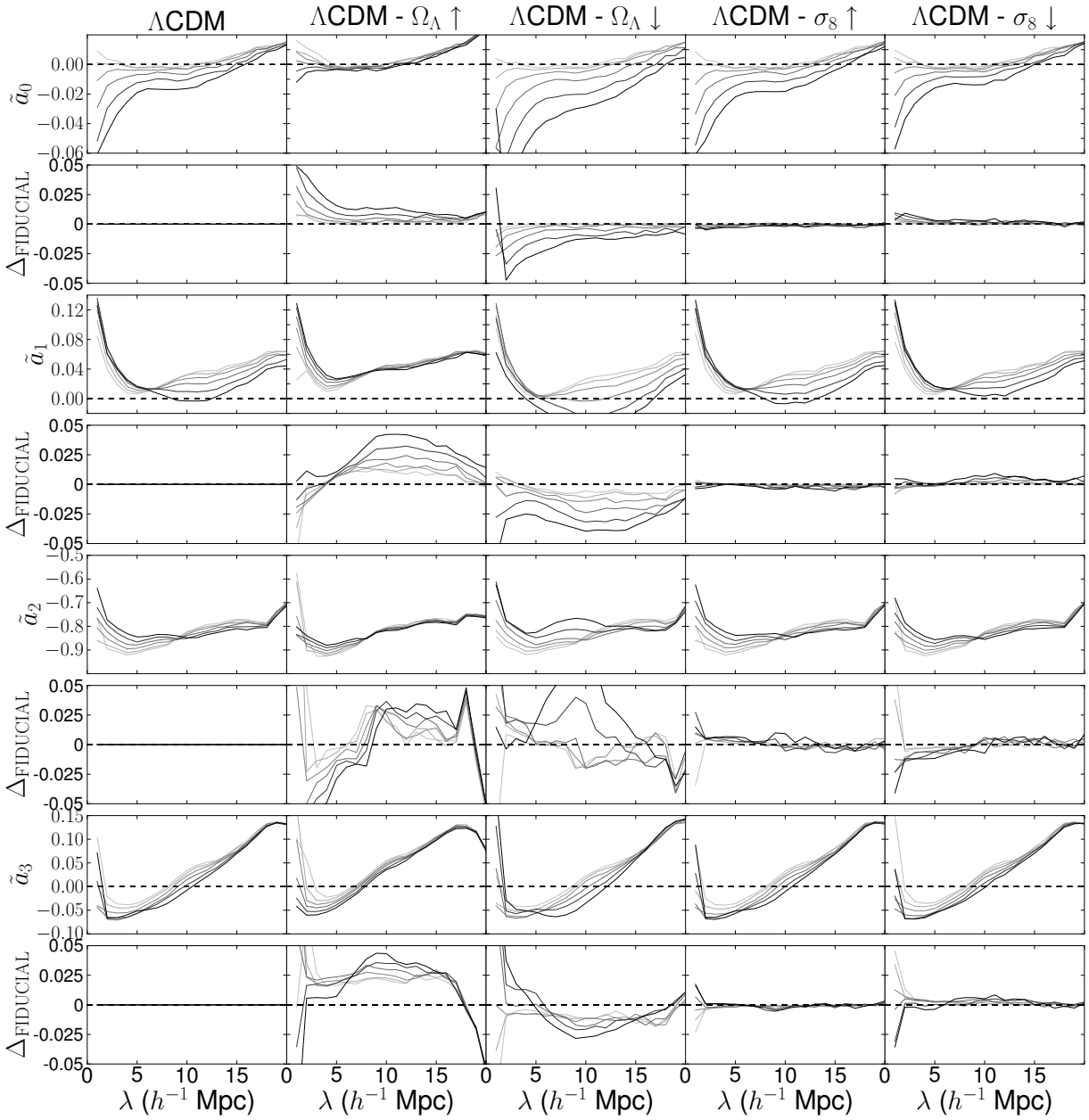
- ΛWDM results are consistent with no topological difference
- Quintessence model has a higher ratio of clusters to voids (3-4% higher cluster abundance, 1-2% lower void abundance).



- The linear Hermite function in the Quintessence model is lower, indicating more clusters and fewer voids.



- Cosmic variance has a large effect on shape of curves, but differences between models are consistent.



- Varying the dark energy density has a significant impact on the Hermite curves. Structure appears to freeze-in at high redshift
- Varying σ effects the power spectrum but has a minimal impact on topology.

Conclusion

- Even in these simple DM-only simulations, the nature of dark energy has a detectable impact on large-scale structure.
- ΛWDM has no effect on large-scale structure topology, as expected.
- Dynamical dark energy favours clusters over voids.
- Future work will focus on mock galaxy catalogues and interacting quintessence models