Structure Growth In Dynamical Dark Energy with Neural ODEs

Peter Taylor

What is driving cosmic acceleration?

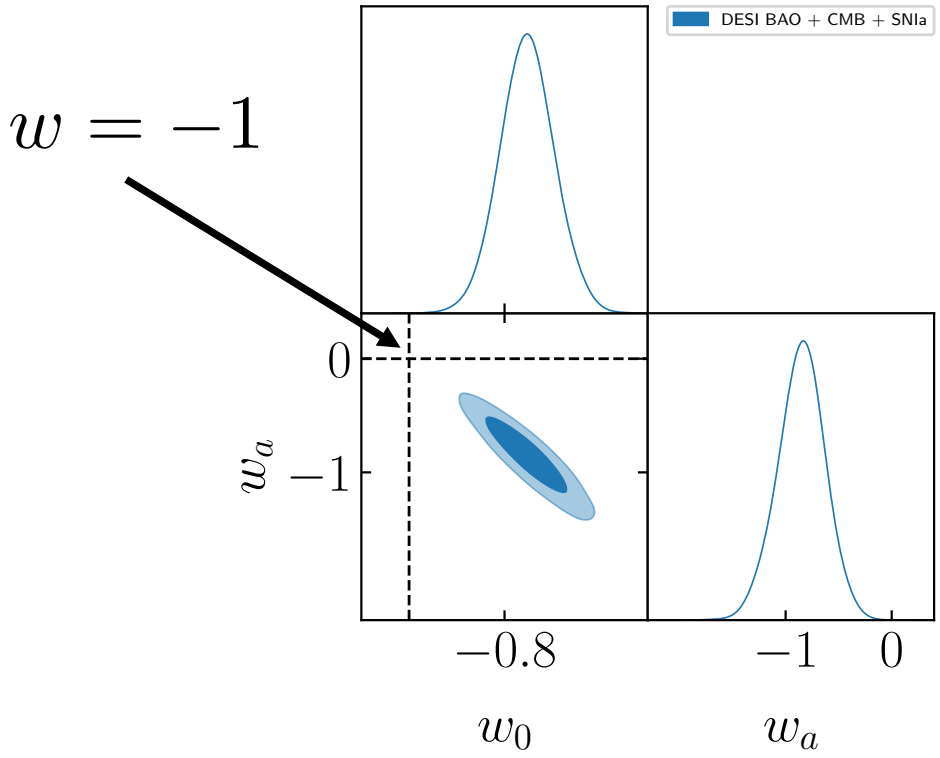
Dark Energy Equation of State

$$w = P/\rho$$

Cosmological Constant (Vacuum Energy)

$$w = -1$$

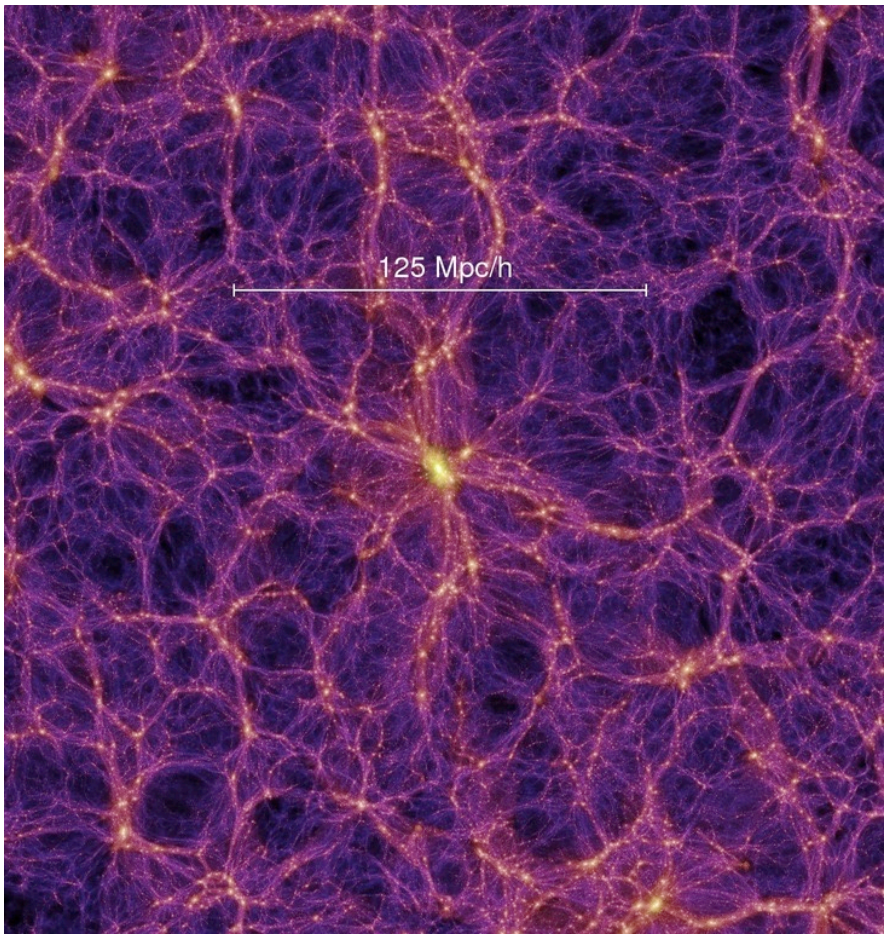
A Paradigm Shift?



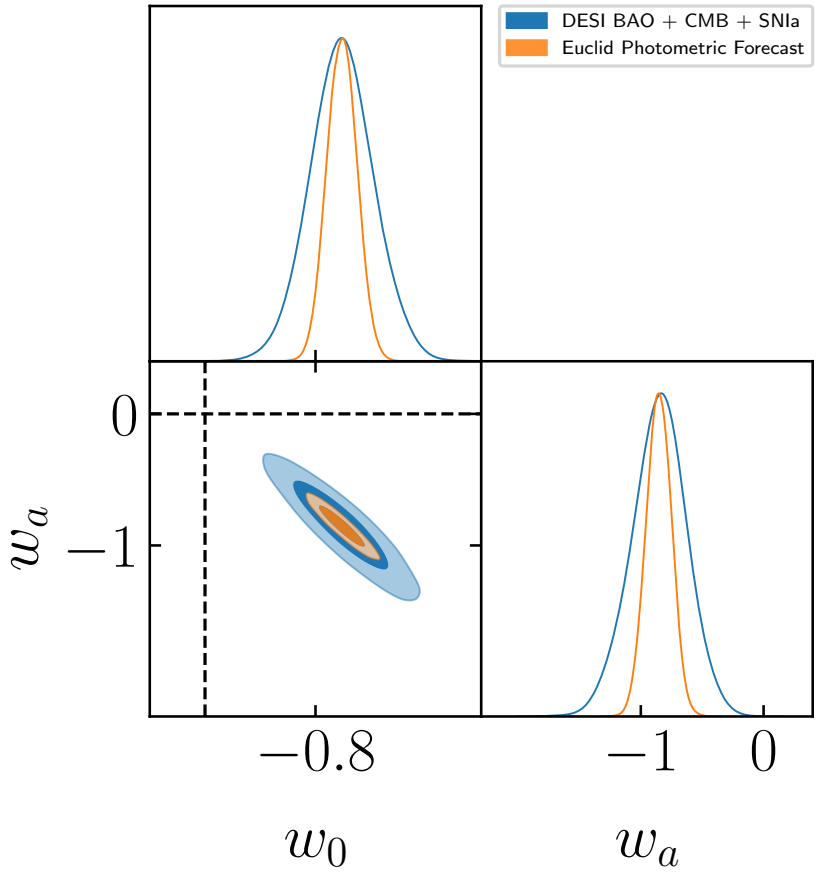
Adapted from DESI Collab. (inc. P Taylor) 25

The Next Frontier: Structure Growth

Structure Growth



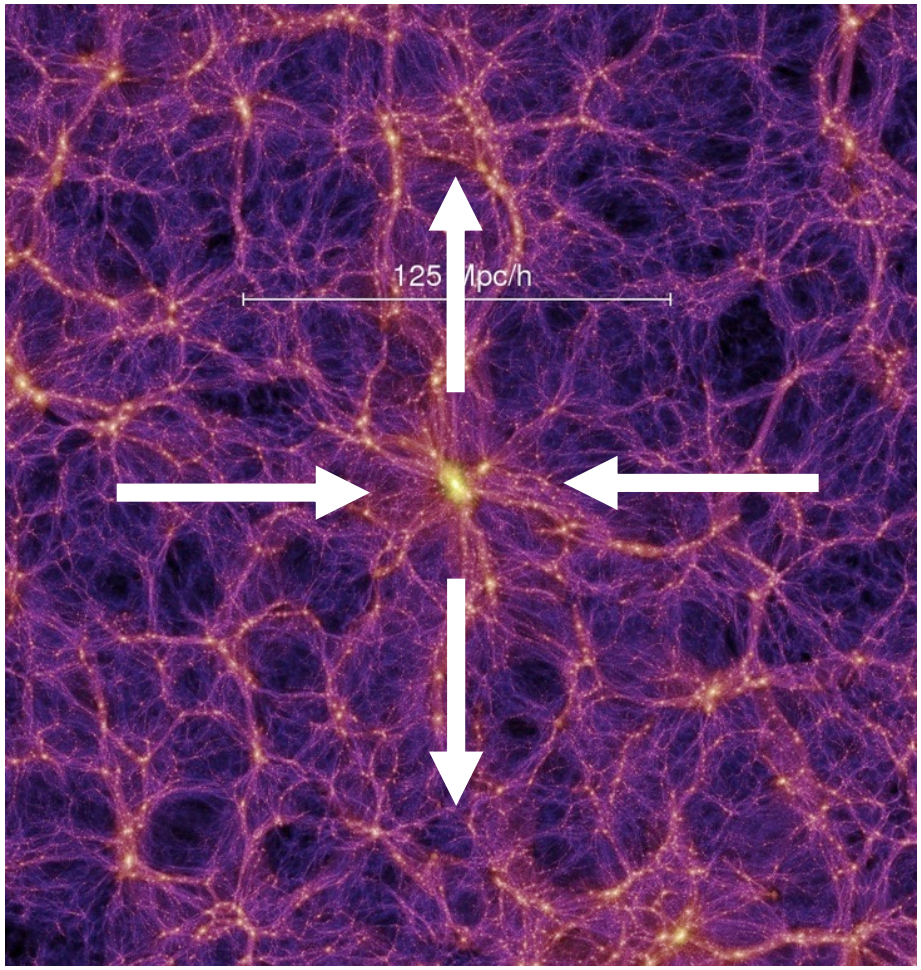
Improved Precision



The Problem: No model for structure growth for arbitrary w(z)

Solution: Neural Ordinary Differential Equations (ODE)

The Growth of Structure



grav. collapse

vs.

background expansion

Neural ODE

summary statistic

mean matter density

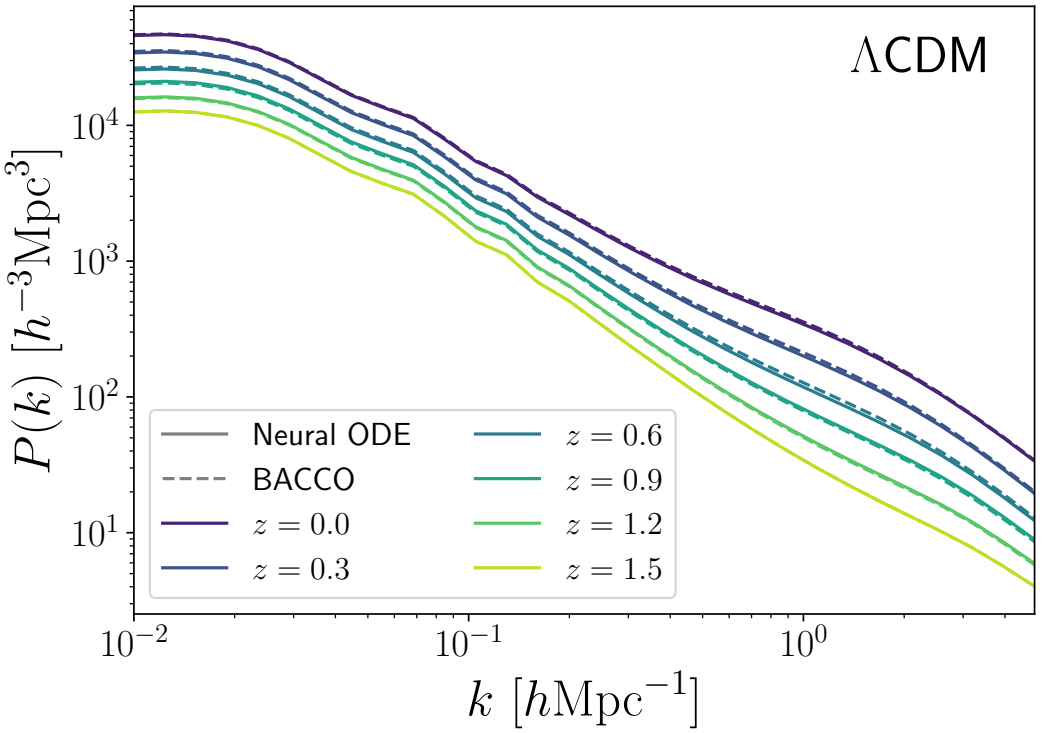
$$\frac{d\boldsymbol{s}(z)}{dz} = \boldsymbol{f}\left(\boldsymbol{s}(z), H(z), \bar{\rho}_m(z), z\right)$$

background expansion

A Solution for Structure Growth

$$\mathbf{s}(z) = \mathbf{s}(z_0) + \int_{z_0}^{z} dz' \; \mathbf{f}(z')$$

The Power Spectrum (Cosmological Constant)



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Neural ODE

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mean matter density

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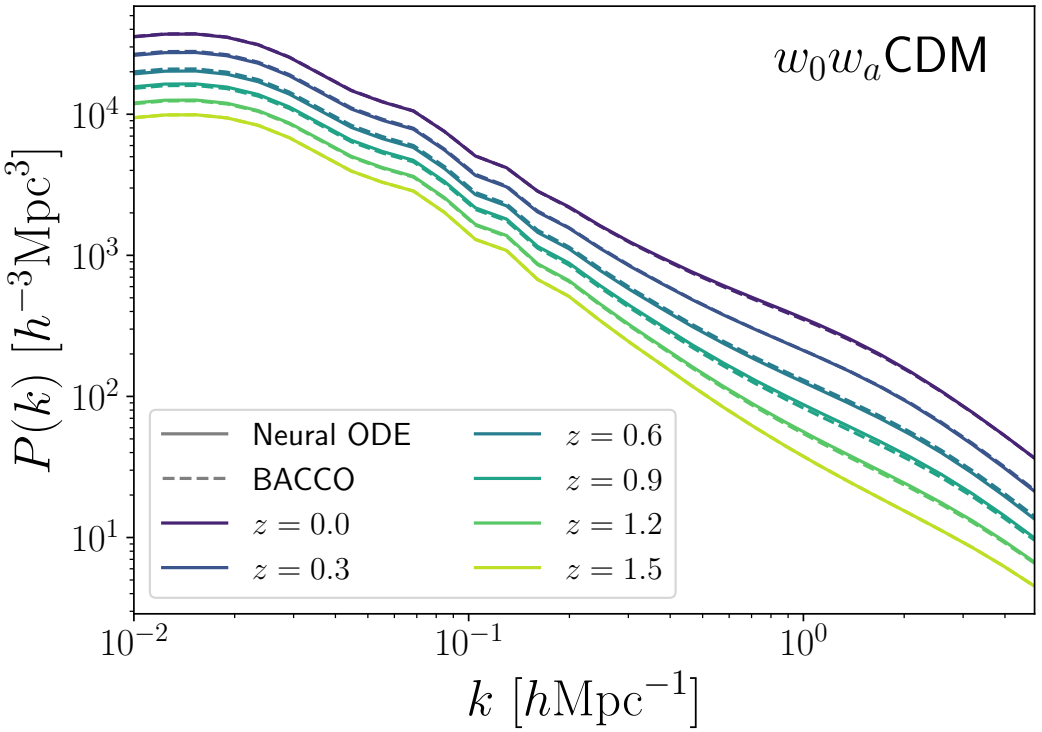
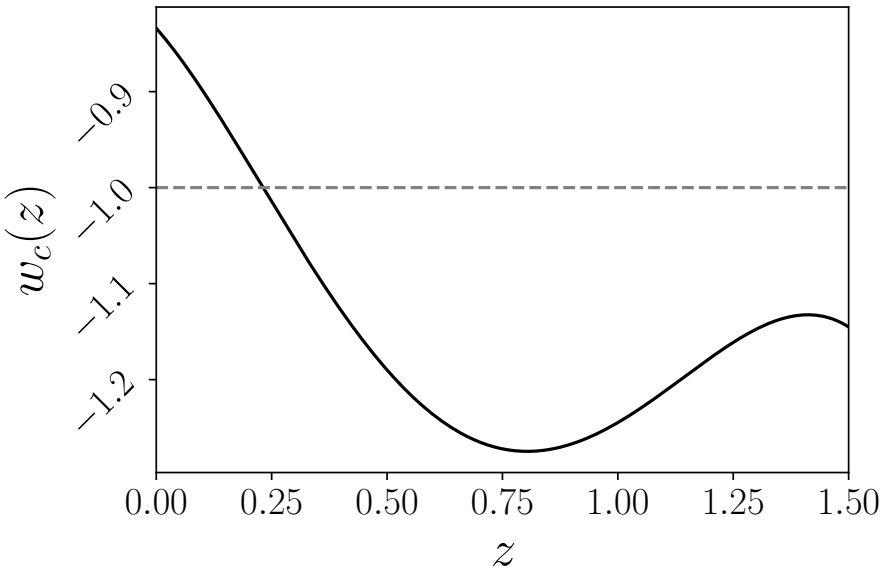
background expansion

Model Generalizes Across DE Models



Custom w(z)



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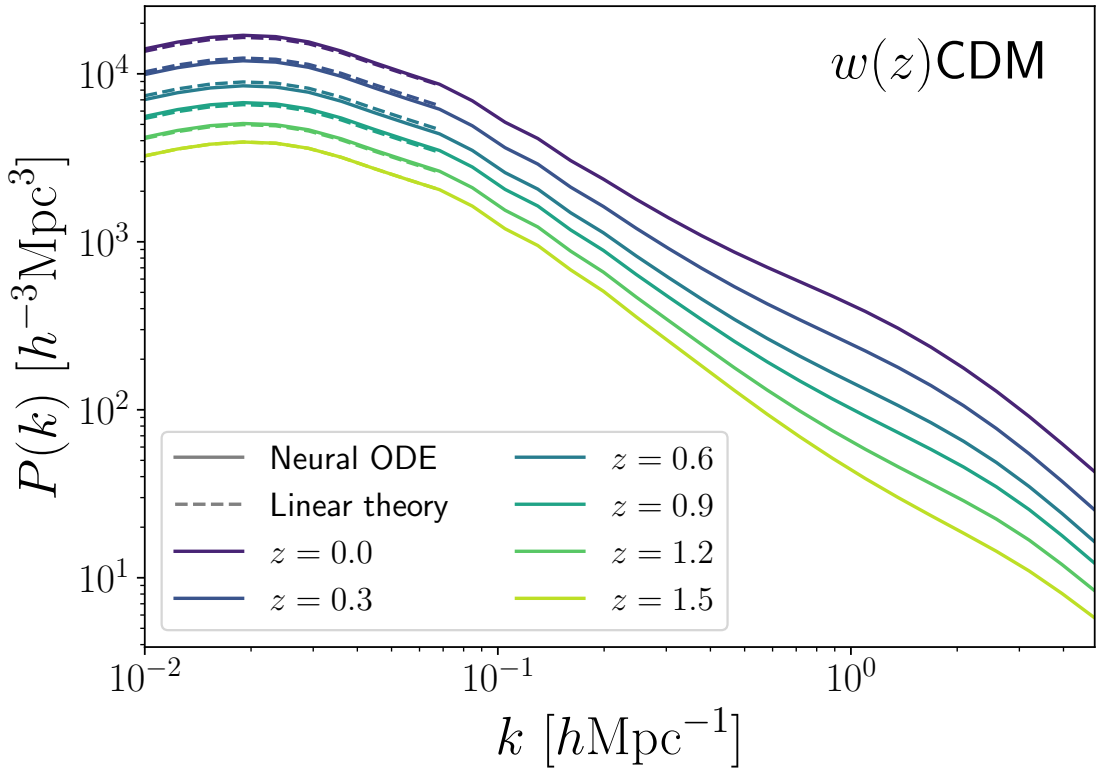
Structure Growth in For Custom w(z)



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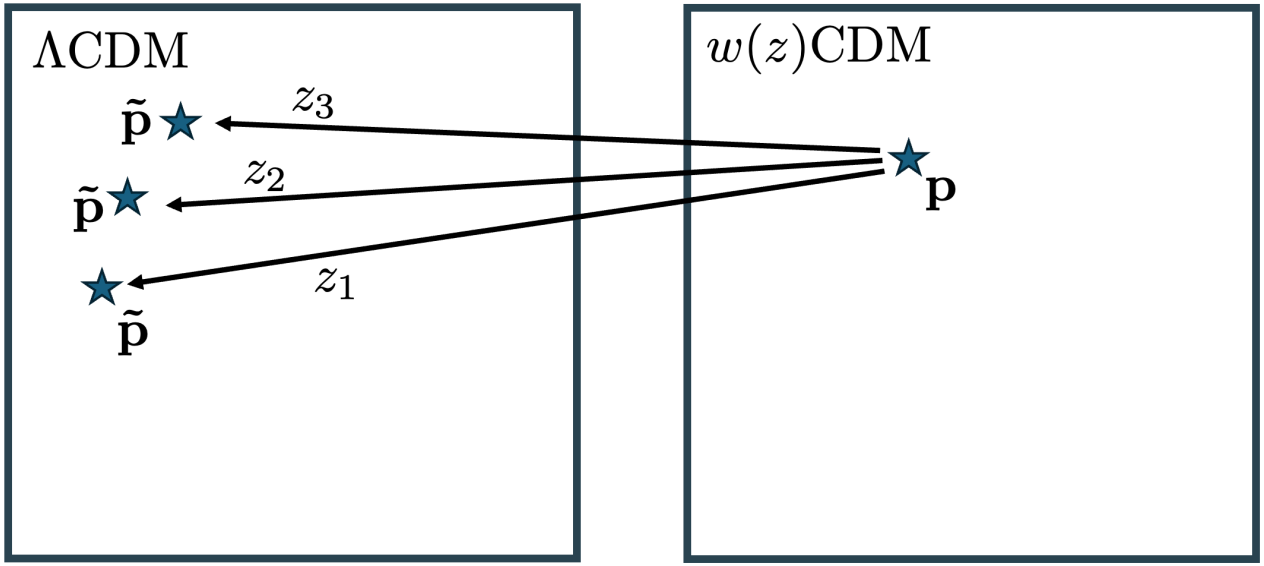
Conclusion

- **Structure growth provide additional constraining power on DE.**
- **Neural ODEs unlock structure growth across dynamical dark energy model space.**
- **Future Plans: Additional statistics + application to data.**

Extras

Model Generalizes Across DE Models



$$\bar{\rho}_m(\mathbf{p}), H(\mathbf{p}), P(k;\mathbf{p}) = \bar{\rho}_m(\tilde{\mathbf{p}}), H(\tilde{\mathbf{p}}), P(k;\tilde{\mathbf{p}})$$