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


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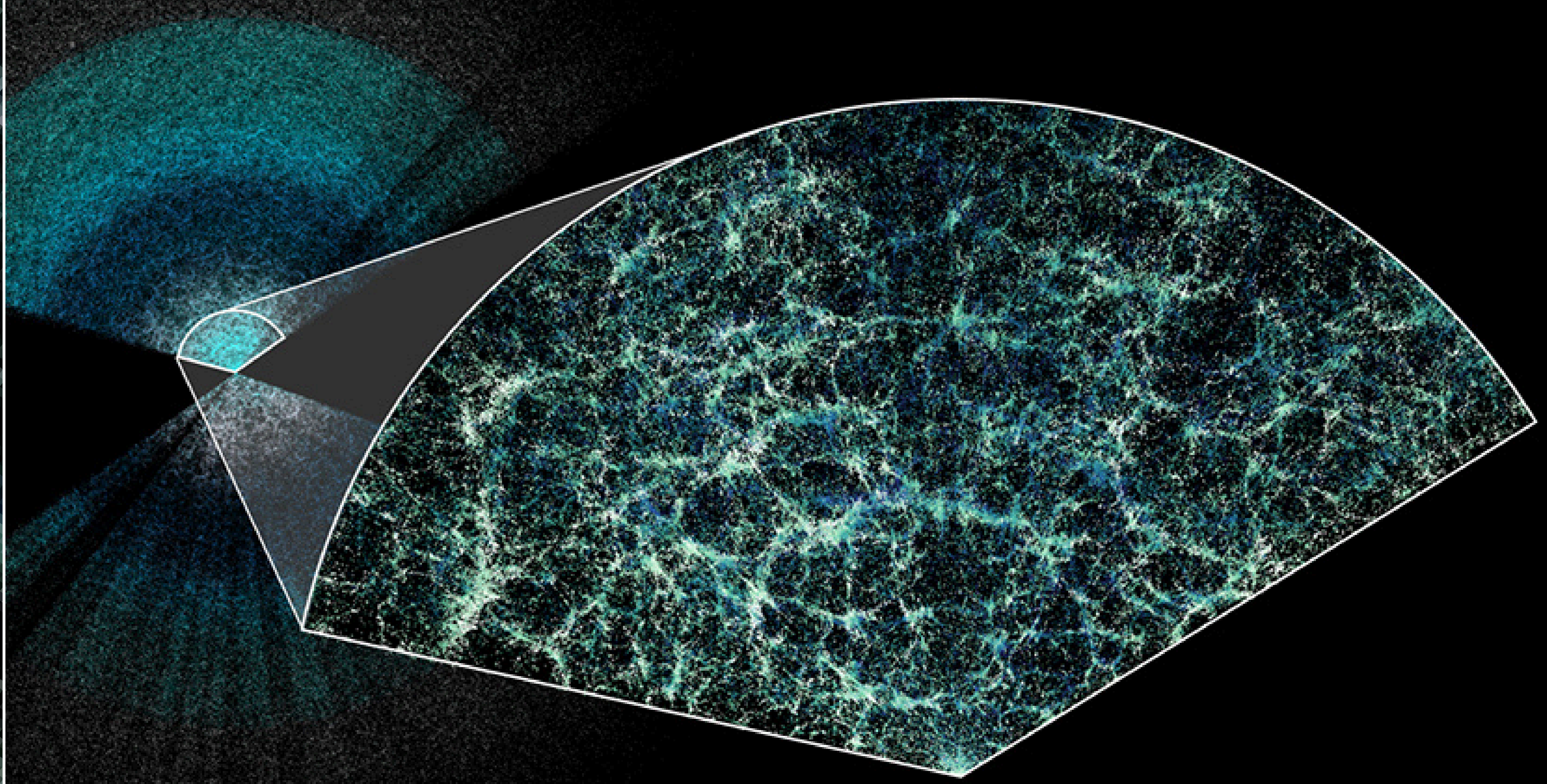
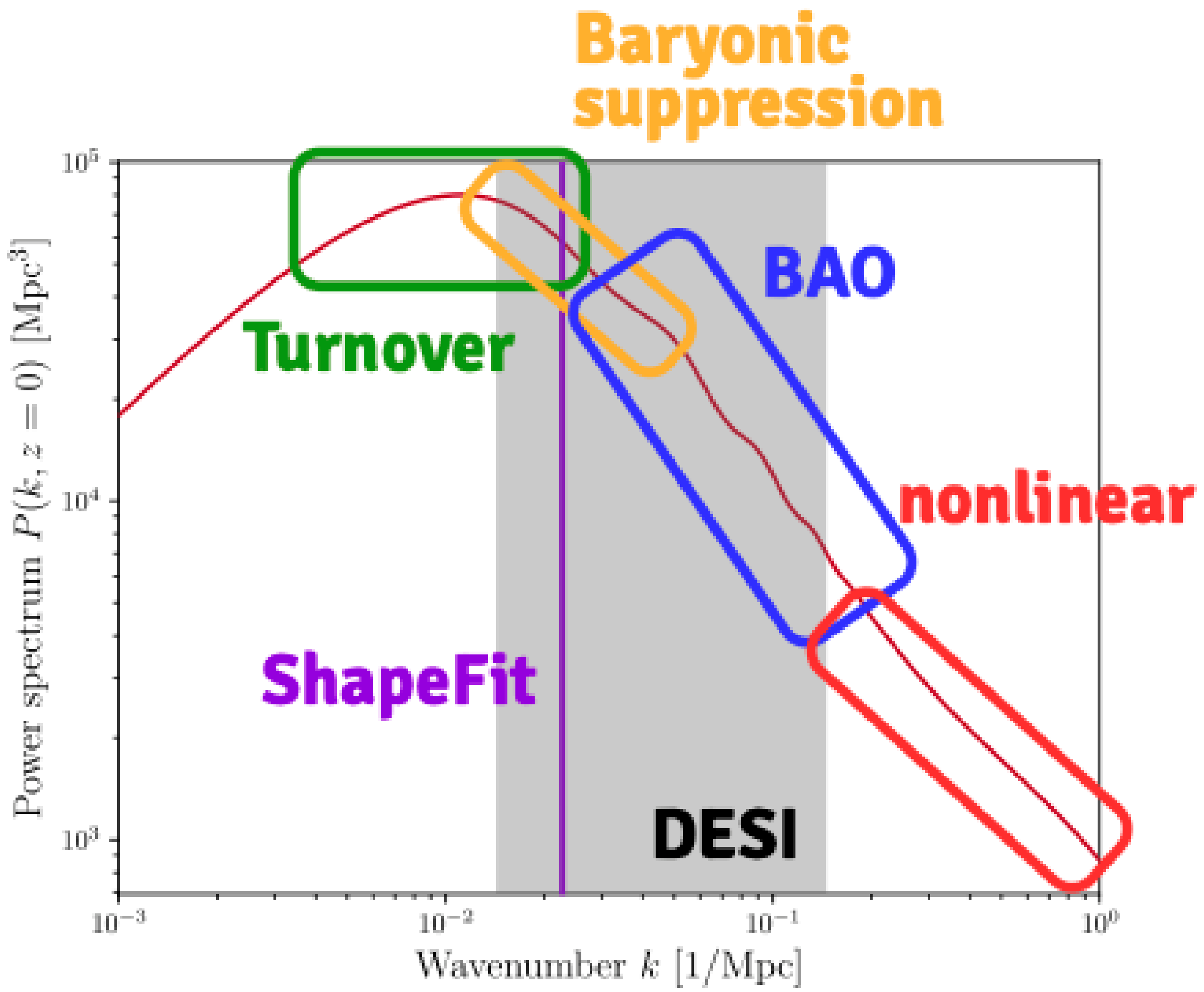
CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM



Credit: Claire Lamman/DESI collaboration

# Outline

- Matter power spectrum
- Extracting information from power spectrum
- Goals of the project
- Obtaining m
- Systematic error budget
- 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

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# 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.

# Classic Approach

- BAO, RSD,
- Template based,
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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.

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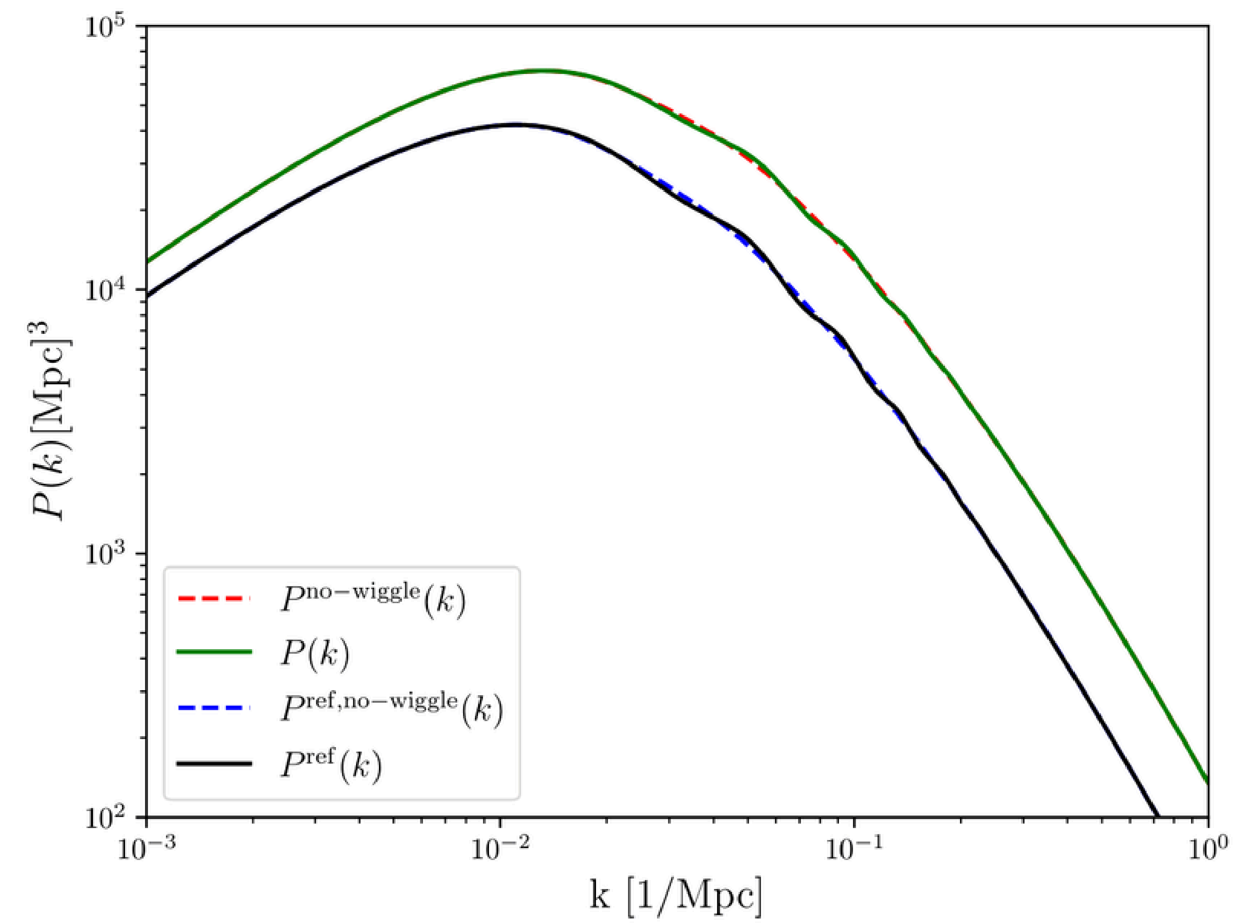
# Goals of the project

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

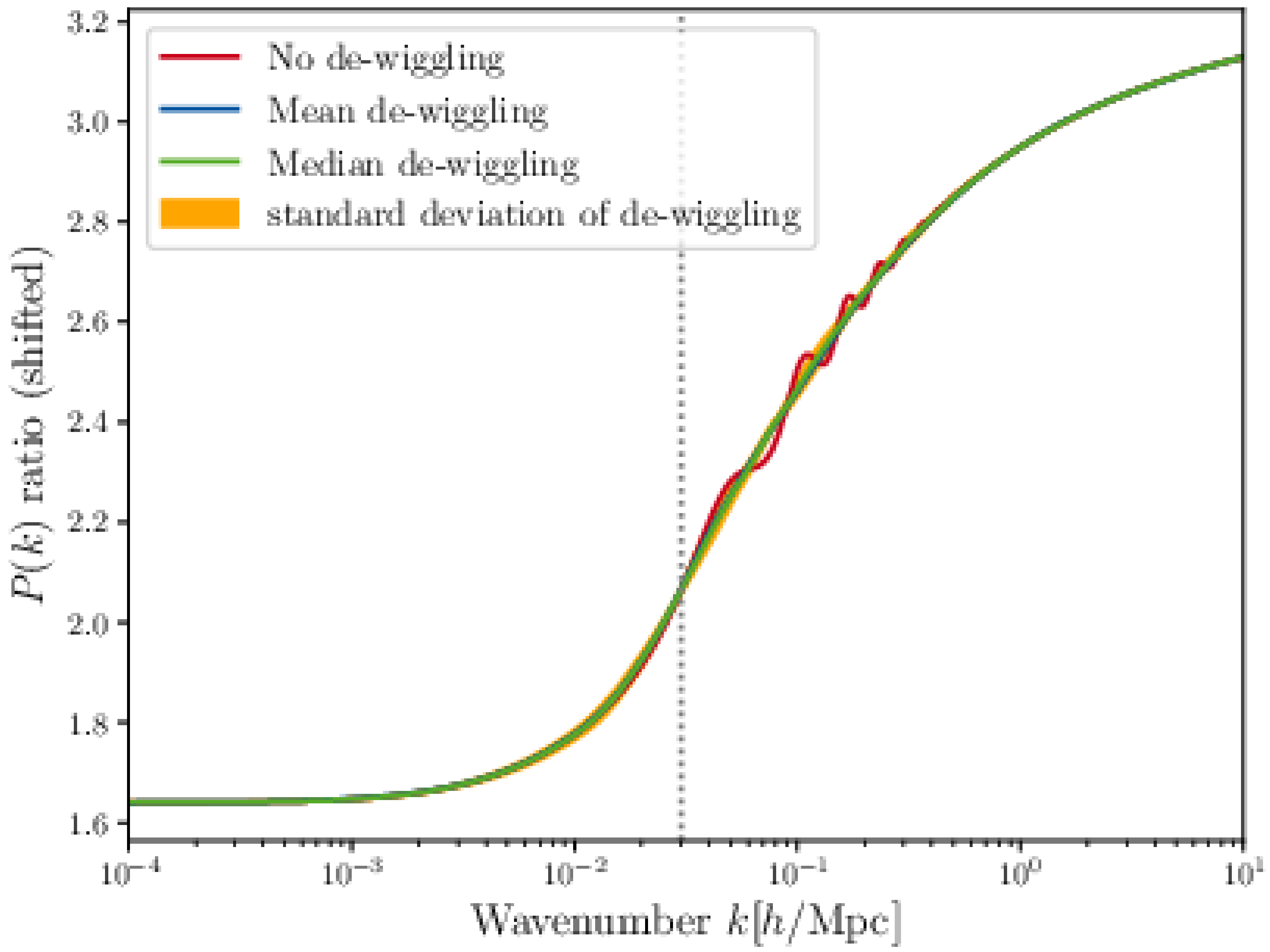
Compare and refine the robustness of methods for steps 1 and 2,

## 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.

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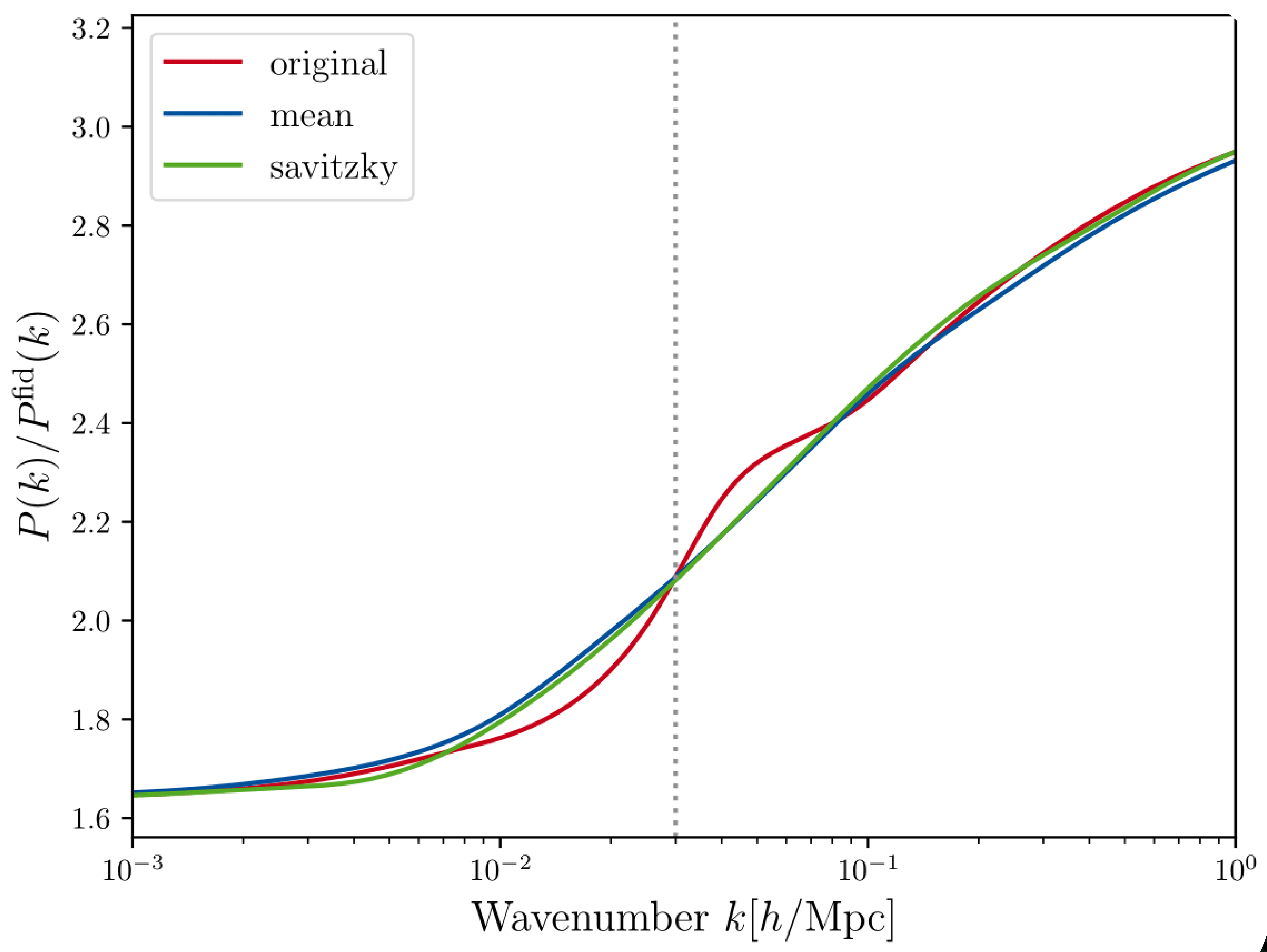


# Post Processing filters

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.

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# Slope, m

The ShapeFit parameter m can be computed as:

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

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

$$m = \mu - n$$

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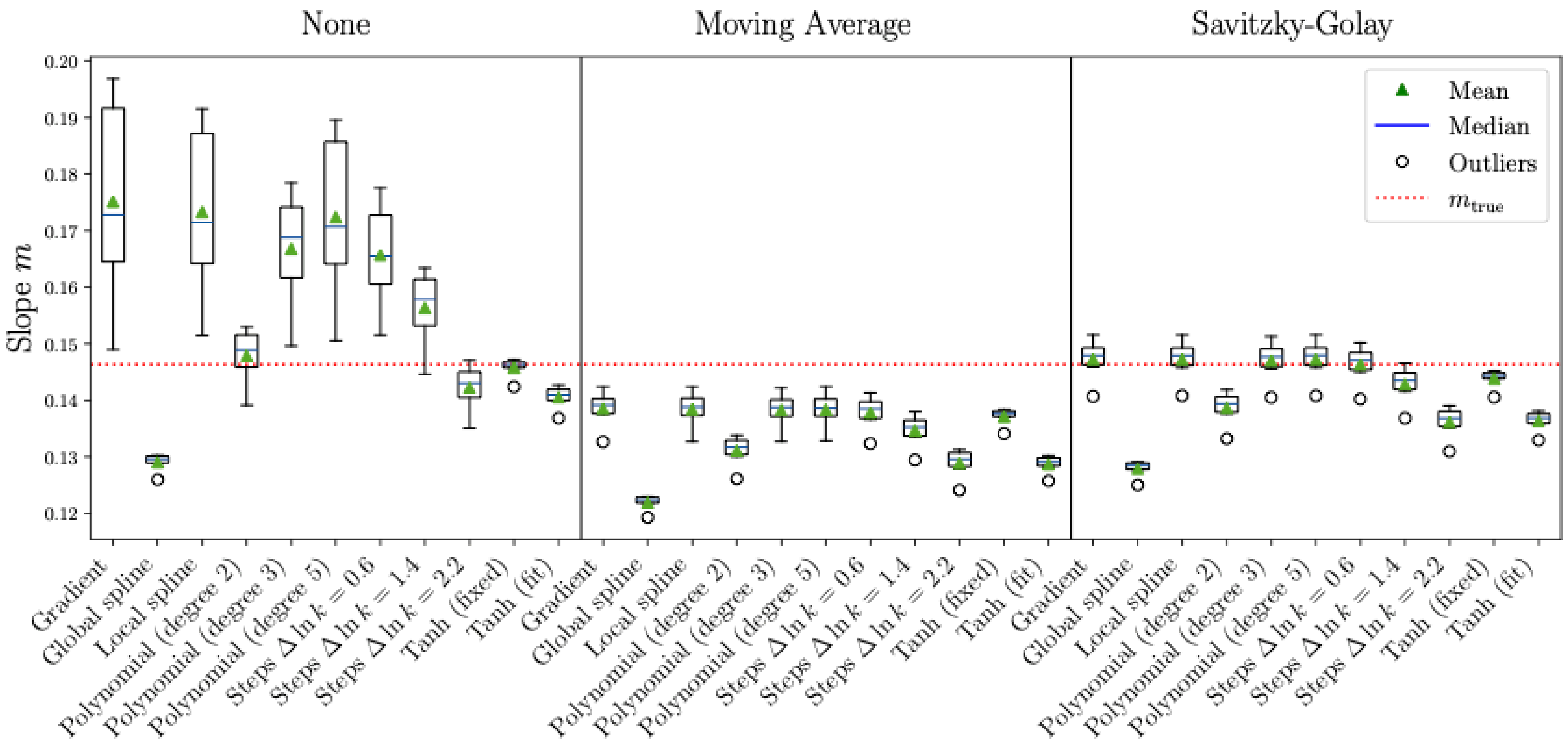
# Calculating the slope

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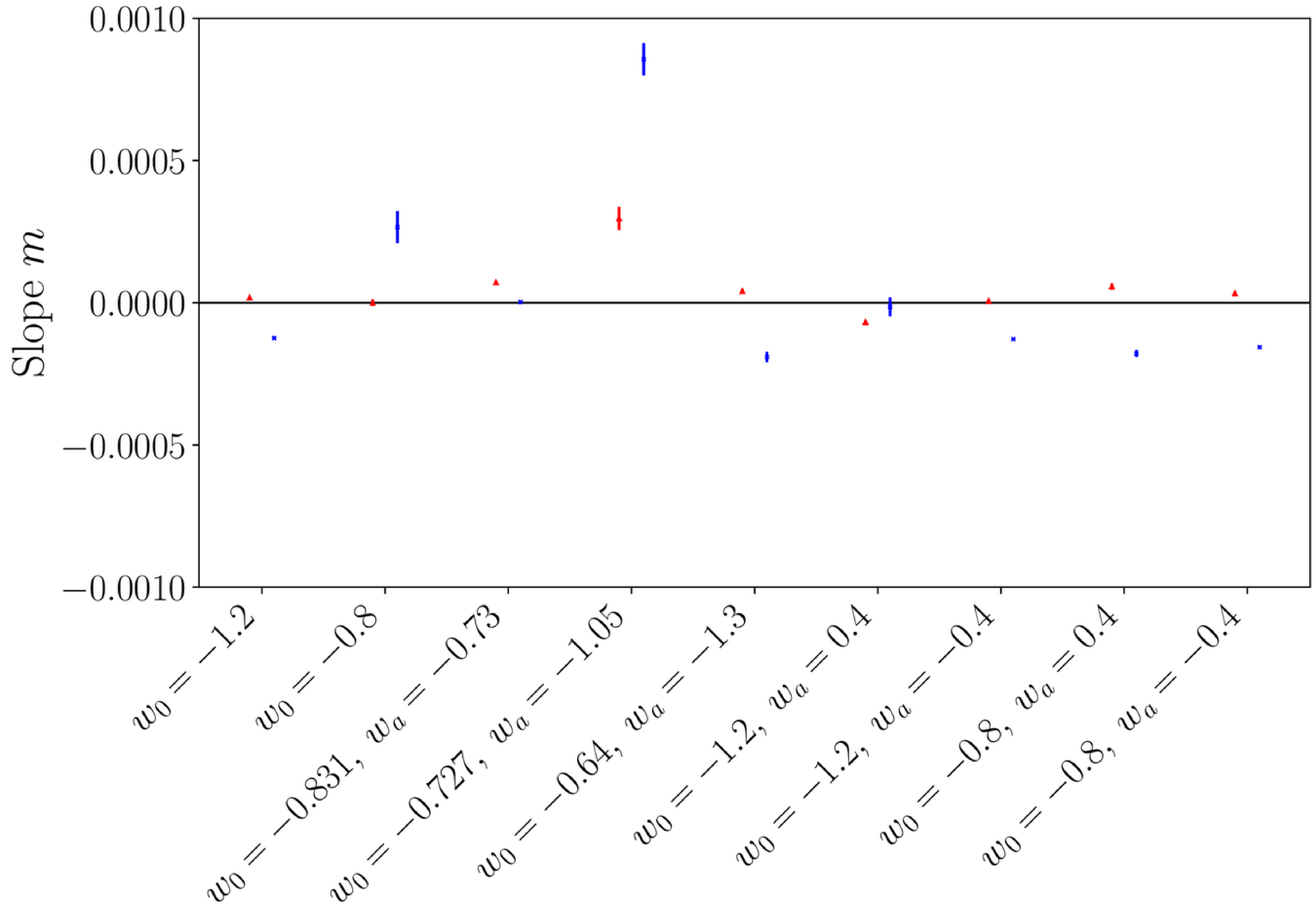
# Testing for different cosmological models

## Null tests

- Varying $A_s$
- Varying $n_s$
- Varying $\Omega_k$
- Evolving dark energy

## Different cosmological models

- Varying $\Omega_m h^2$, with fixed $\Omega_b/\Omega_{cdm}$
- Varying $\Omega_m h^2$, with fixed $\Omega_b$
- Varying $\Sigma m_\nu$
- Varying $N_{eff}$
- Early dark energy




# Evolving dark energy

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

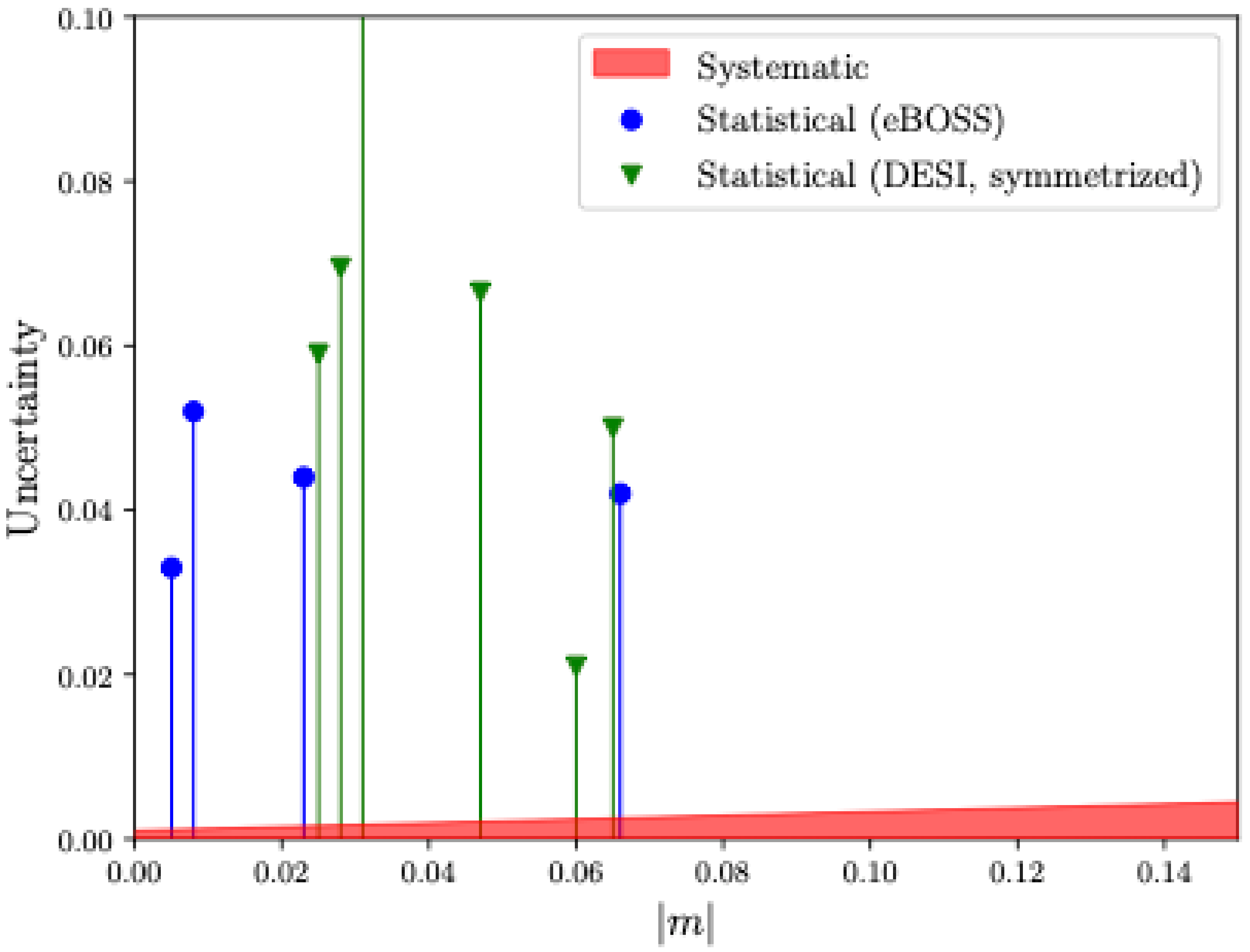
# Systematic error

Systematic uncertainty:

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

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

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

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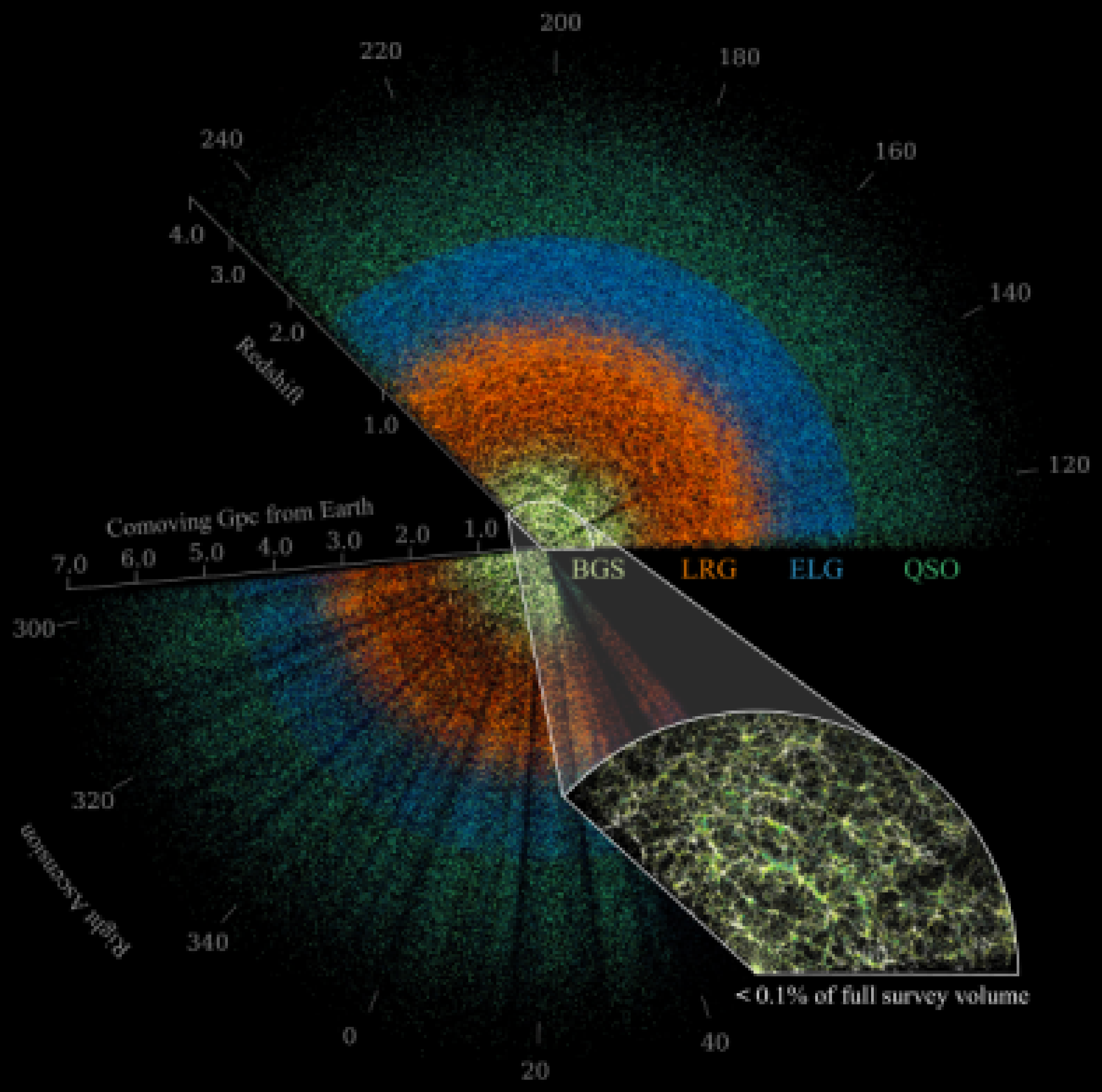
# Conclusions

- 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!



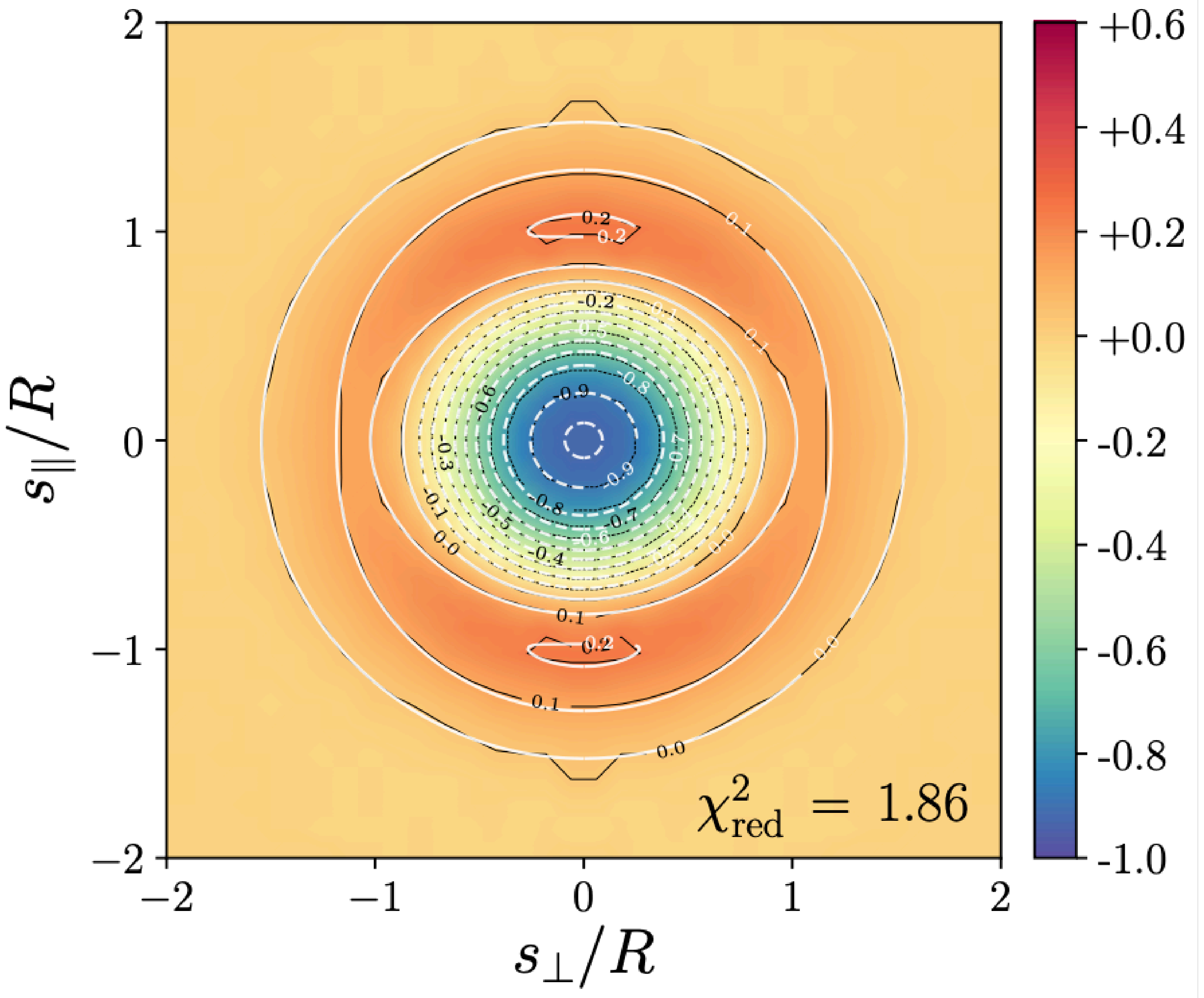

Credit: Claire Lamman/DESI collaboration

# 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.




Credit: Hammaus et al 2020

# Void-galaxy cross-correlation function

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

Leading the paper on:
Cosmological constraints from DESI Y3 void-galaxy cross-correlation function measurements in redshift space.

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 | $0.197 \pm 0.118$ | $-0.053 \pm 0.021$ | $\mathbf{0.006 \pm 0.023}$ |
| Global spline | $-0.118 \pm 0.010$ | $-0.167 \pm 0.009$ | $-0.126 \pm 0.010$ |
| Local spline | $0.185 \pm 0.099$ | $-0.054 \pm 0.021$ | $\mathbf{0.006 \pm 0.023}$ |
| Polynomial (degree 2) | $\mathbf{0.011 \pm 0.032}$ | $-0.104 \pm 0.017$ | $-0.052 \pm 0.019$ |
| Polynomial (degree 3) | $0.140 \pm 0.067$ | $-0.055 \pm 0.021$ | $\mathbf{0.005 \pm 0.023}$ |
| Polynomial (degree 5) | $0.178 \pm 0.096$ | $-0.055 \pm 0.021$ | $\mathbf{0.006 \pm 0.023}$ |
| Steps $\Delta \ln k = 0.6$ | $0.132 \pm 0.061$ | $-0.058 \pm 0.020$ | $\mathbf{0.000 \pm 0.022}$ |
| Steps $\Delta \ln k = 1.4$ | $0.068 \pm 0.044$ | $-0.080 \pm 0.019$ | $-0.024 \pm 0.021$ |
| Steps $\Delta \ln k = 2.2$ | $-0.028 \pm 0.027$ | $-0.119 \pm 0.017$ | $-0.069 \pm 0.018$ |
| Tanh (fixed) | $\mathbf{-0.004 \pm 0.011}$ | $-0.063 \pm 0.010$ | $-0.017 \pm 0.011$ |
| Tanh (fit) | $-0.039 \pm 0.013$ | $-0.120 \pm 0.010$ | $-0.068 \pm 0.012$ |

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.