Smooth sailing or ragged climb? — Increasing the robustness of power spectrum de-wiggling and ShapeFit parameter compression

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Les Houches - Dark Universe

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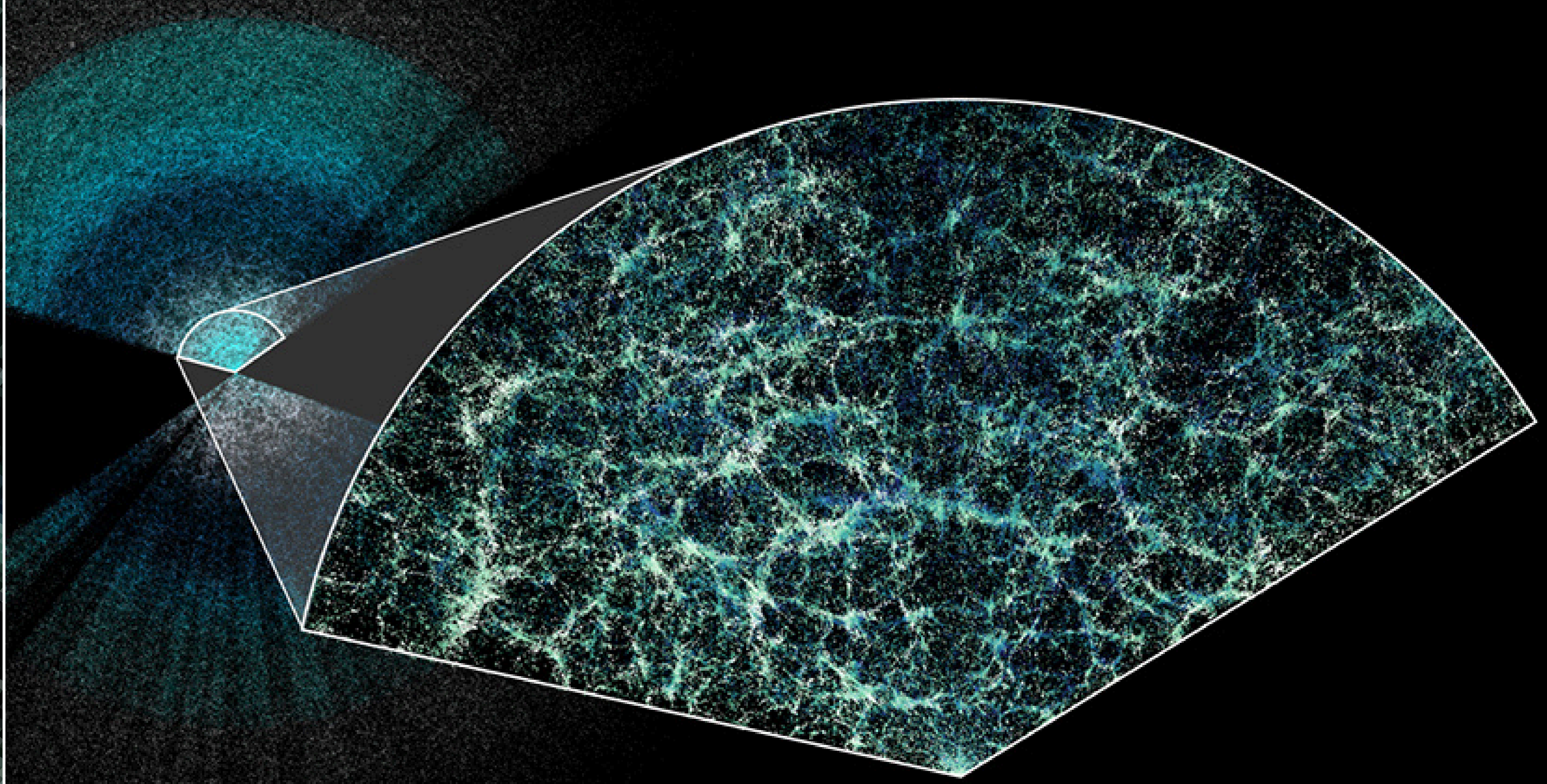
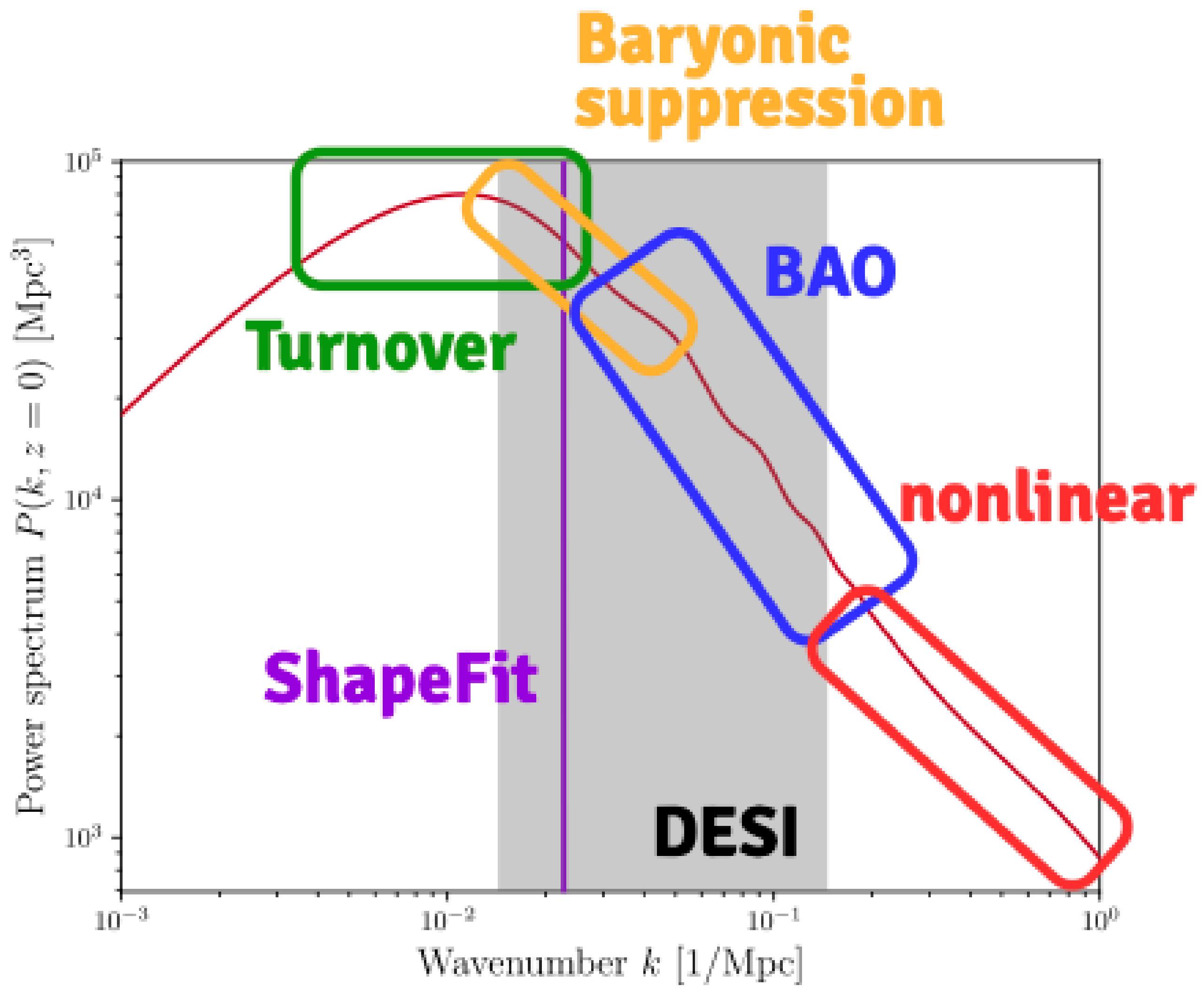


Credit: Claire Lamman/DESI collaboration

Outline

- Matter power spectrum
- Extracting information from power spectrum
- Goals of the project
- Results
- Conclusion
- Few words on cosmic voids



Matter Power Spectrum

Matter Power Spectrum

Fourier transform of the correlation function from galaxy surveys.

Amplitude

Baryonic Acoustic Oscillations (BAO)

Arise from the primordial sound waves.

Shape

Extracting information from power spectrum

Classic approach (BAO + RSD):

BAO + RSD, extracting $\alpha_{\parallel}$,$\alpha_{\perp}$, $f\sigma_8$ in a model independent way.

Full shape

Fits the whole power spectrum with EFT.

ShapeFit

It is an extension of the classic approach.

Compresses the broadband information in a scale-dependent slope, m.

The slope is senstive to matter-radiation equality and baryon suppression.

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- BAO, RSD,
- Template based,
- Uses BAO + amplitude of the power spectrum,
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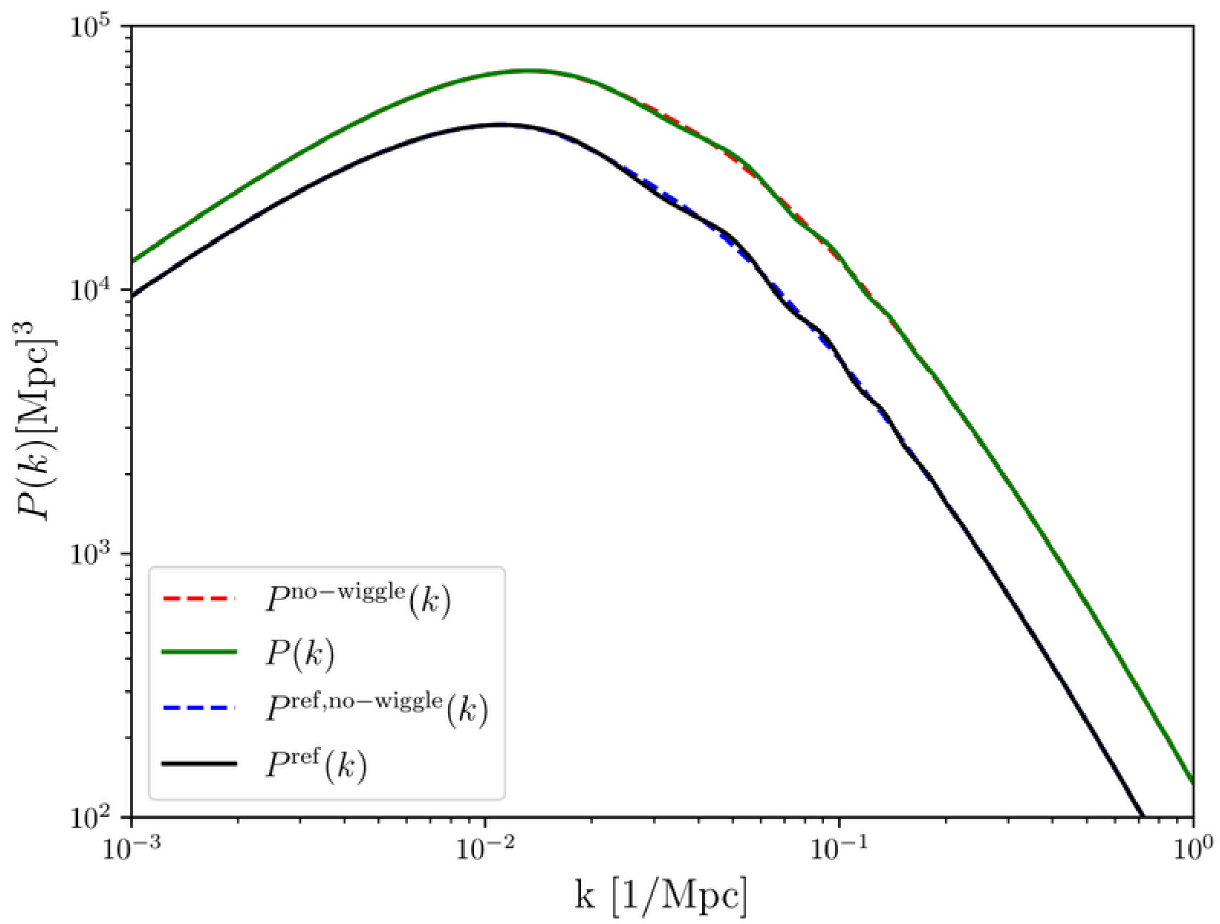
ShapeFit

- Compresses the broadband information in a scale-dependent slope, m.
- More model agnostic
- The constraints are almost as tight as full modelling.

Goals of the project

Extracting the shape of the power spectrum relies on two crucial steps:

1. Smoothing the power spectrum (thirteen different methods),
2. Calculating the derivative at a given wavenumber k_p.



Goal 1

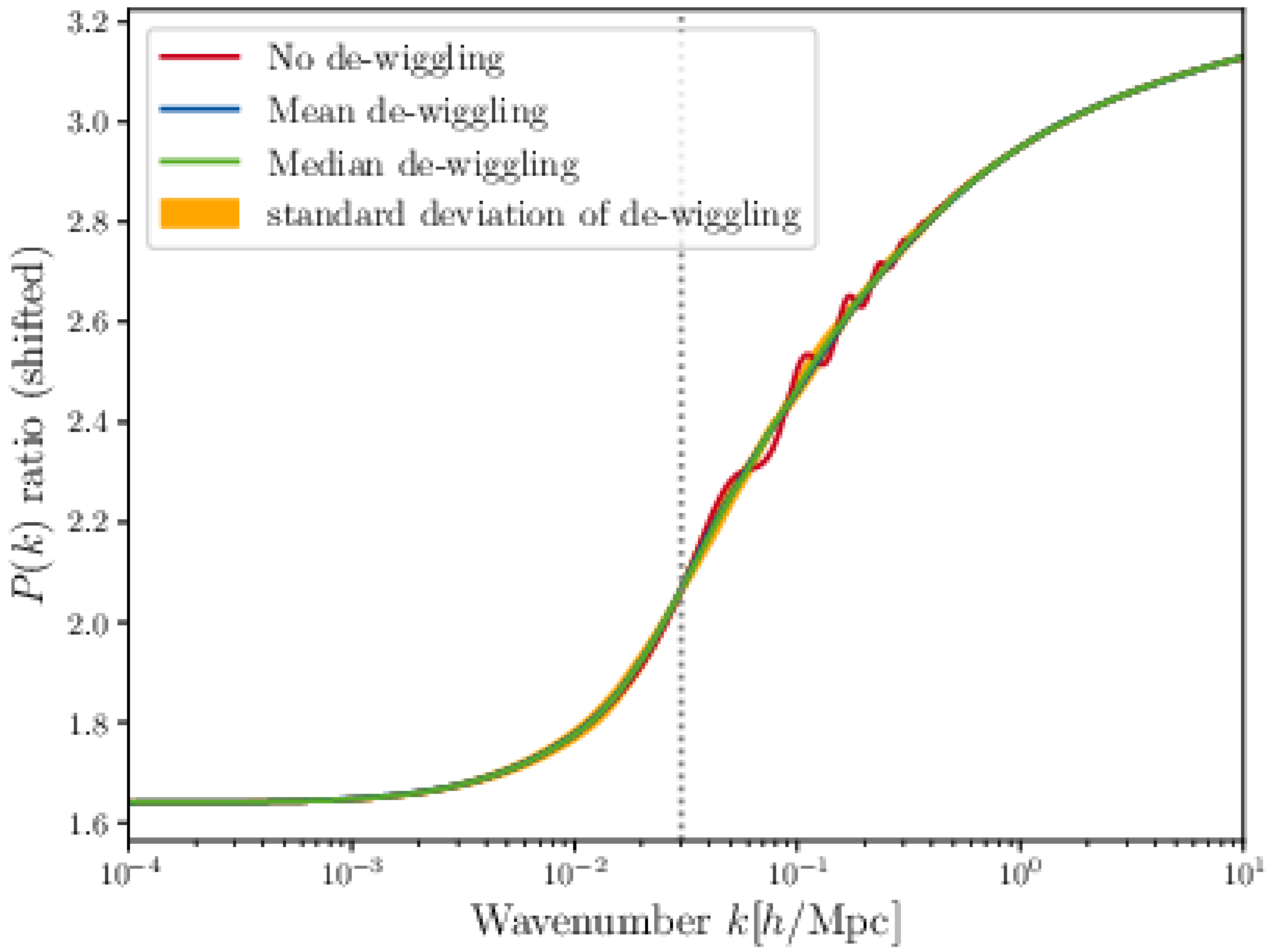
Compare and refine the robustness of methods for steps 1 and 2,

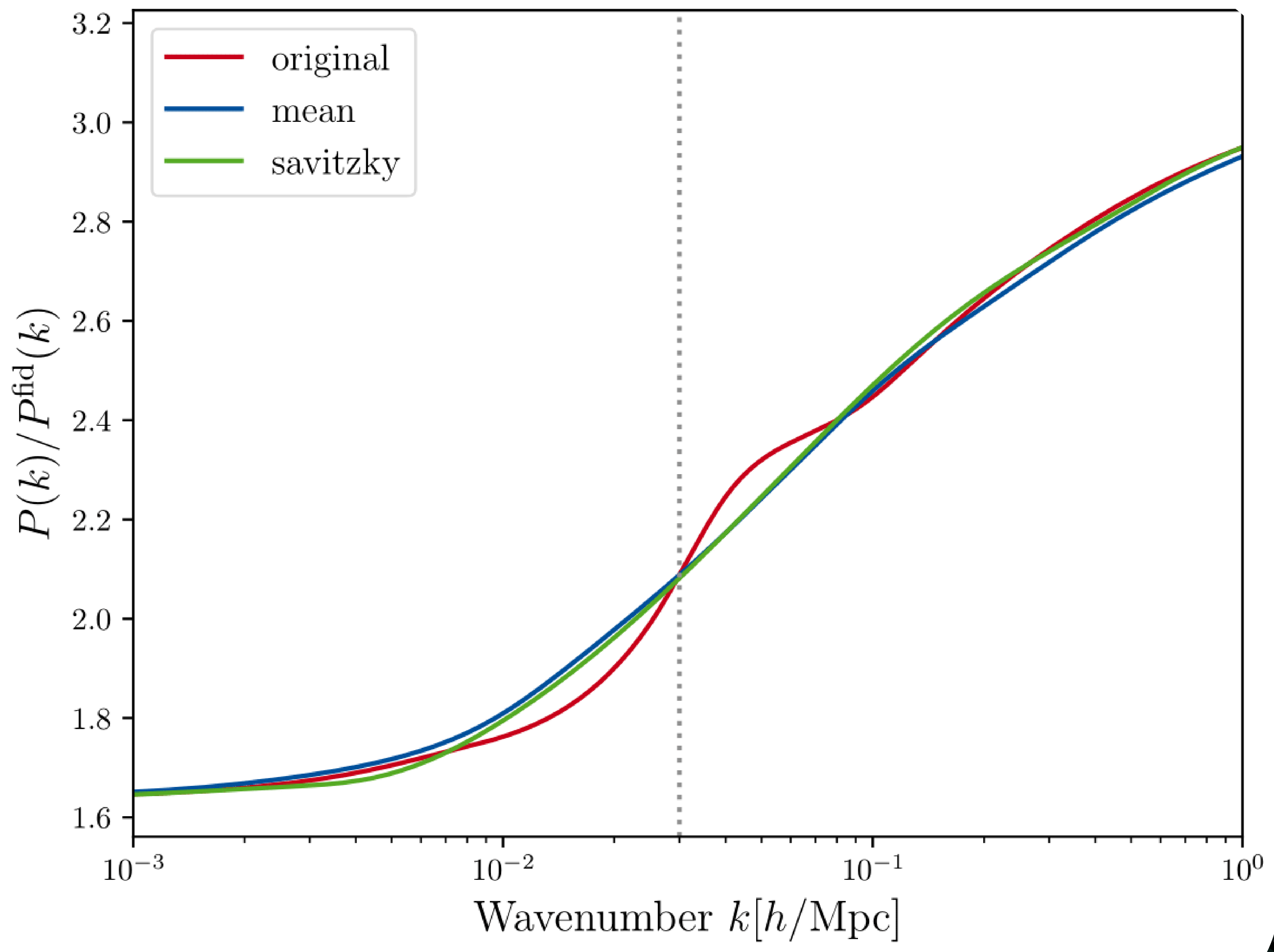
Goal 2

Compute the systematic error, and compare to statistical error of Dark Energy Spectroscopic Instrument (DESI).

The golden sample

Six of the de-wiggling methods which perform better for recovering the broadband shape in the full wavenumber range.





Post Processing filters

Differences between the smoothing methods are 1-5%.

Methods of further smoothing the de-wiggled power spectrum ratios were developed to obtain more consistent slope values.

Slope, m

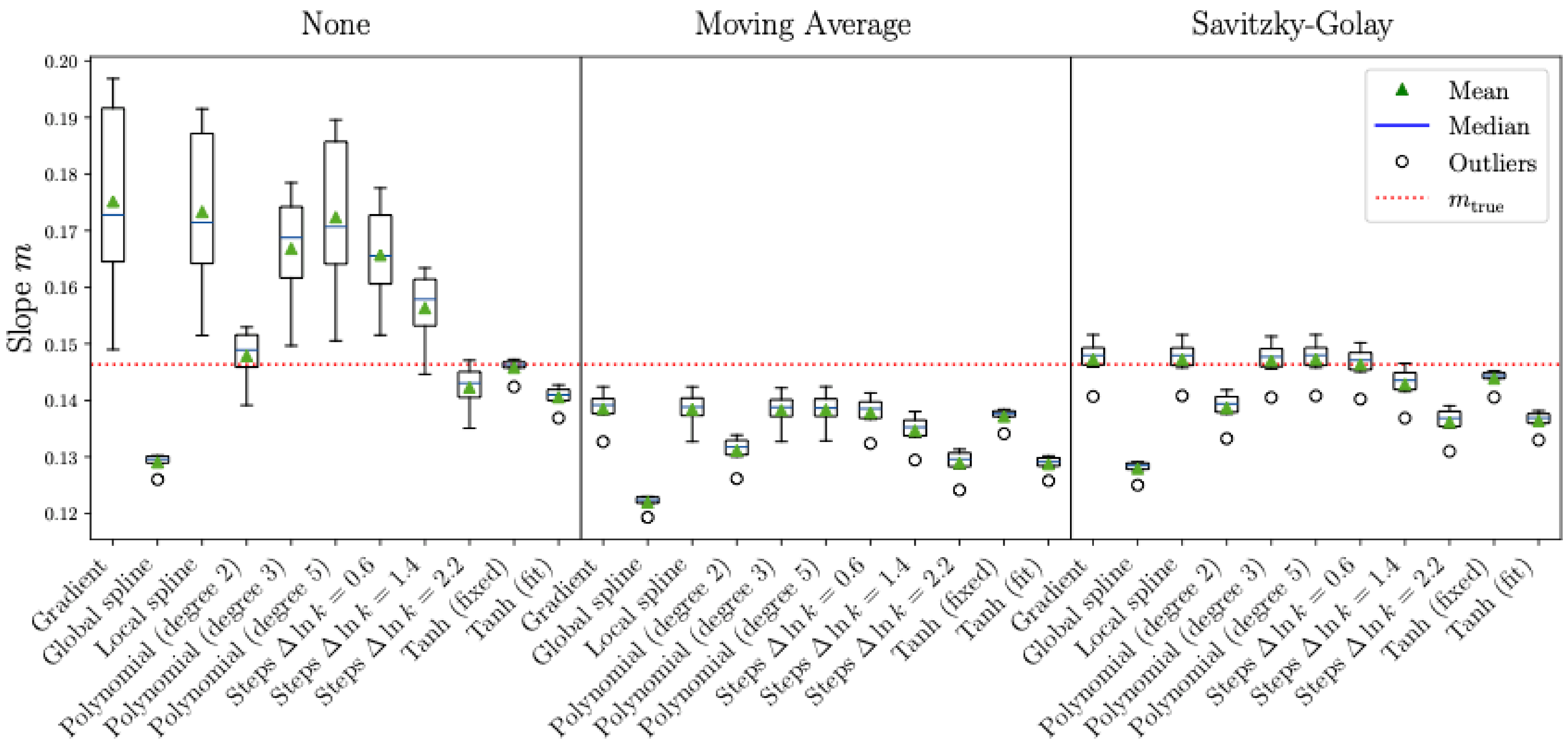
The ShapeFit parameter m can be computed as:

$$\mu = \frac{\partial ln(\frac{P_{lin}^{no-wiggle}(k/s)}{P_{lin}^{ref,no-wiggle}(k)})}{\partial lnk}\bigg|_{k=k_p} \equiv \frac{\partial lnR\left(k,s\right)}{\partial lnk}\bigg|_{k=k_p}$$

$$n = \frac{\partial ln\left(\frac{P_{prim}(k/s)}{P_{prim}^{ref}(k)}\right)}{\partial lnk}\bigg|_{k=k_p}$$

$$m = \mu - n$$

Calculating the slope



Testing for different cosmological models

Null tests

- Varying A_s
- Varying n_s
- Varying Ω_k
- Evolving dark energy

Different cosmological models

- Varying $\Omega_m h^2$, with fixed Ω_b/Ω_{cdm}
- Varying $\Omega_m h^2$, with fixed Ω_b
- Varying Σm_ν
- Varying N_{eff}
- Early dark energy

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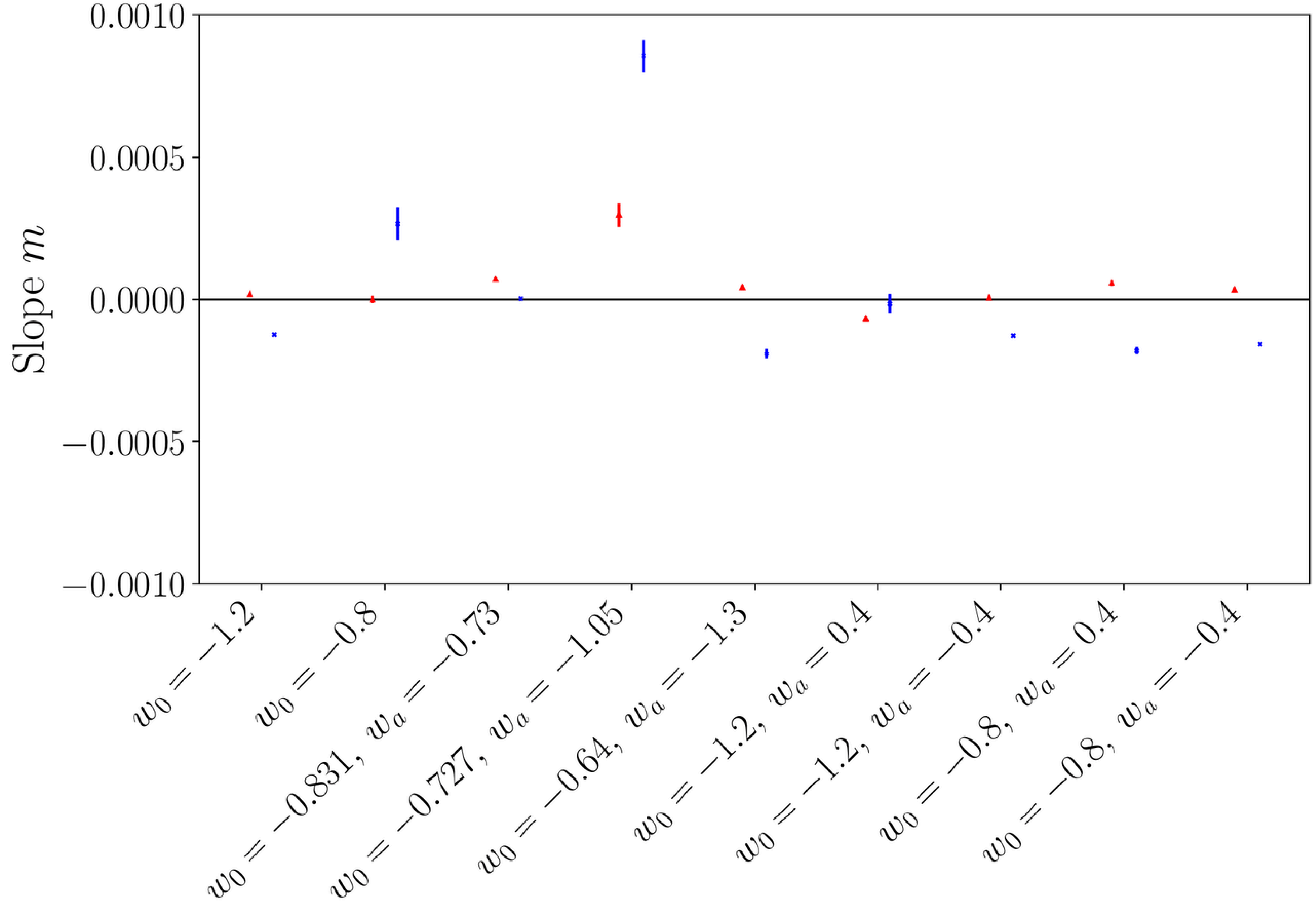

Evolving dark energy

The resulting slope m should be identically zero in null tests.

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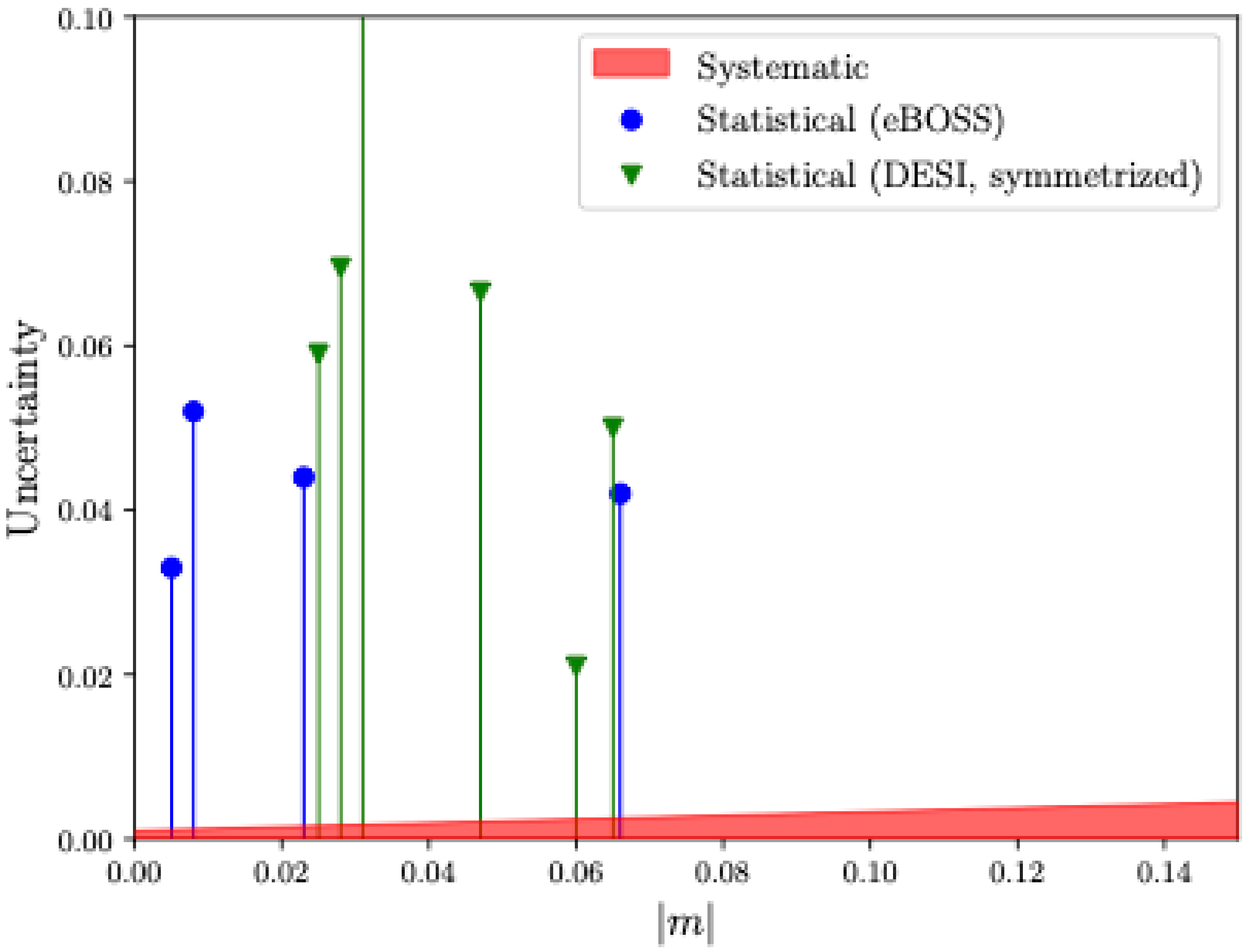
Systematic error

Systematic uncertainty:

$$\sigma_{m,syst} = 0.023|m| + 0.001$$

If the slope is obtained through the suggested steps described in the paper:

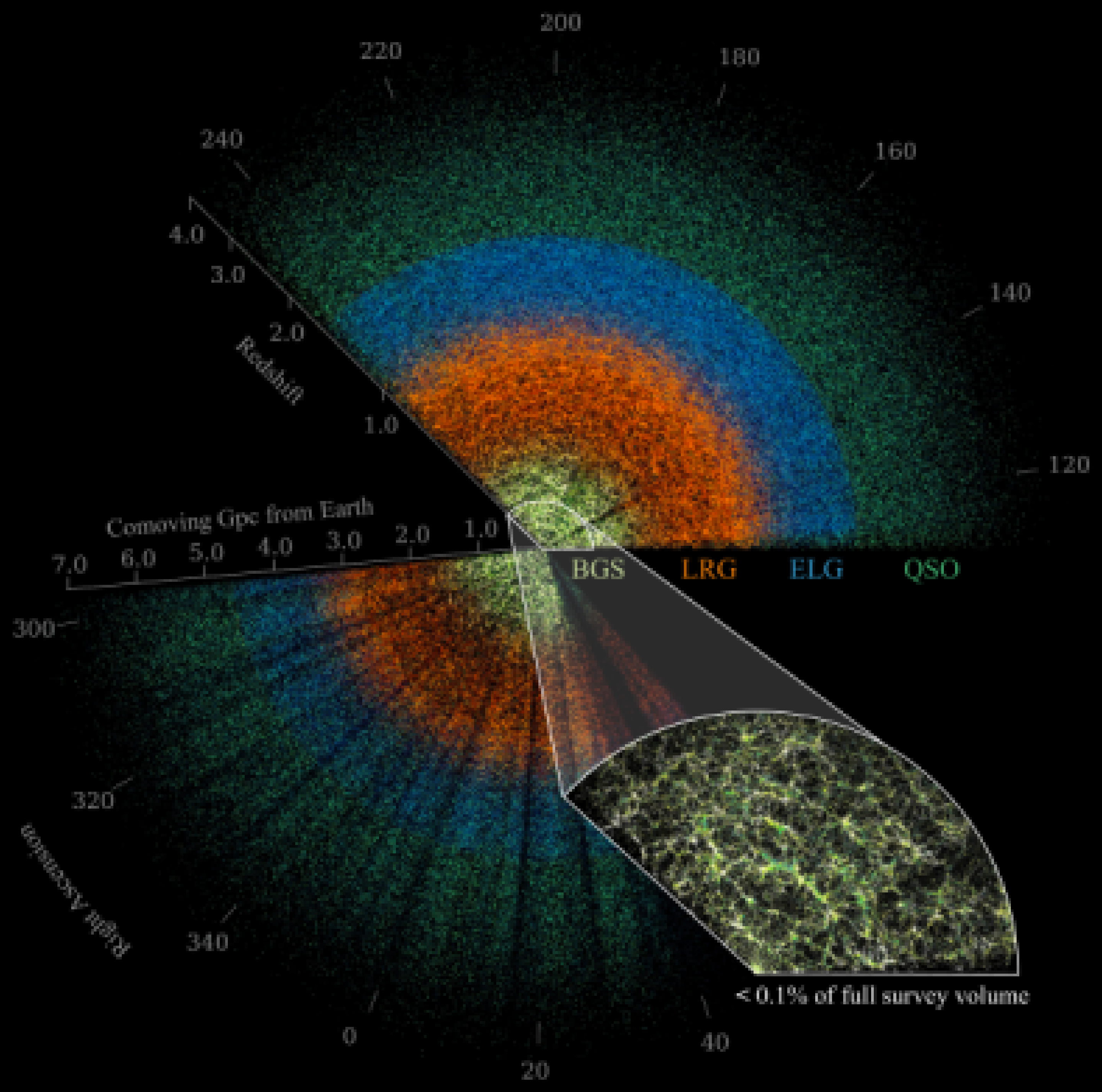
$$\sigma_{m,syst} = 0.011|m| + 0.001$$



Conclusions

- There is a roughly 1-2% level difference between different de-wiggling methods to be considered an inherent uncertainty.
- As long as the theory pipeline is consistent with the data analysis pipeline, there is no bias on the cosmological parameters.
- The systematic uncertainty $\sigma_{m,syst}$, is much smaller than current statistical uncertainties.

Read the paper!



Credit: Claire Lamman/DESI collaboration

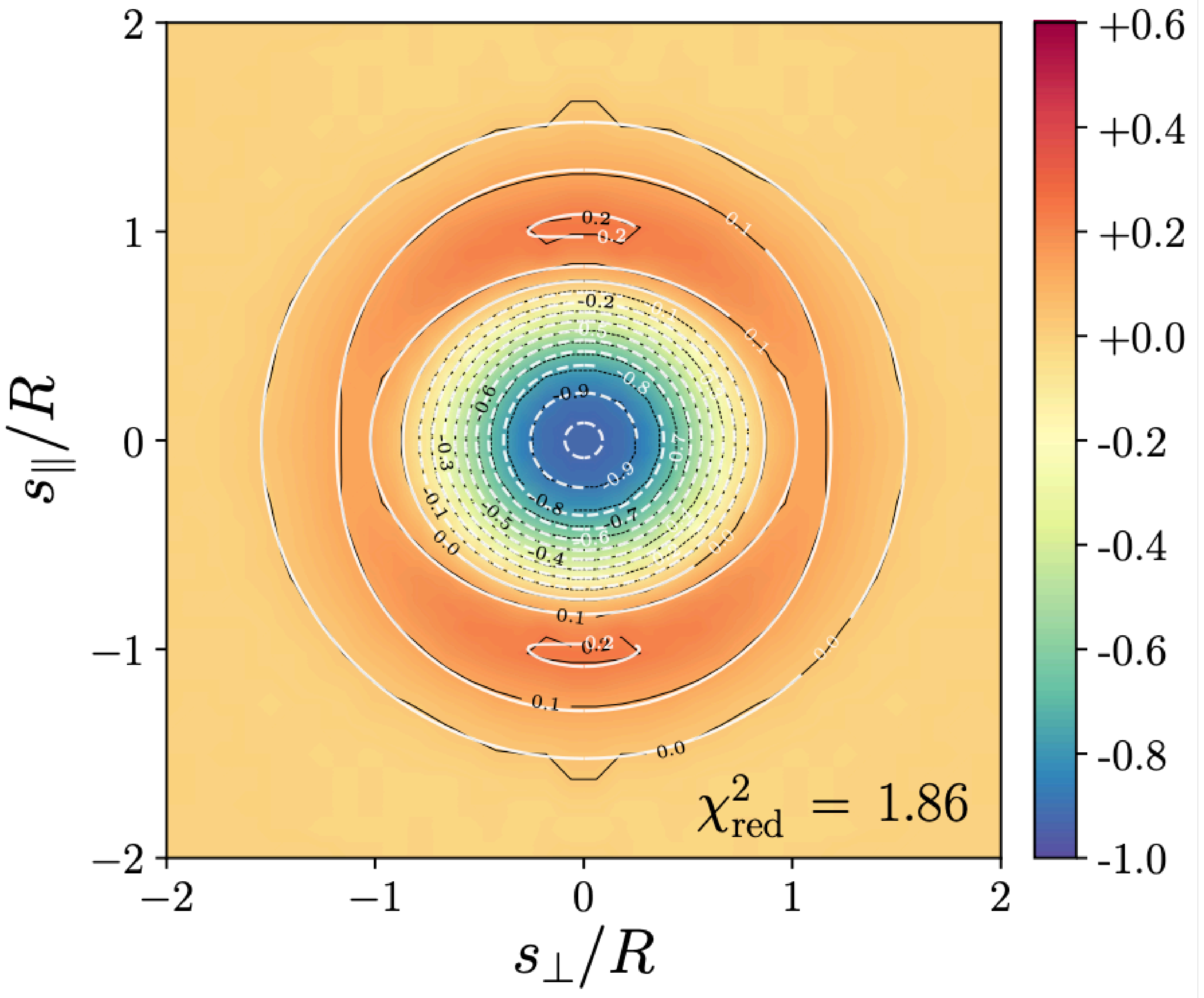
Cosmic Voids

Cosmic voids are large under-dense regions in the universe.

They are sensitive to structure growth, dark energy, modified gravity, sum of neutrino masses.

Therefore, they are promising to answer some of the cosmological mysteries.

Void-galaxy cross-correlation function



Credit: Hammaus et al 2020

Measures the probability of finding a galaxy at comoving distance r from the void center.

Current project in DESI:
Cosmological constraints from DESI Y3 void-galaxy cross-correlation function measurements in redshift space, first author.

STAY TUNED!

Thank you for your attention!

Method	$\Delta m/m$ (no post-proc.)	$\Delta m/m$ (moving average)	$\Delta m/m$ (Savitzky-Golay)
Gradient	0.197 ± 0.118	-0.053 ± 0.021	$\mathbf{0.006 \pm 0.023}$
Global spline	-0.118 ± 0.010	-0.167 ± 0.009	-0.126 ± 0.010
Local spline	0.185 ± 0.099	-0.054 ± 0.021	$\mathbf{0.006 \pm 0.023}$
Polynomial (degree 2)	$\mathbf{0.011 \pm 0.032}$	-0.104 ± 0.017	-0.052 ± 0.019
Polynomial (degree 3)	0.140 ± 0.067	-0.055 ± 0.021	$\mathbf{0.005 \pm 0.023}$
Polynomial (degree 5)	0.178 ± 0.096	-0.055 ± 0.021	$\mathbf{0.006 \pm 0.023}$
Steps $\Delta \ln k = 0.6$	0.132 ± 0.061	-0.058 ± 0.020	$\mathbf{0.000 \pm 0.022}$
Steps $\Delta \ln k = 1.4$	0.068 ± 0.044	-0.080 ± 0.019	-0.024 ± 0.021
Steps $\Delta \ln k = 2.2$	-0.028 ± 0.027	-0.119 ± 0.017	-0.069 ± 0.018
Tanh (fixed)	$\mathbf{-0.004 \pm 0.011}$	-0.063 ± 0.010	-0.017 ± 0.011
Tanh (fit)	-0.039 ± 0.013	-0.120 ± 0.010	-0.068 ± 0.012

Relative m deviation with respect to m_{true}, and its scatter across the different dewiggling algorithms.

Back-up slides

Calculating the systematic error

m_{true} is set to the median of tanh (fixed) method.

This method is robust to dewiggling methods and suitable for cosmological inference.

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