Redshift-space distortion analysis from the DR14 eBOSS quasar sample in Fourier space

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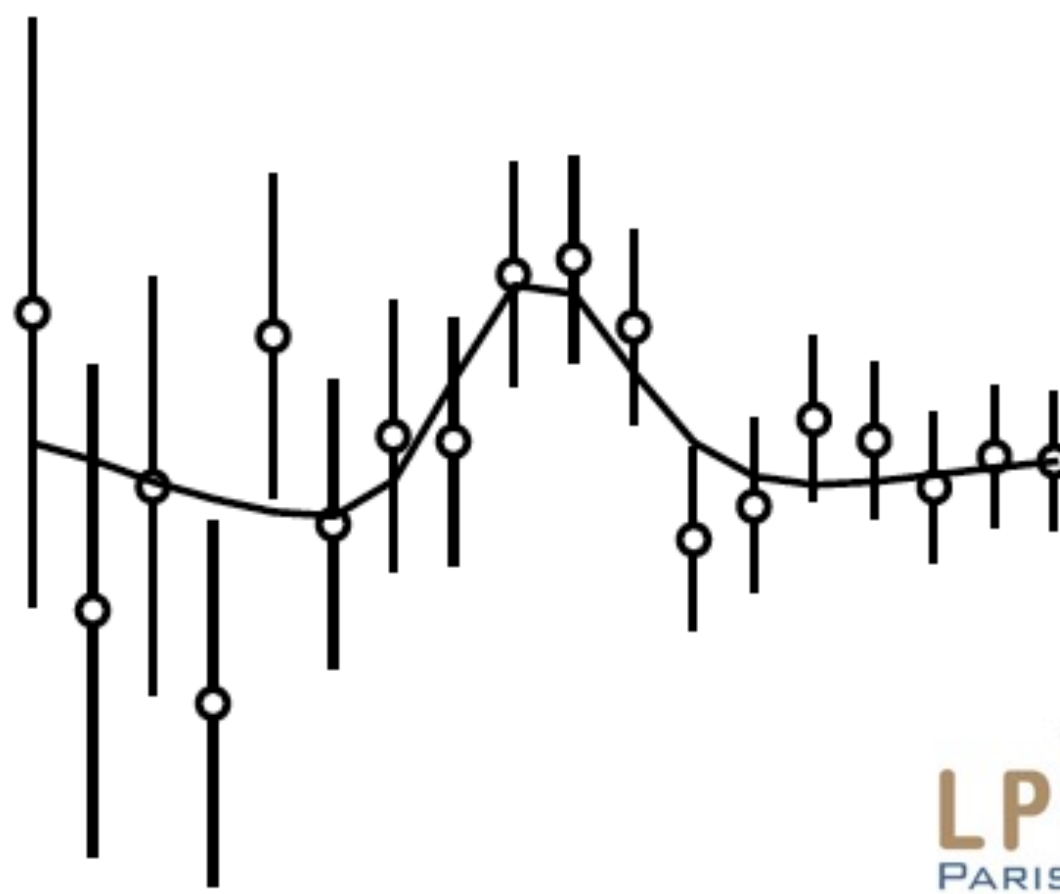
Statistical challenges for large-scale structure in the era of LSST

Oxford, 20th April 2018

Based on HGM et al. 2018, arXiv:1801.02689



BAO & RSD Papers on DR14Q

This talk

RSD - Full Shape

- Gil-Marín et al. 18 (RSD in Fourier space)
- Hou et al. 18 (RSD in config. Space)
- Zarrouk et al. 18 (RSD in conf. space)

→ $f\sigma_8(z_{eff})$, $H(z_{eff})$, $D_A(z_{eff})$

- Ruggeri et al. 18 (z-weighting RSD in Fourier Space)
- Zhao et al. 18 (z-weighting RSD in Fourier Space)

→ $f\sigma_8(0.8<z<2.2)$, $H(0.8<z<2.2)$, $D_A(0.8<z<2.2)$

BAO

- Ata et al. 18 (BAO isotropic, Fourier & conf. space) → $D_V(z_{eff})$
- Wang et al. 18 (z-weighting BAO in Fourier space)
- Zhu et al. 18 (z-weighting BAO in conf. space)

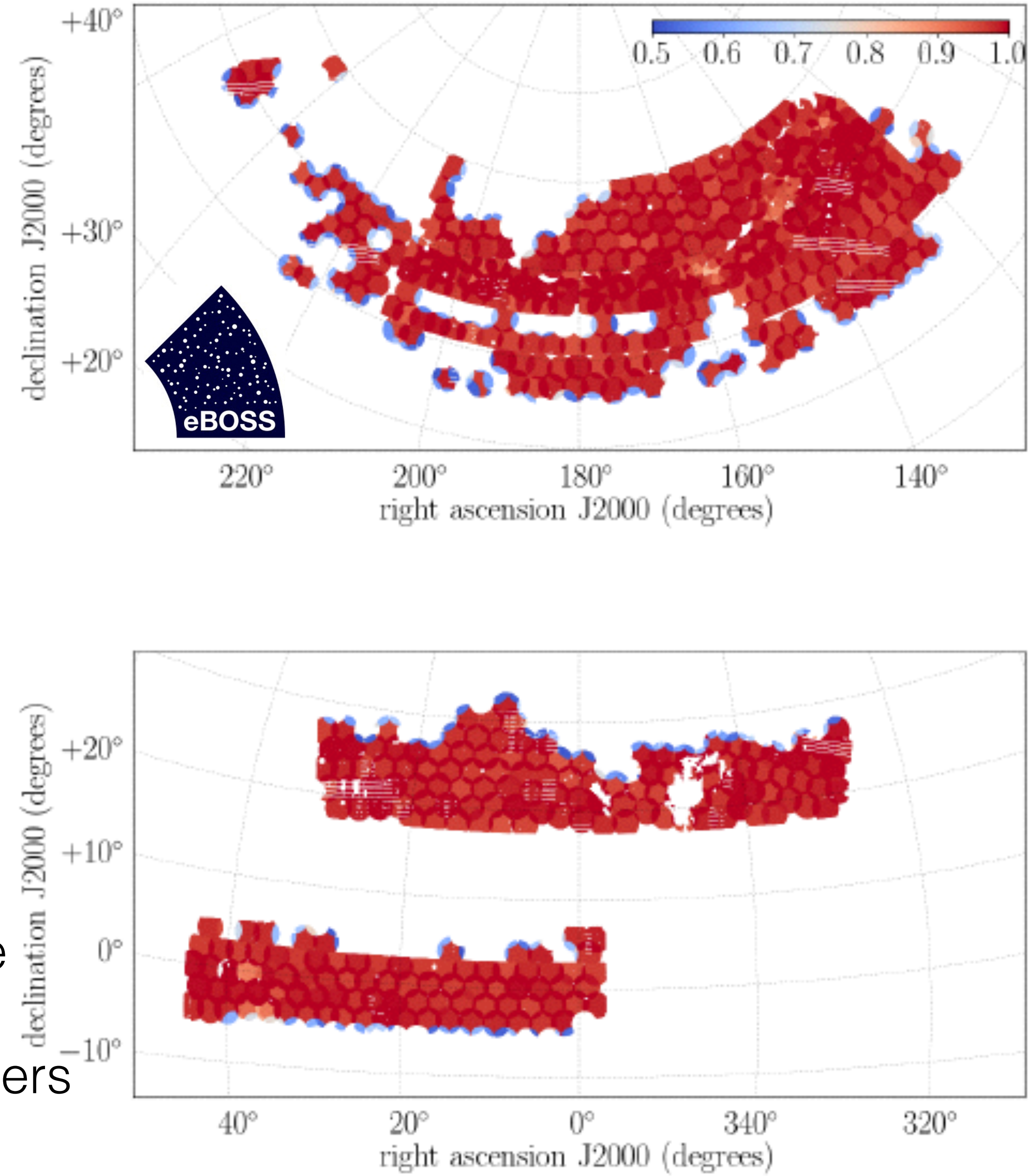
→ $D_V(\ 0.8<z<2.2\ )$

eBOSS in a nutshell

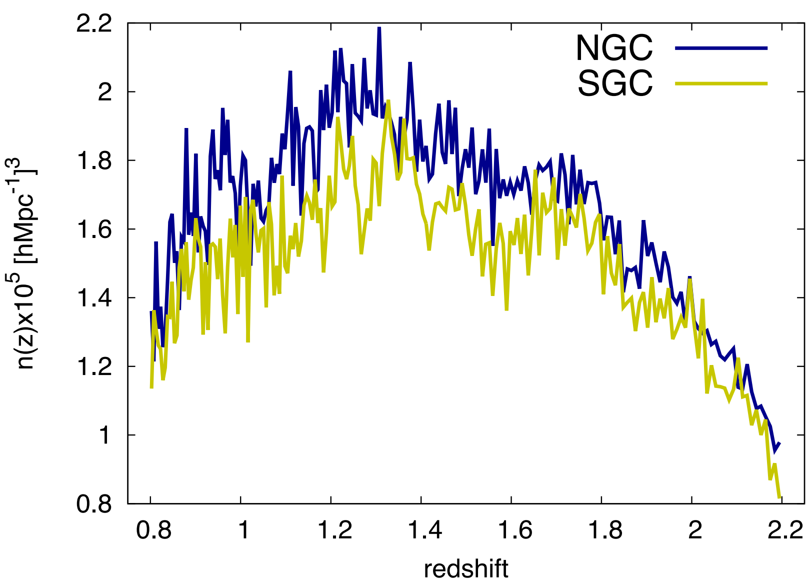
extended **B**aryon **O**scillation **S**pectroscopic **S**urvey

- Part of SDSS-IV collaboration
- Spectroscopic survey: σ_z~0.001
- Apache Point Telescope 2.5m
- 2014 - 2019 observing LRGs, ELGs, quasars + Lya
- 1000fibres per plate (~7deg^2)
- 1000 EZ & 400 QPM mocks for covariances

DR14 footprint for the quasar sample

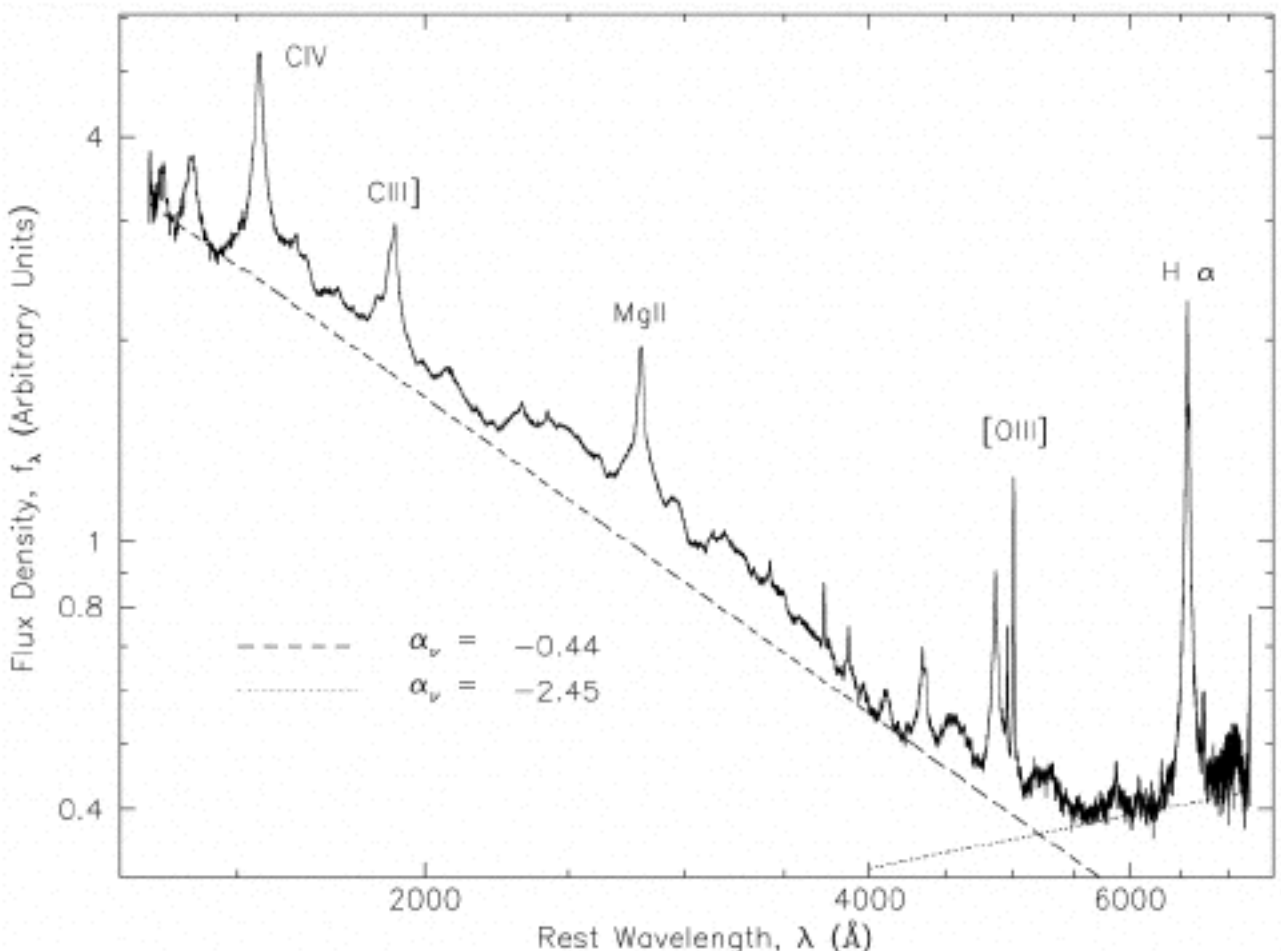


2112.9 deg²

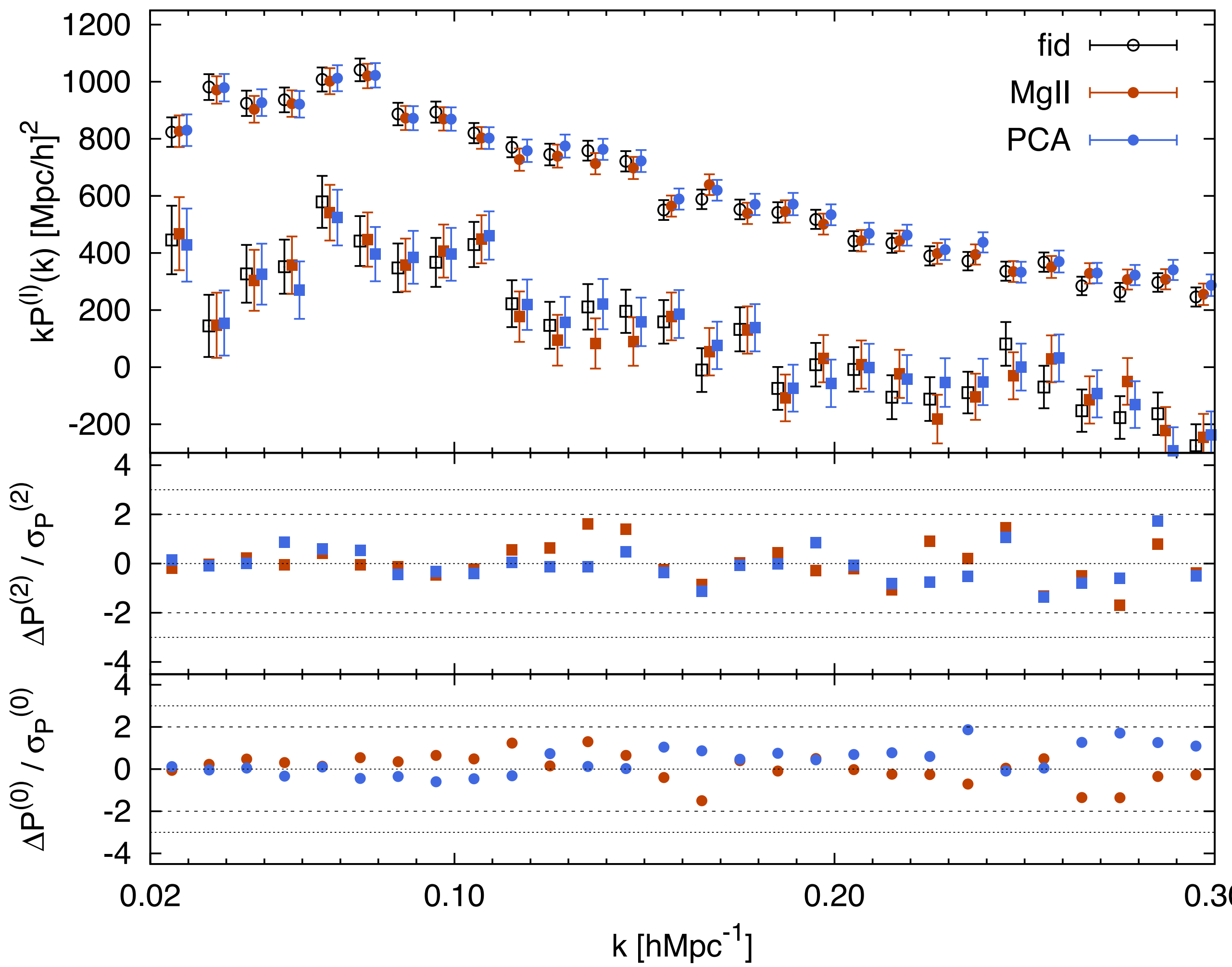


- $0.8 < z < 2.2$
- Wide redshift range
- 148,659 quasars
- Low density of tracers 2×10^{-5} h/Mpc
- Low density variation

Three types of redshift estimates



Credit: Vanden Berk et al. 2001



- The z_{PL} **automated classification:** Template-based PCA fit to CIV-line
- The z_{PCA} **automated classification:** Template-based PCA fit to MgII-line
- The z_{MgII} **automated classification:** Location of the MgII-line peak (when present).
- **Standard redshift estimate z_{fid}:** Any of the above options depending on the particular object, which provides the **lowest rate of catastrophic failures**.

Potential observational Systematics

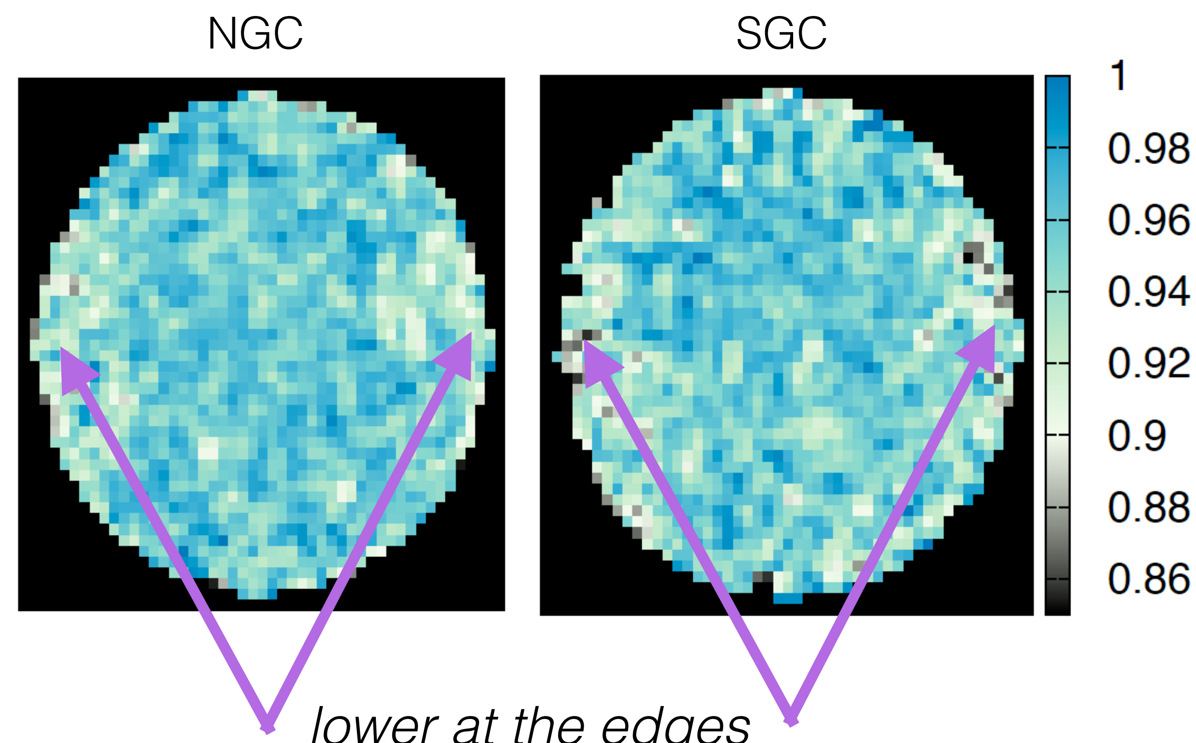
- **Redshift Failures:** *i)* Weight the nearest neighbour (NN), use in BOSS analysis. *ii)* Weight all observed galaxies by their position in the plate,

$$w_{spec}(x_{foc}, y_{foc}) \sim \frac{1}{P_{sucess}(x_{foc}, y_{foc})}$$

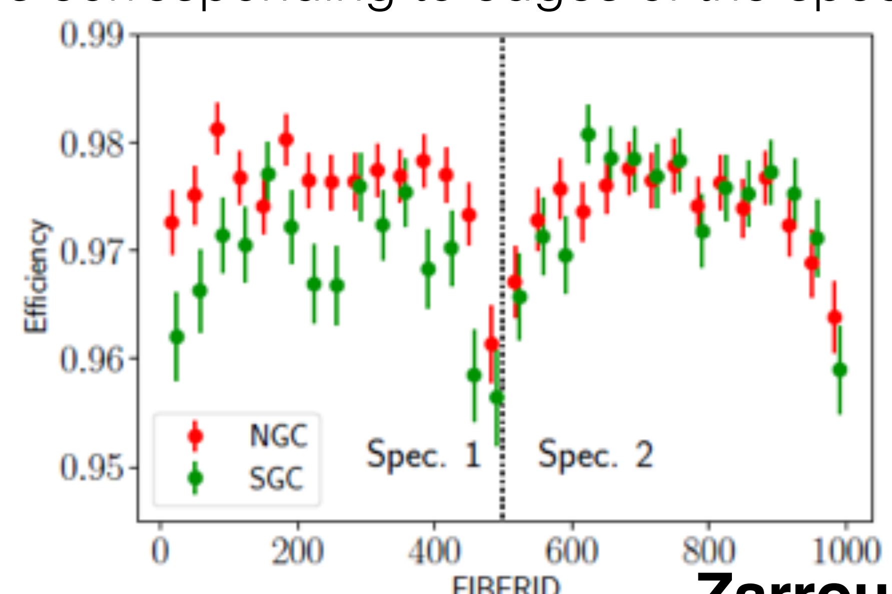
- **Collision Pairs:** Traditional nearest neighbour weighting (NN)

Imprint such effects on the mocks and check how these correction schemes perform

Redshift efficiency pattern

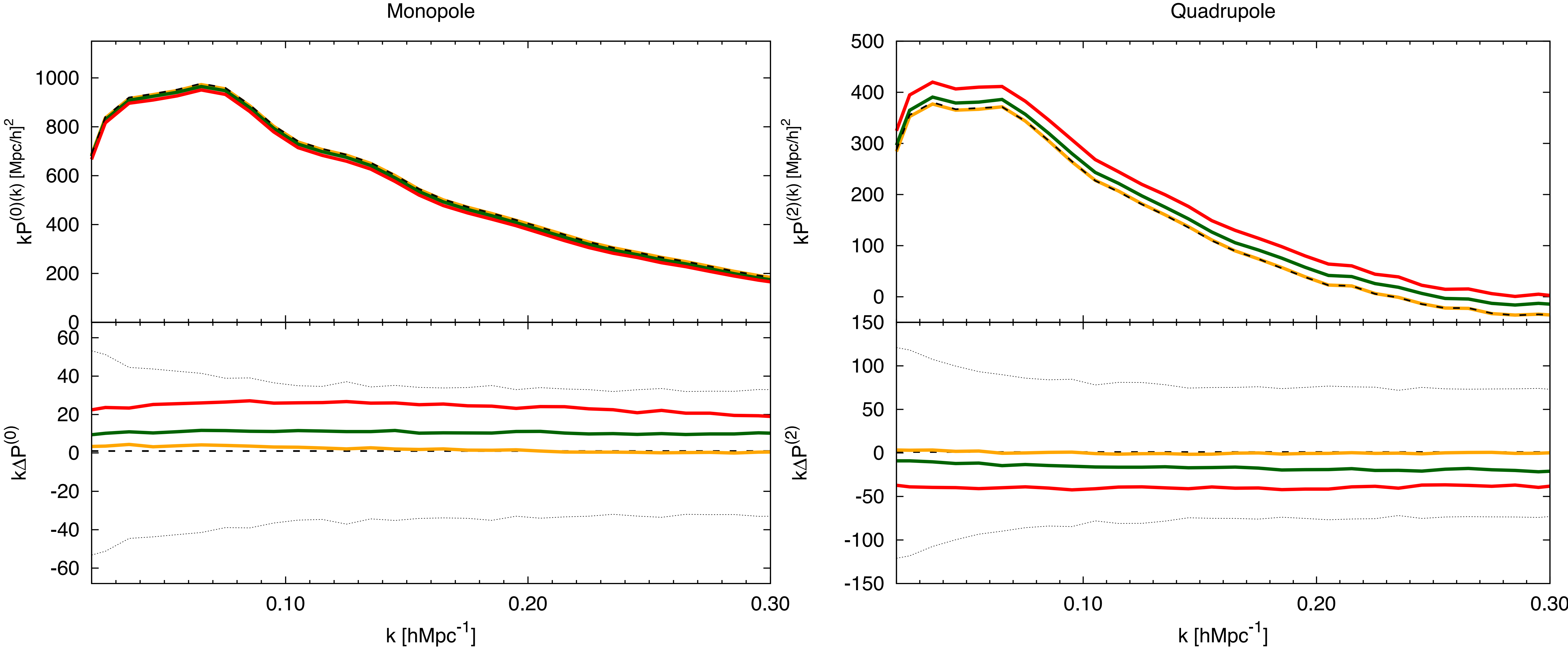


Fibres corresponding to edges of the spectrograph



Zarrouk et al. 18

Potential observational Systematics



True signal (systematic effect not applied)

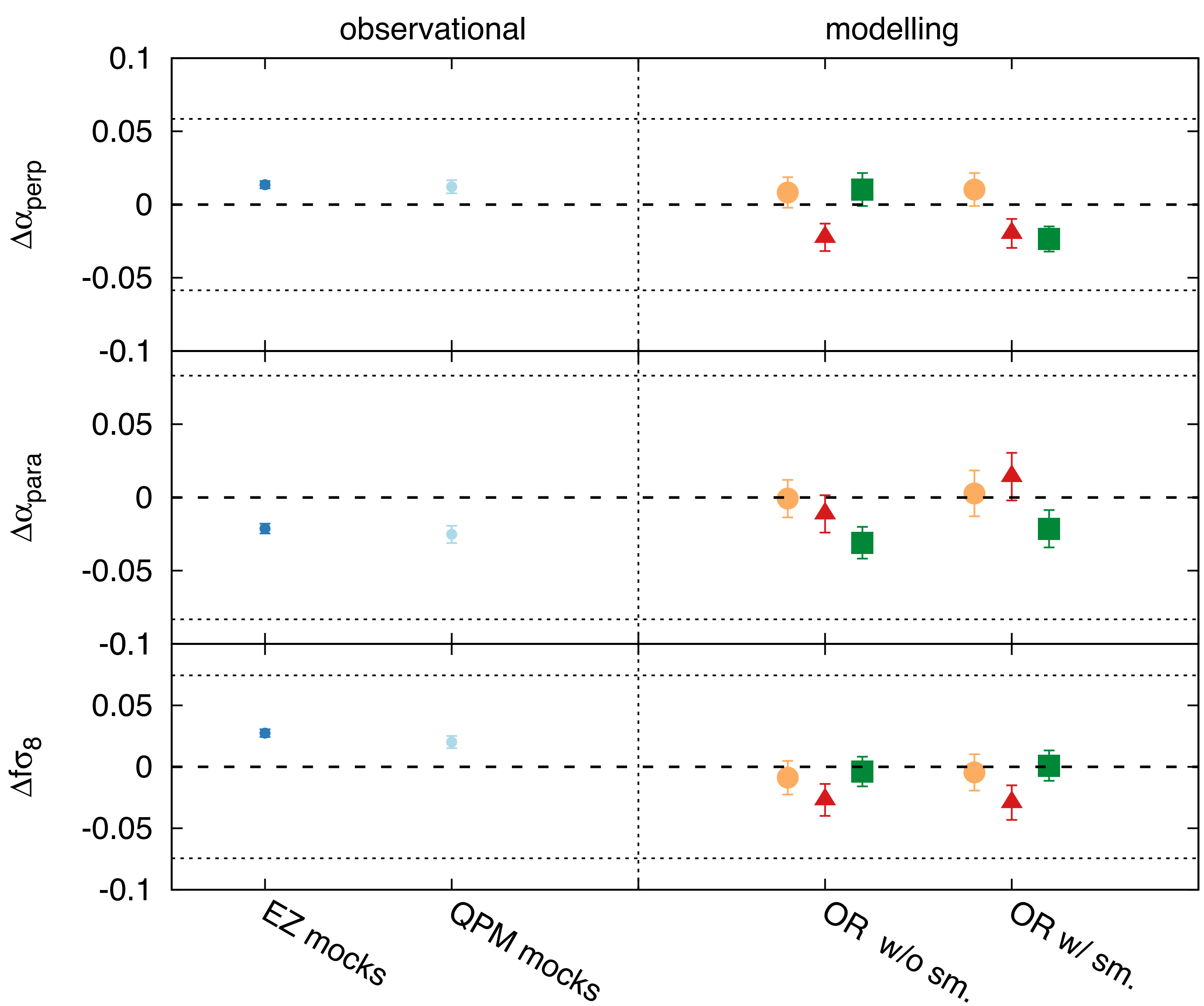
Corrected: redshift failures (focal weight) + close pairs (NN)

Corrected: redshift failures (NN) + close pairs (NN)

Corrected: redshift failures (focal weight) [close pairs not applied]

Potential modelling Systematics

- Use OuterRim N-body simulation at z=1.43 (Habib et al 2016) with different HOD prescriptions & w/ or wo/ (Gaussian) redshift smearing.



HOD of quasars

no satellite fraction → no sys?
13% satellite fraction → problems?
22% satellite fraction

Model: 2-loop RPT + TNS @ z=1.43, 0.02<k[h/Mpc]<0.30

$f\sigma_8$, α_{para}, α_{perp}, $b_1\sigma_8$, $b_2\sigma_8$, σ_{fog}, A_{noise}

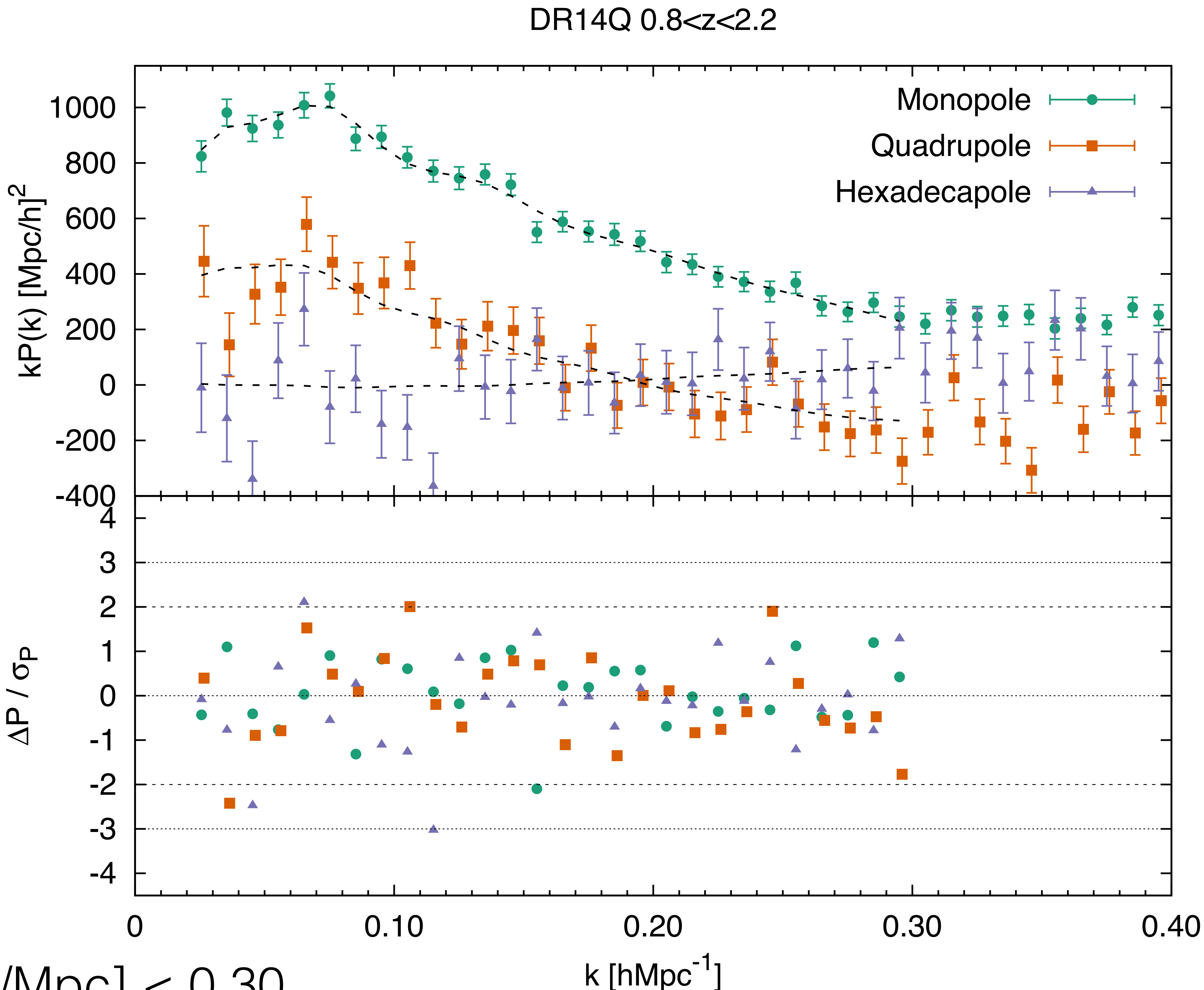
	$\sigma_{obs}\times 10^2$	$\sigma_{mod}\times 10^2$	$\sigma^2_{systot}\times 10^3$	
$f\sigma_8$	+2.74	−2.91	1.598	+17%
$\alpha_\parallel$	−2.12	−3.09	1.404	+16%
$\alpha_\perp$	+1.36	−2.35	0.737	+13%

Take highest deviation from obs & mod

add in quadrature both 'obs' and 'sys' errors

… but not clear if the overall measurement would be shifted

Measurement and best-fitting model on DR14Q

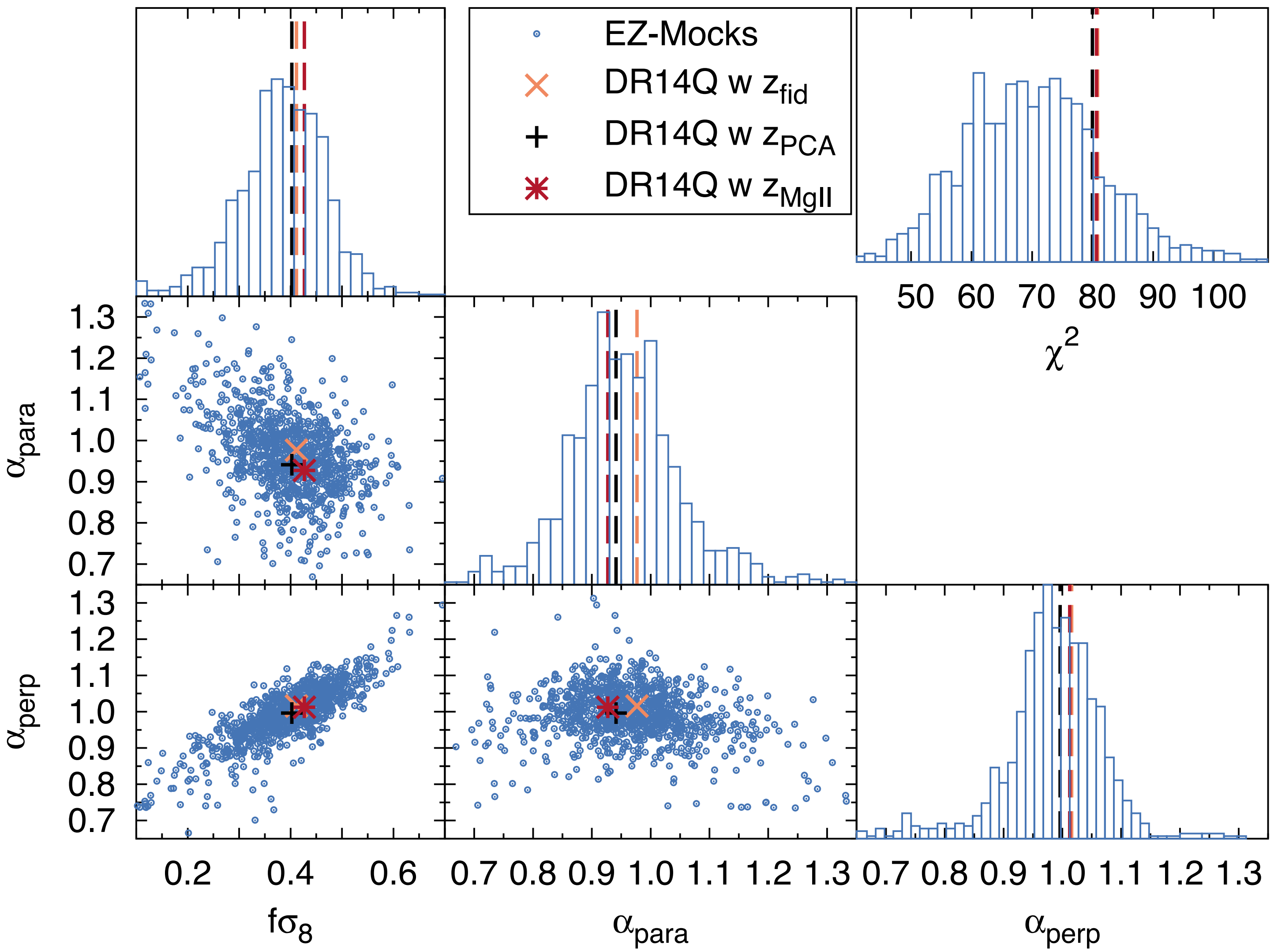


$\chi^2=84/(84-7)$

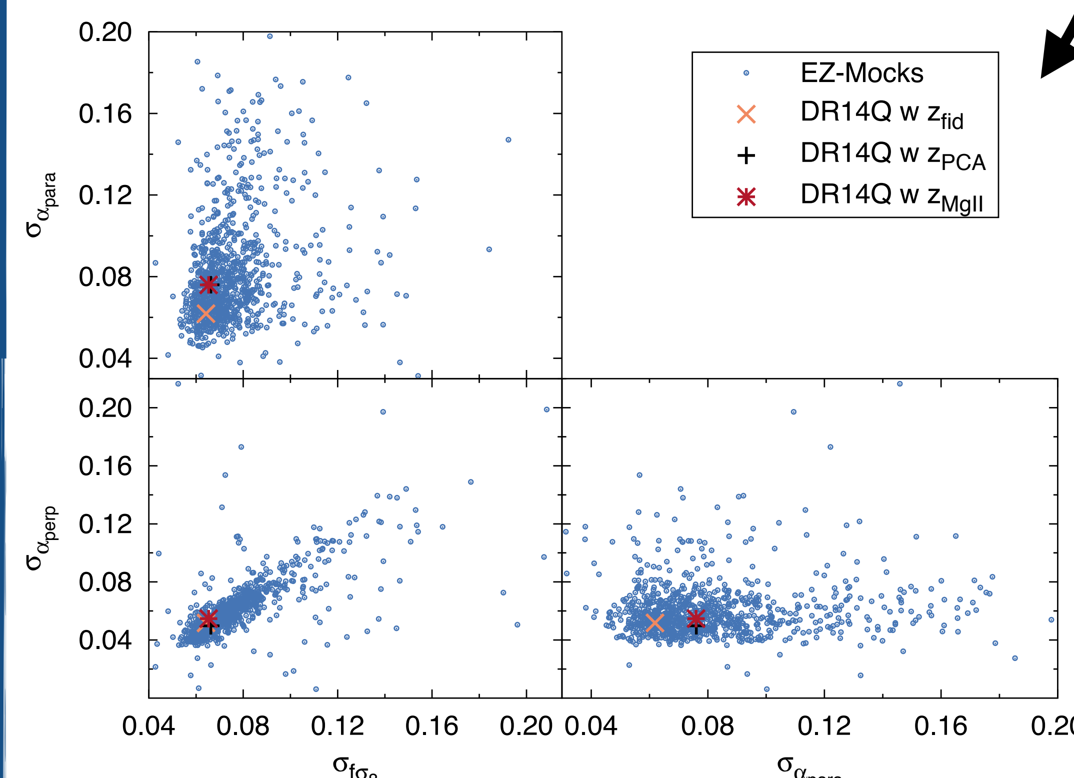
$\chi^2_{P0}=20/(28-7)$
$\chi^2_{P2}=30/(28-6)$
$\chi^2_{P4}=35/(28-4)$

$0.02 < k\ [h/Mpc] < 0.30$

Comparing data with mocks



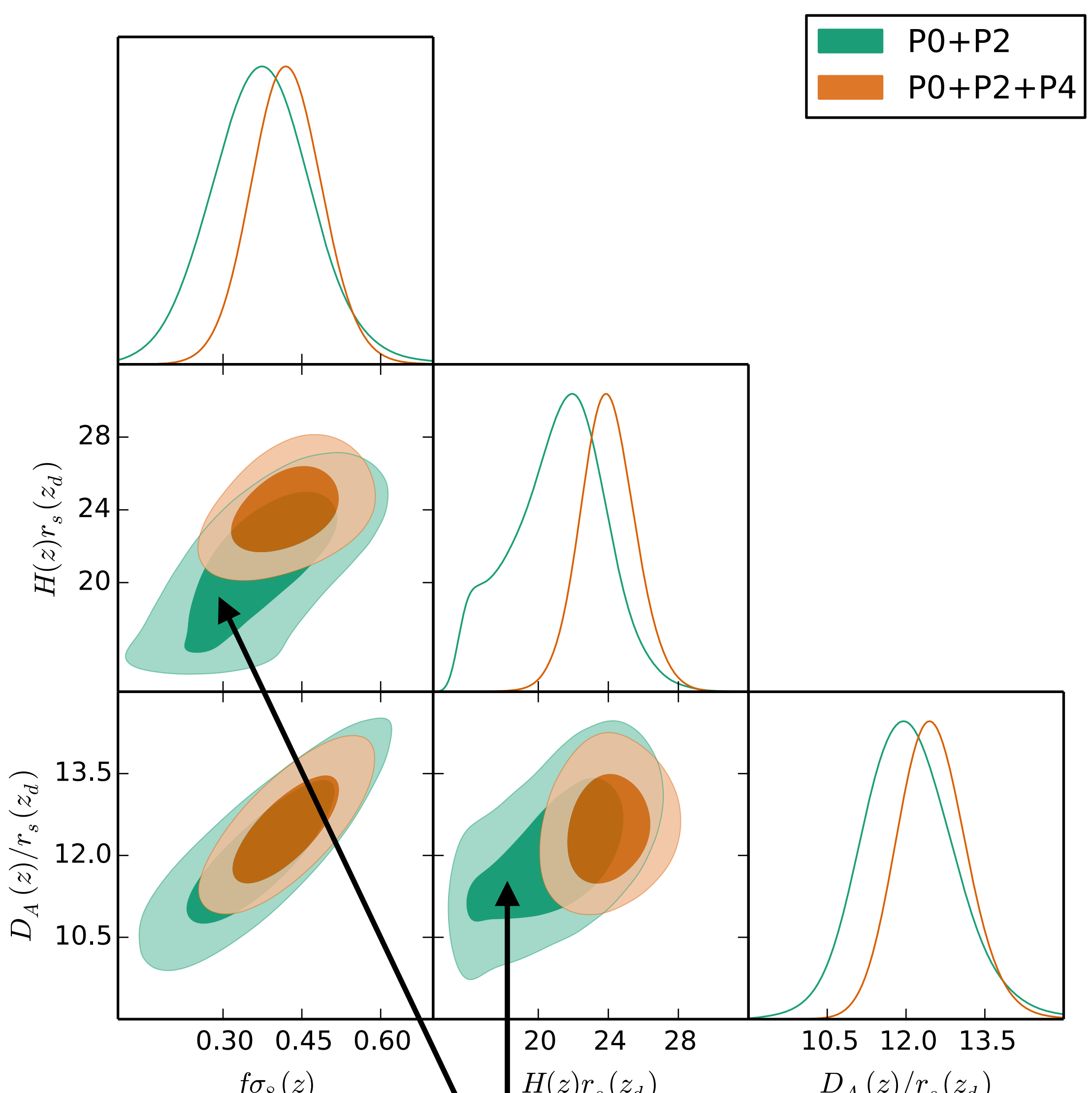
- Data looks like a typical realisation wrt the mocks
- Redshift estimate does not affect the best-fitting value significantly
- However, does affect the tails (errors) of the distribution

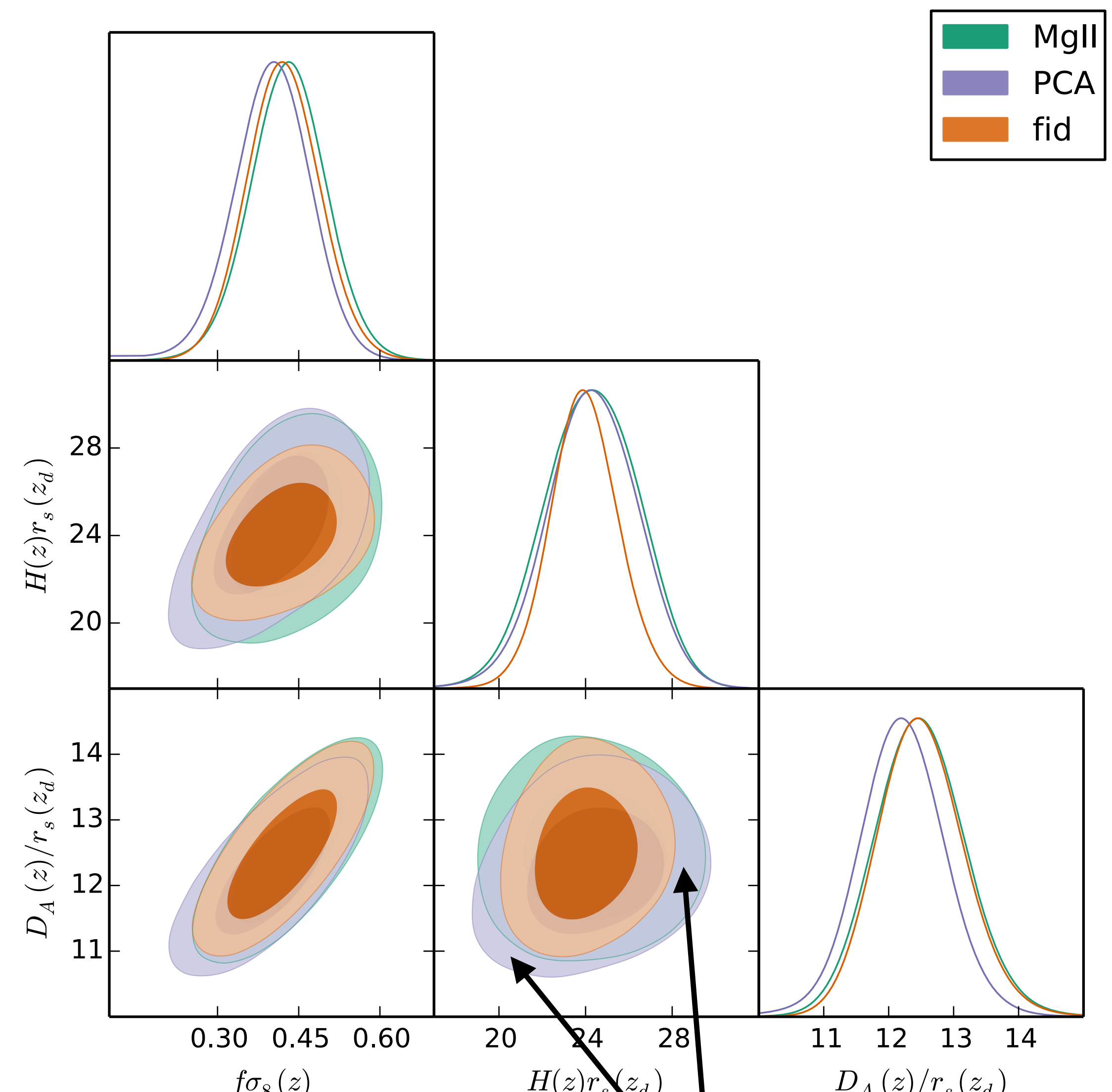


- Mocks as pipeline validation
- Potential systematic tests
- Unfortunately, mocks do not have spectra

Consistency results on the data

Test the effect of adding/removing the hexadecapole
Test the effect of redshift estimates on the cosmological parameters





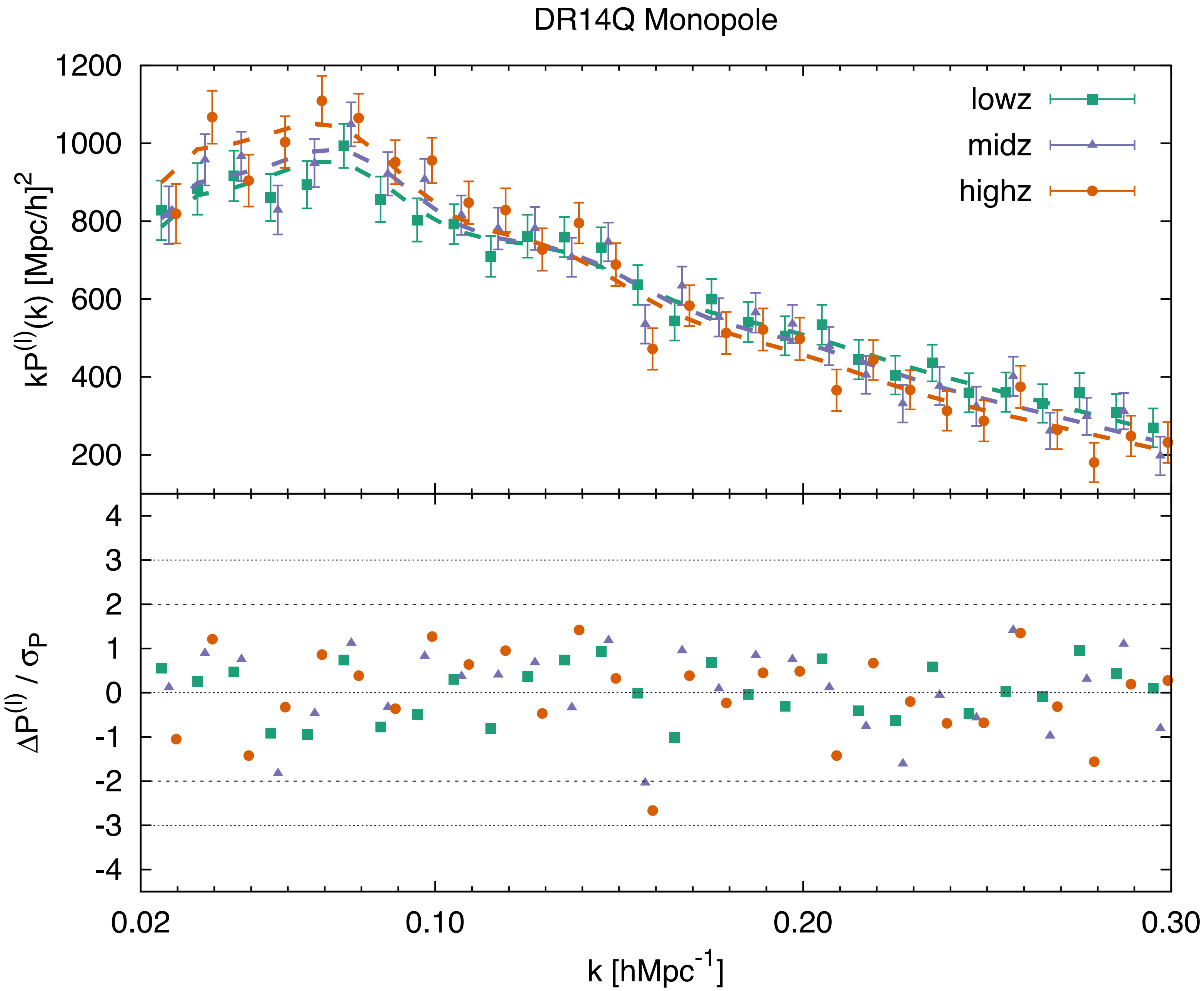
Hexadecapole helps to break H vs. $f\sigma_8$ and D_A vs H degeneracies

z_{PCA} larger tails

Split the 0.8<z<2.2 in 3 overlapping z-bins

- We individually fit the 3 redshift bins
- The covariance among parameters is computed through the EZmocks

lowz 0.8< z <1.5
midz 1.2< z <1.8
highz 1.5< z <2.2



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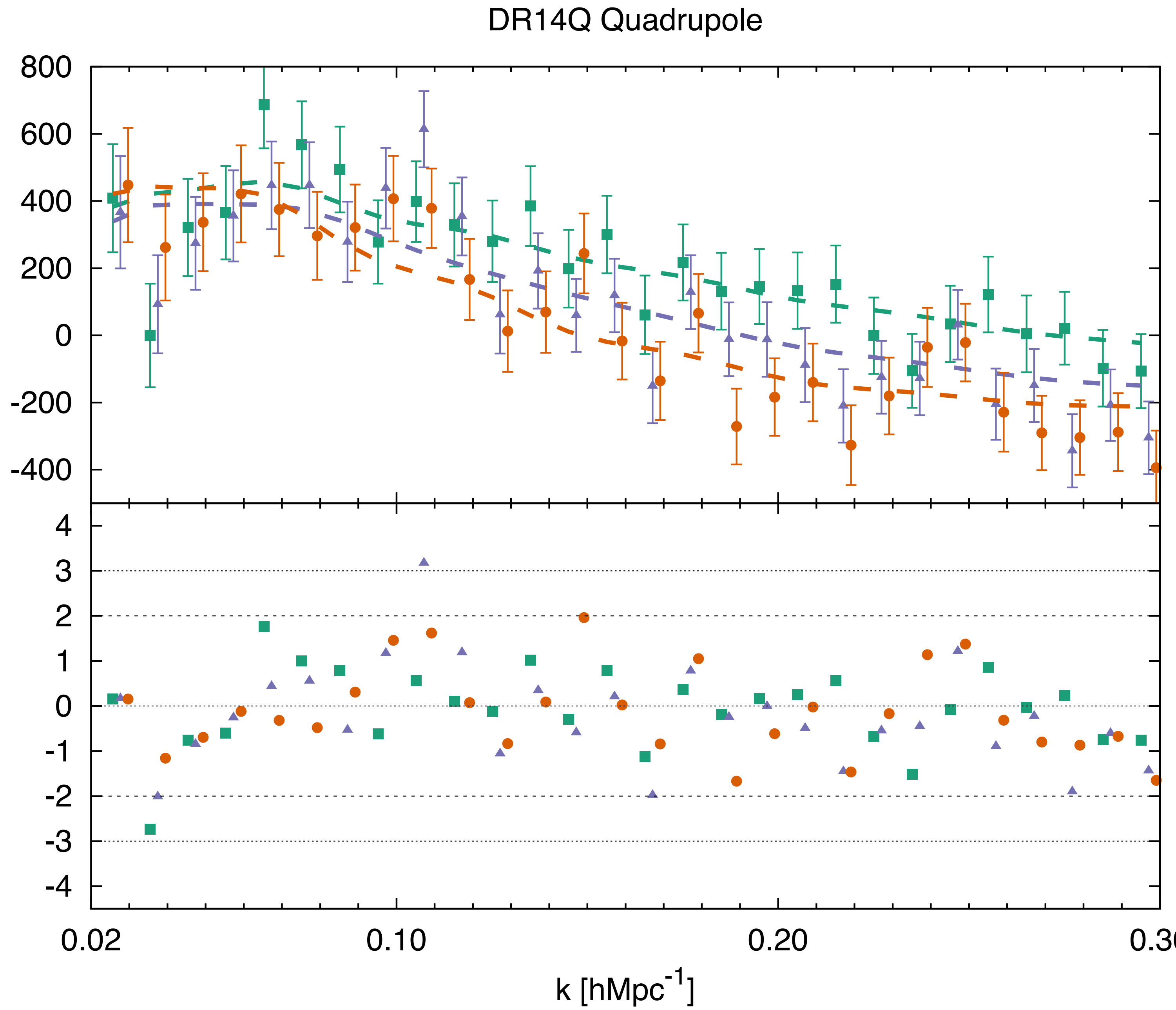

Split the 0.8<z<2.2 in 3 overlapping z-bins

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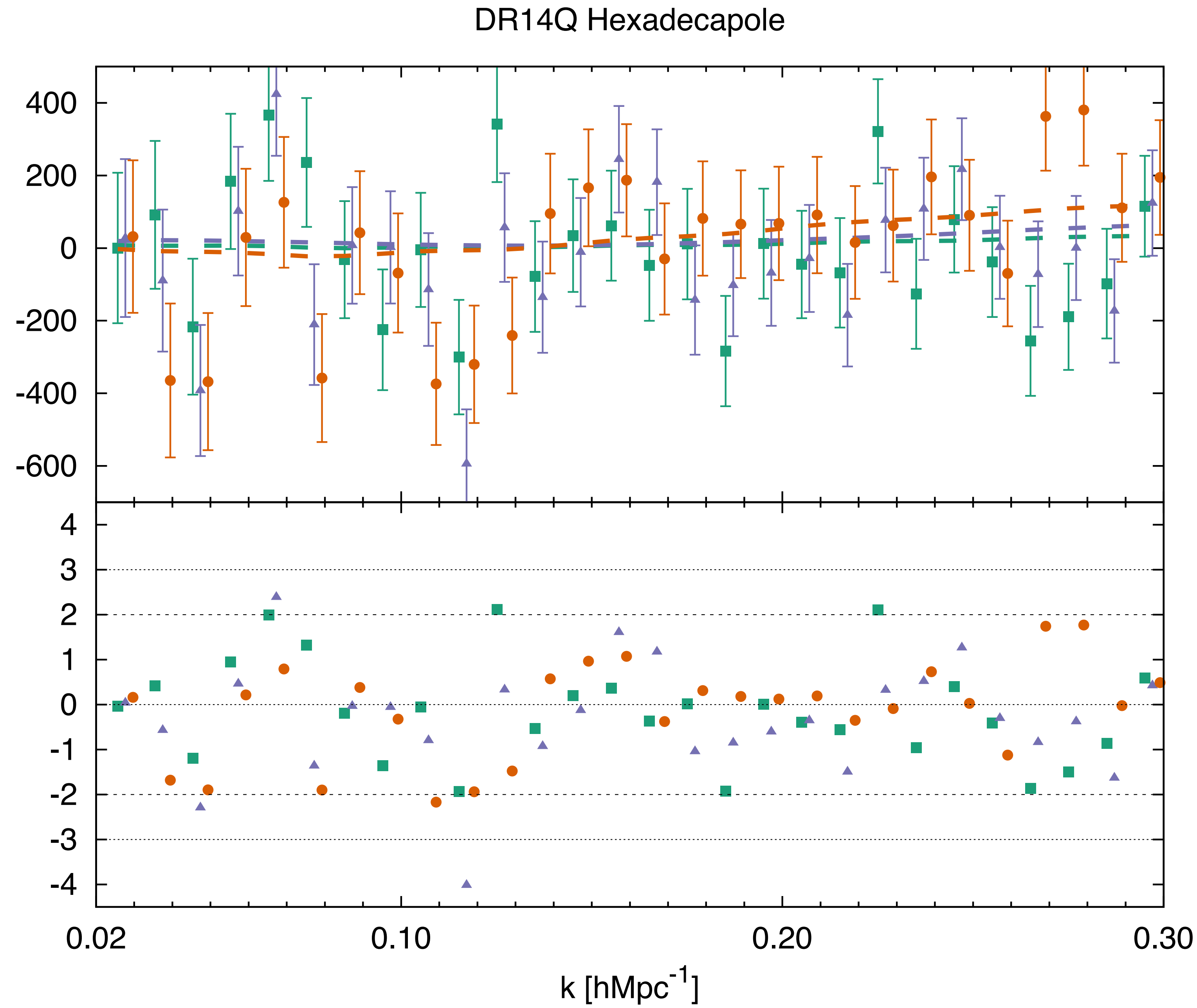
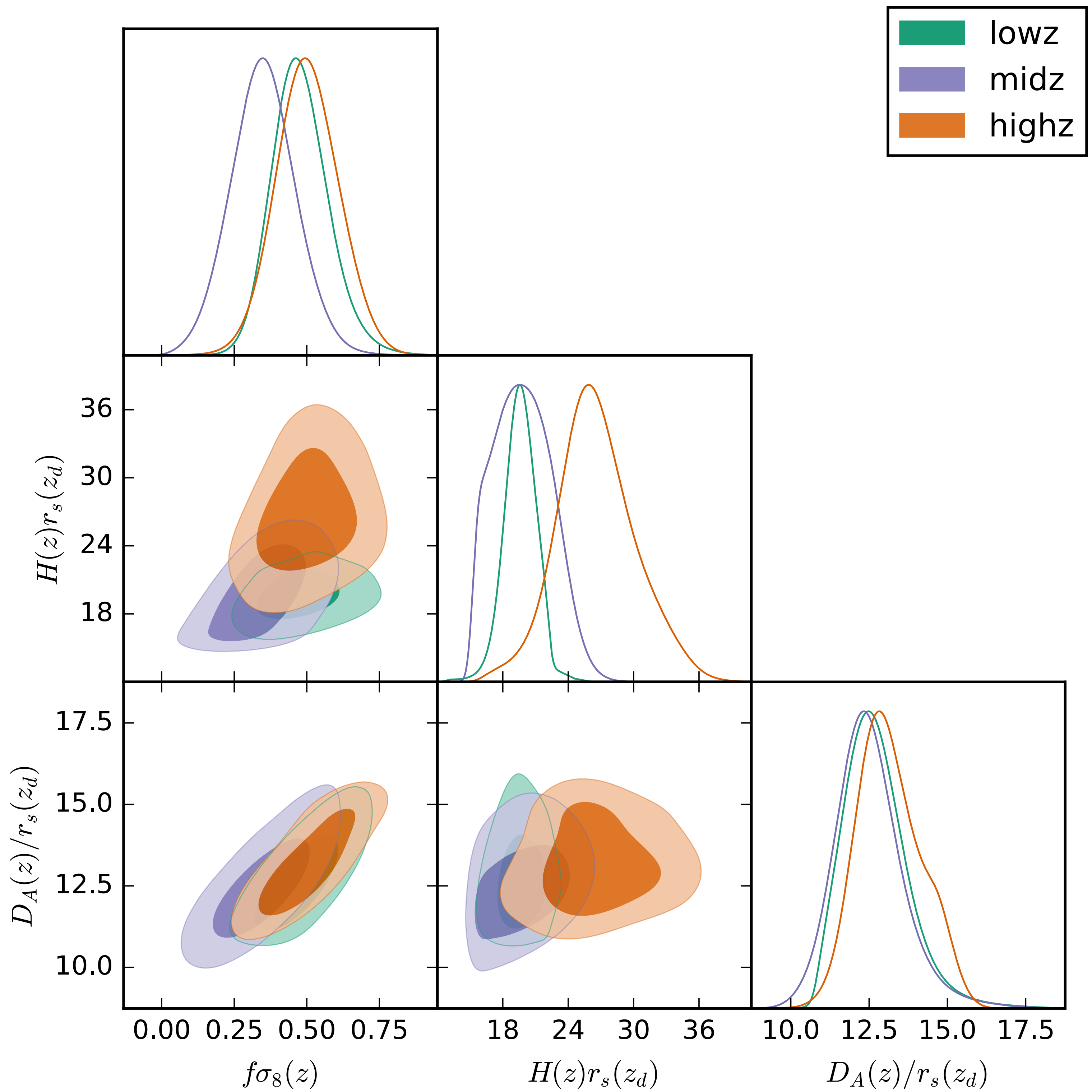
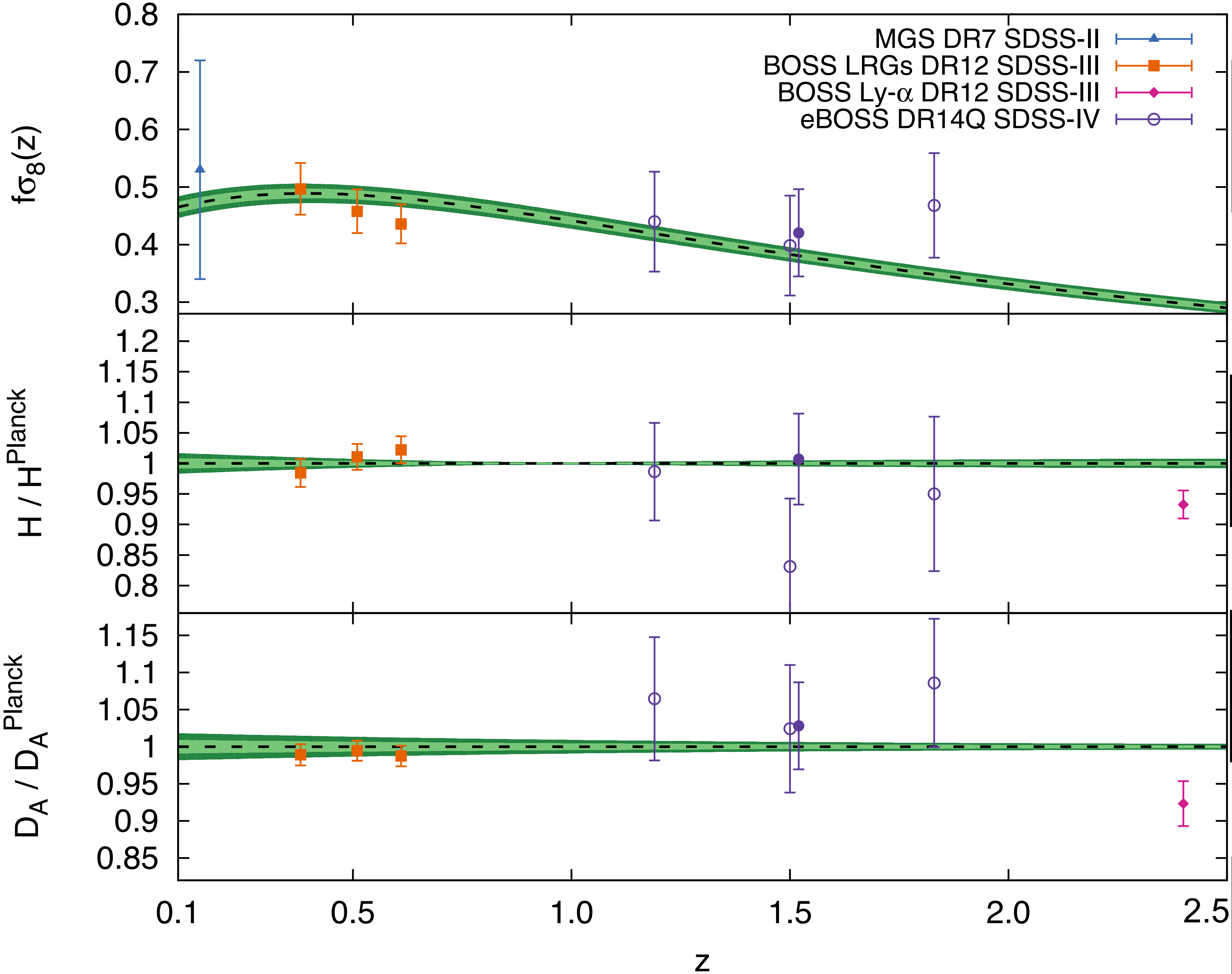


Split the 0.8<z<2.2 in 3 overlapping z-bins



Cosmological Results



0.8<z<2.2

$$f\sigma_8(1.52) = 0.420 \pm 0.076$$
$$H(1.52) = [162 \pm 12](r_s^{fid}/r_s)$$
$$D_A(1.52) = [1.85 \pm 0.11] \times 10^3 (r_s/r_s^{fid})$$

0.8<z<1.5

$$f\sigma_8(1.19) = 0.474 \pm 0.099$$
$$H(1.19) = [133 \pm 11](r_s^{fid}/r_s)$$
$$D_A(1.19) = [1.87 \pm 0.15] \times 10^3 (r_s/r_s^{fid})$$

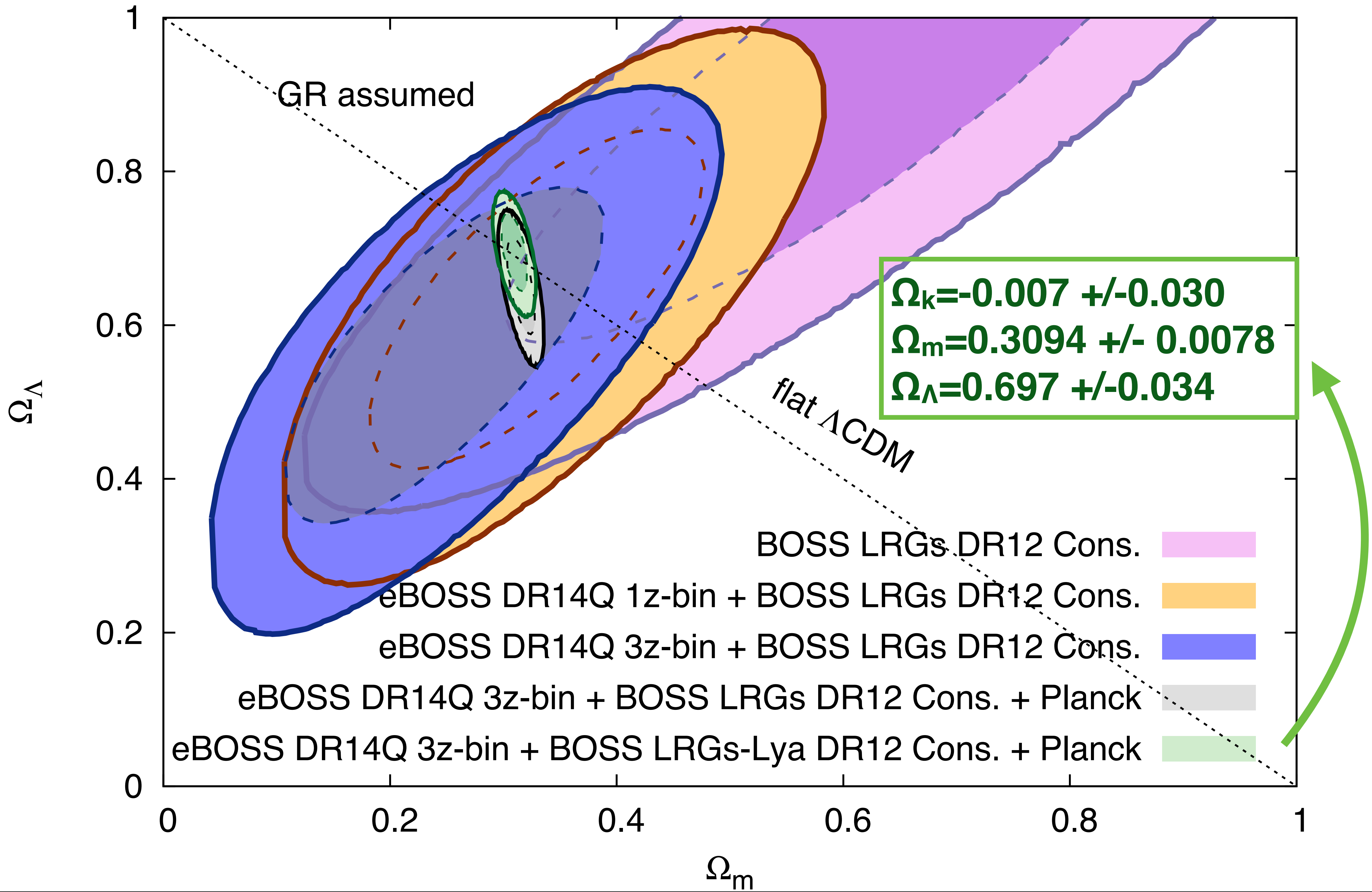
1.2<z<1.8

$$f\sigma_8(1.50) = 0.34 \pm 0.11$$
$$H(1.50) = [134 \pm 18](r_s^{fid}/r_s)$$
$$D_A(1.50) = [1.84 \pm 0.15] \times 10^3 (r_s/r_s^{fid})$$

1.5<z<2.2

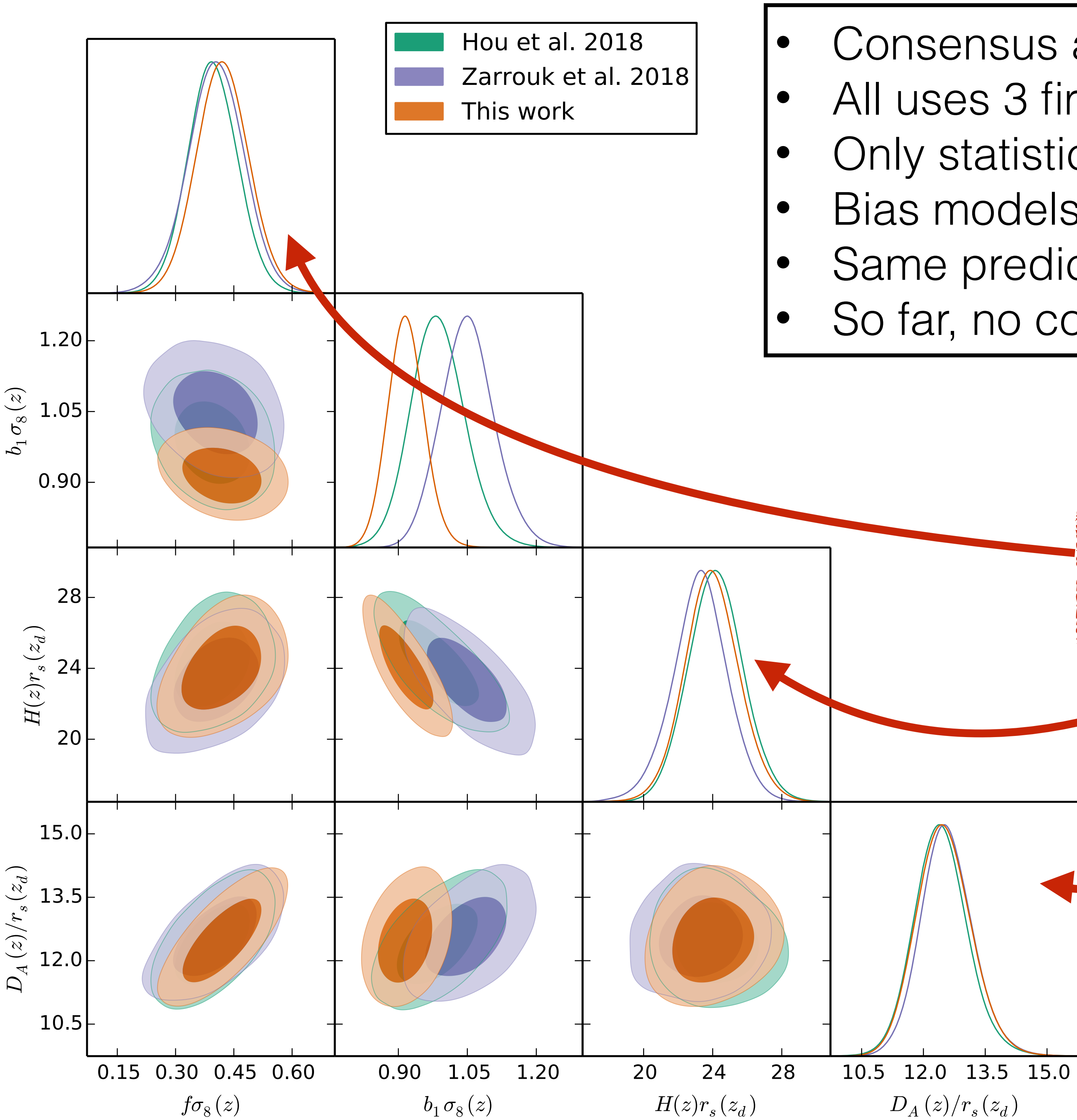
$$f\sigma_8(1.83) = 0.50 \pm 0.11$$
$$H(1.83) = [181 \pm 24](r_s^{fid}/r_s)$$
$$D_A(1.83) = [1.94 \pm 0.15] \times 10^3 (r_s/r_s^{fid})$$

Test of flatness



Ω_k=-0.007 +/-0.030
Ω_m=0.3094 +/- 0.0078
Ω_Λ=0.697 +/-0.034

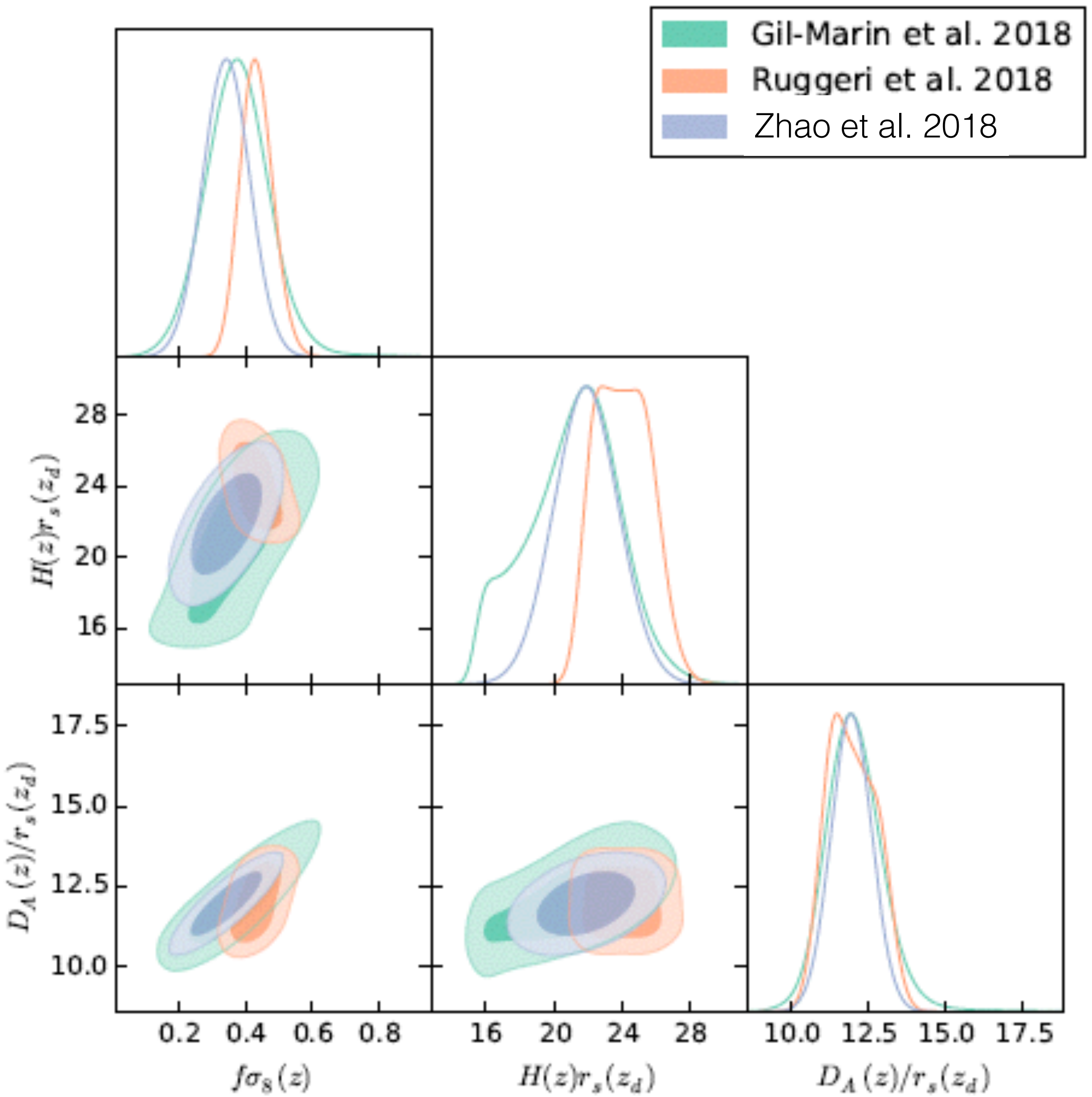
Consensus with other 'classical' analyses

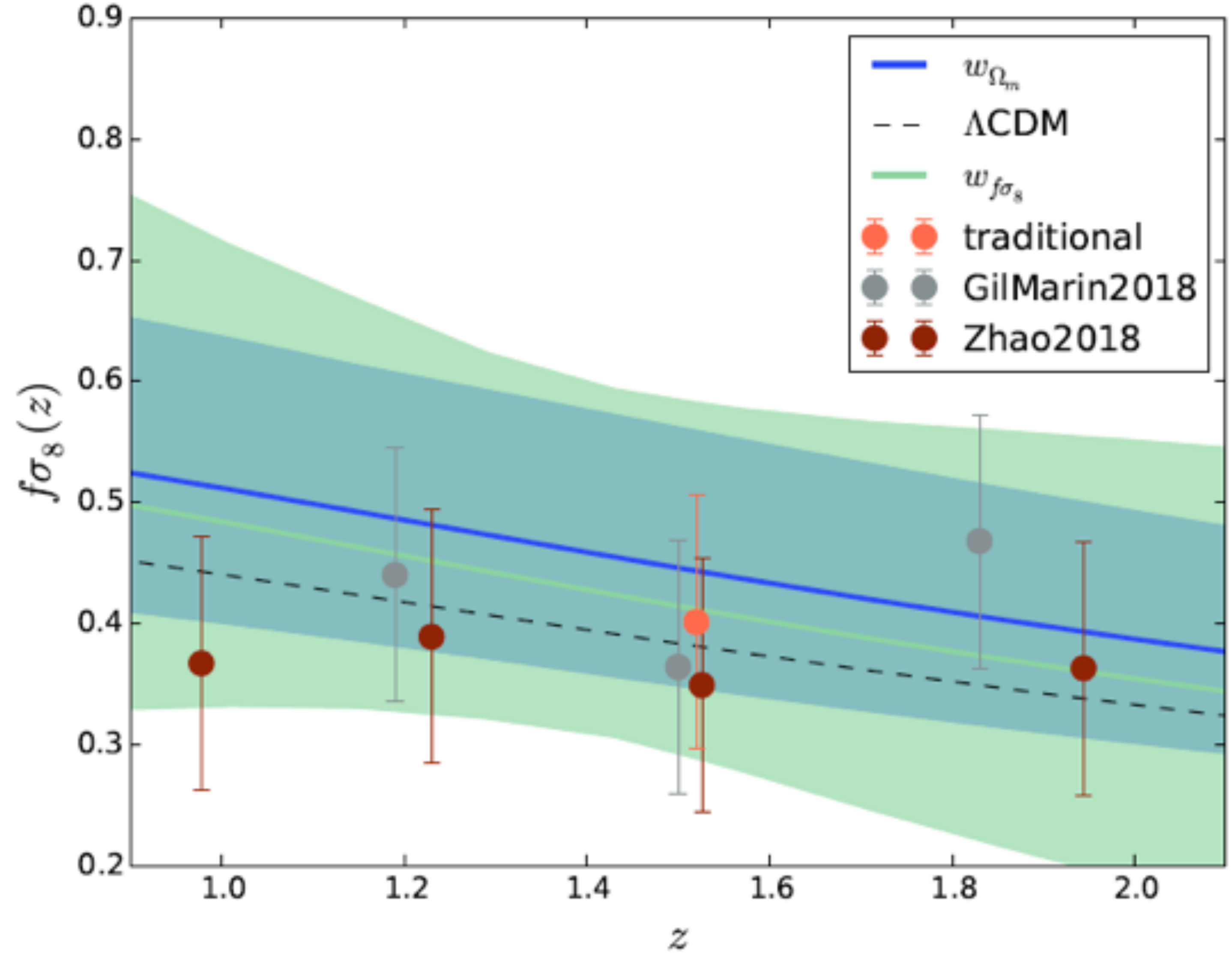


- Consensus among 'classical' analysis
- All uses 3 first non-null multipoles
- Only statistical errors included
- Bias models different
- Same prediction for cosmological parameters
- So far, no consensus values (alphabetical paper)

Excellent agreement among cosmological parameters

Consensus with redshift-weighted analyses





$$\frac{f\sigma_8(z)}{[f\sigma_8(z)]_{fid}} = p_0\left[1 + p_1 x(z) + p_2 x^2(z) + \ldots\right]$$

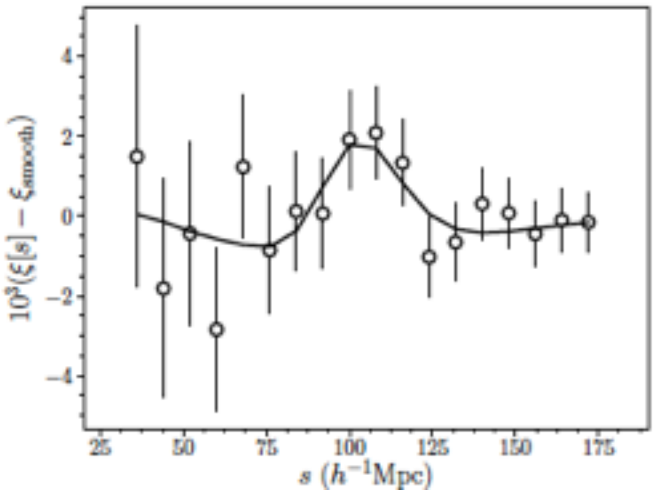
Find optimal weights, $\mathbf{p_i}$

Ruggeri et al. 2018 arxiv:1801.02891

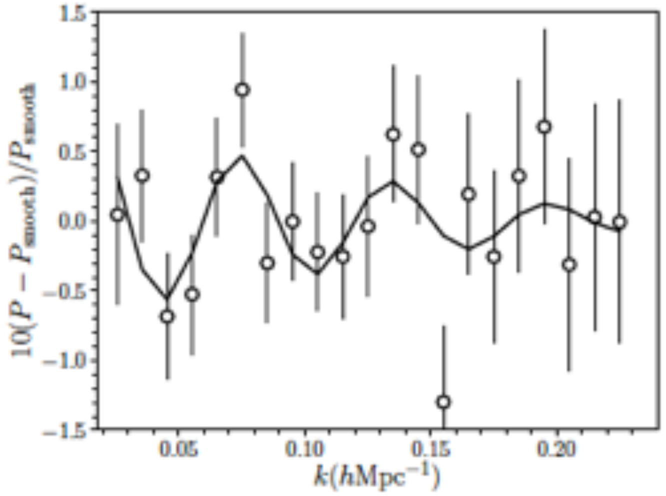
Zhao et al. 2018 arxiv:1801.03043

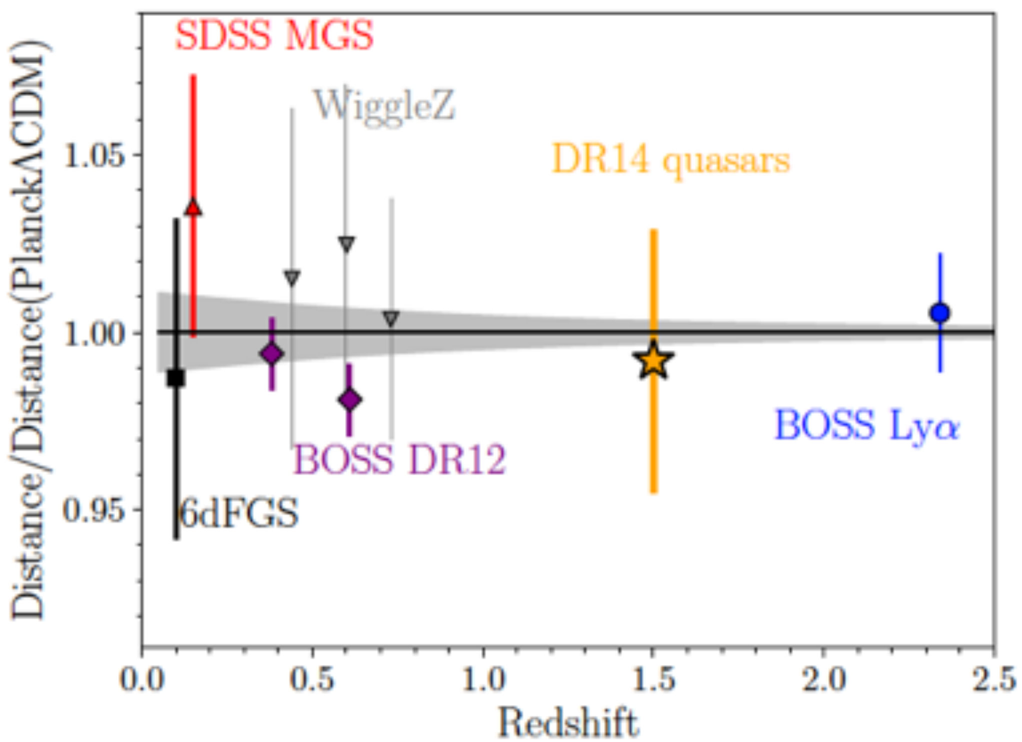
DR14Q BAO results

Correlation Function

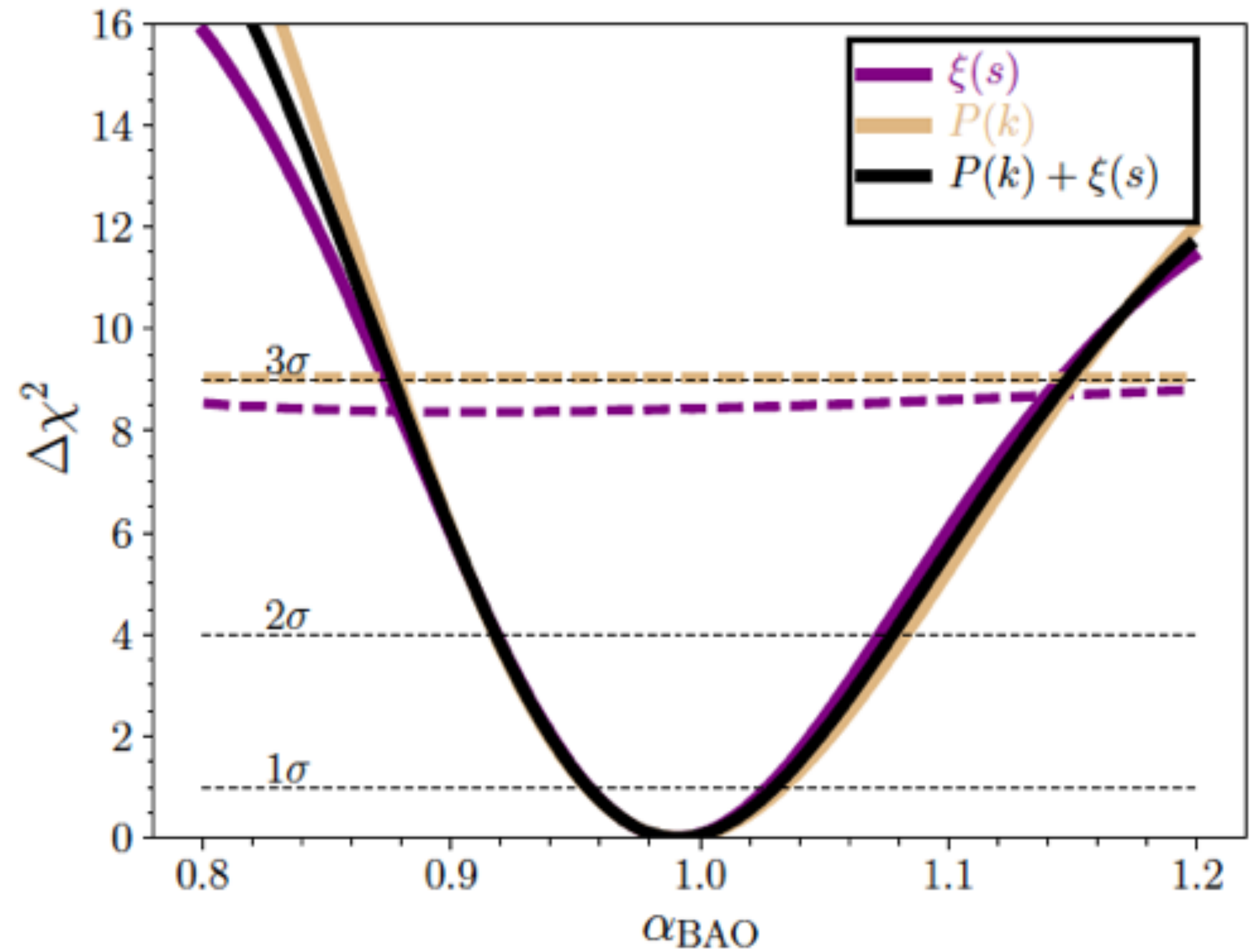


Power Spectrum





Significance of BAO peak



- Correlation factor ρ=0.97
- 3σ detection
- In good agreement with Planck+GR
- $D_V(z=1.52)=3843 \pm 147$ Mpc (3.8%)
- $\chi^2=6.2/13$ for $\xi(R)$ and 27.7/33 for $P(k)$

Ata et al. 2017 arXiv:1705.06373

Conclusions

- **DR14Q data.** RSD & iso-BAO analyses completed. Measurements on D_A, H and $f\sigma 8$ at zeff=1.52 for **the first time**
- Some remaining systematics on RSD to be corrected. So far sub-dominant wrt the statistics
- Results in agreement with the forecasted errors by Zhao et al. 2014
- Non-consensus results for DR14Q, but different groups present excellent agreement

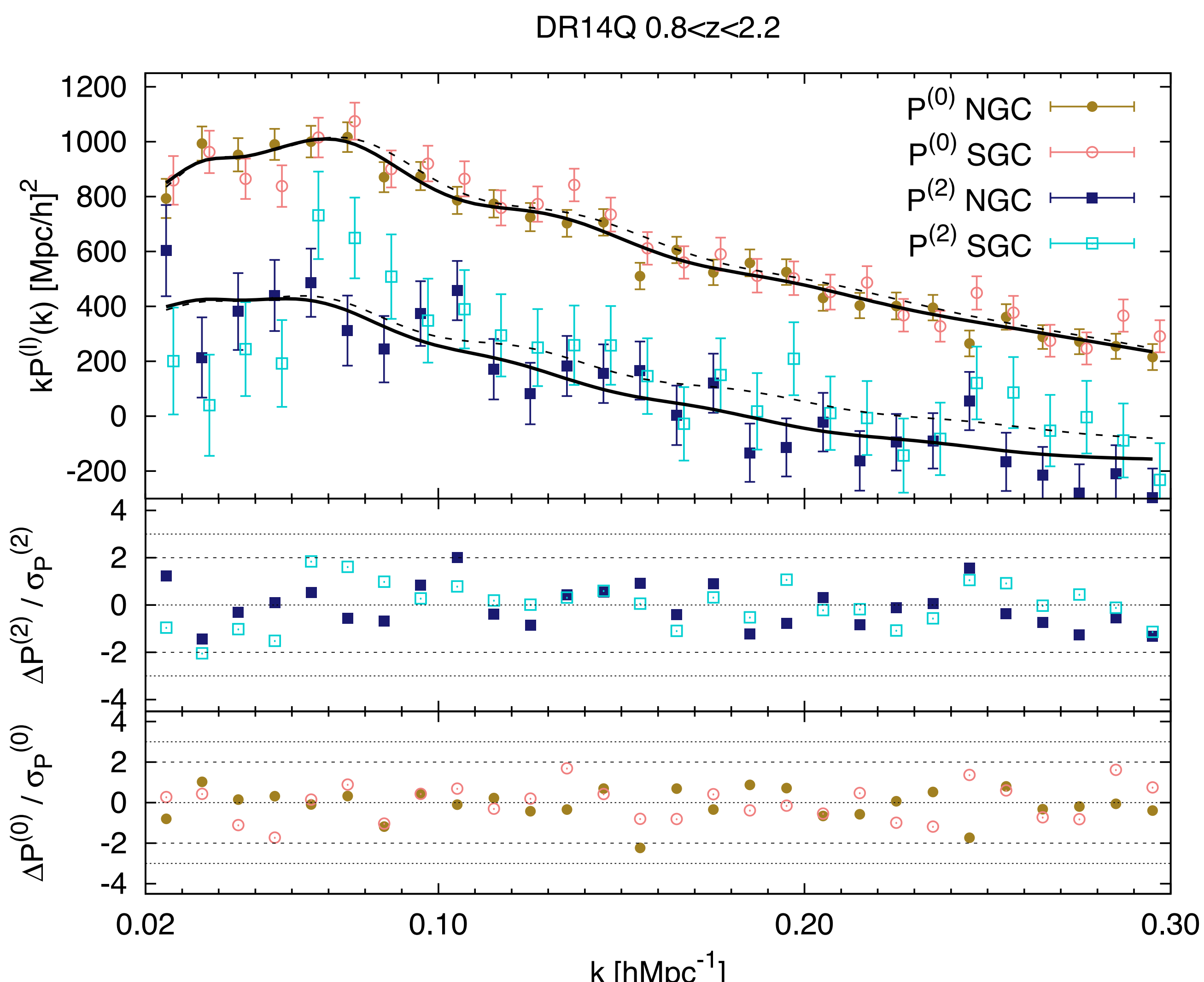
Key dates on eBOSS

stay tuned!

- June ’17: BAO DR14Q
- January ’18: BAO DR14L
- January ’18: RSD DR14Q ← **ELG observations completed** **(February 2018)**
- ~July ’18: RSD DR14L
- ~December ’18: BAO & RSD DR16E ← **LRG & QSO observations completed** **(February 2019)**
- ~Fall ’19: Final DR16 BAO-RSD LRG-ELG-quasar+Lya

Backup slides

NGC vs SGC



NGC

χ^2=65/(84-7)

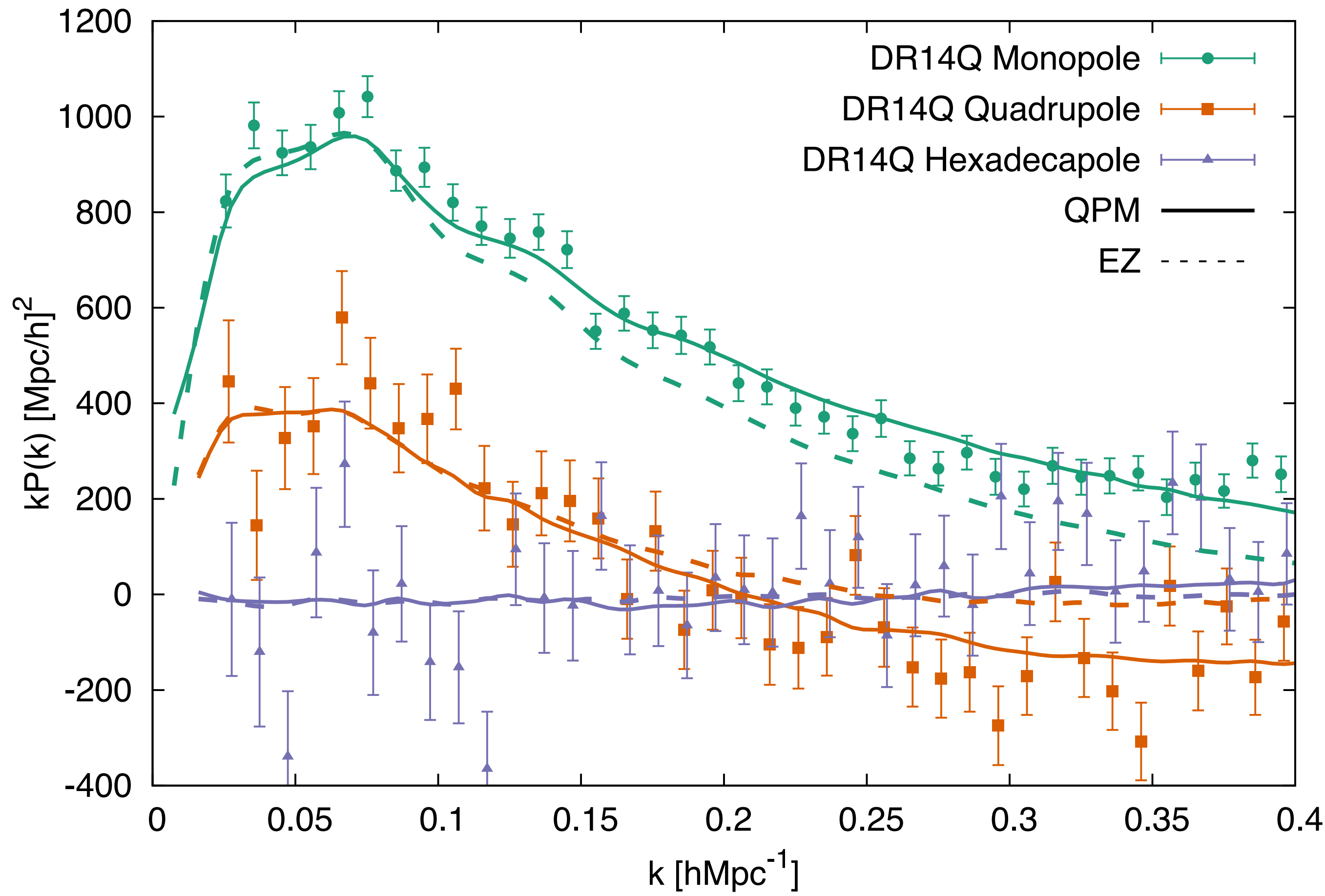
χ^2_{P0}=20/(28-7)
χ^2_{P2}=22/(28-6)
χ^2_{P4}=25/(28-4)

SGC

χ^2=77/(84-7)

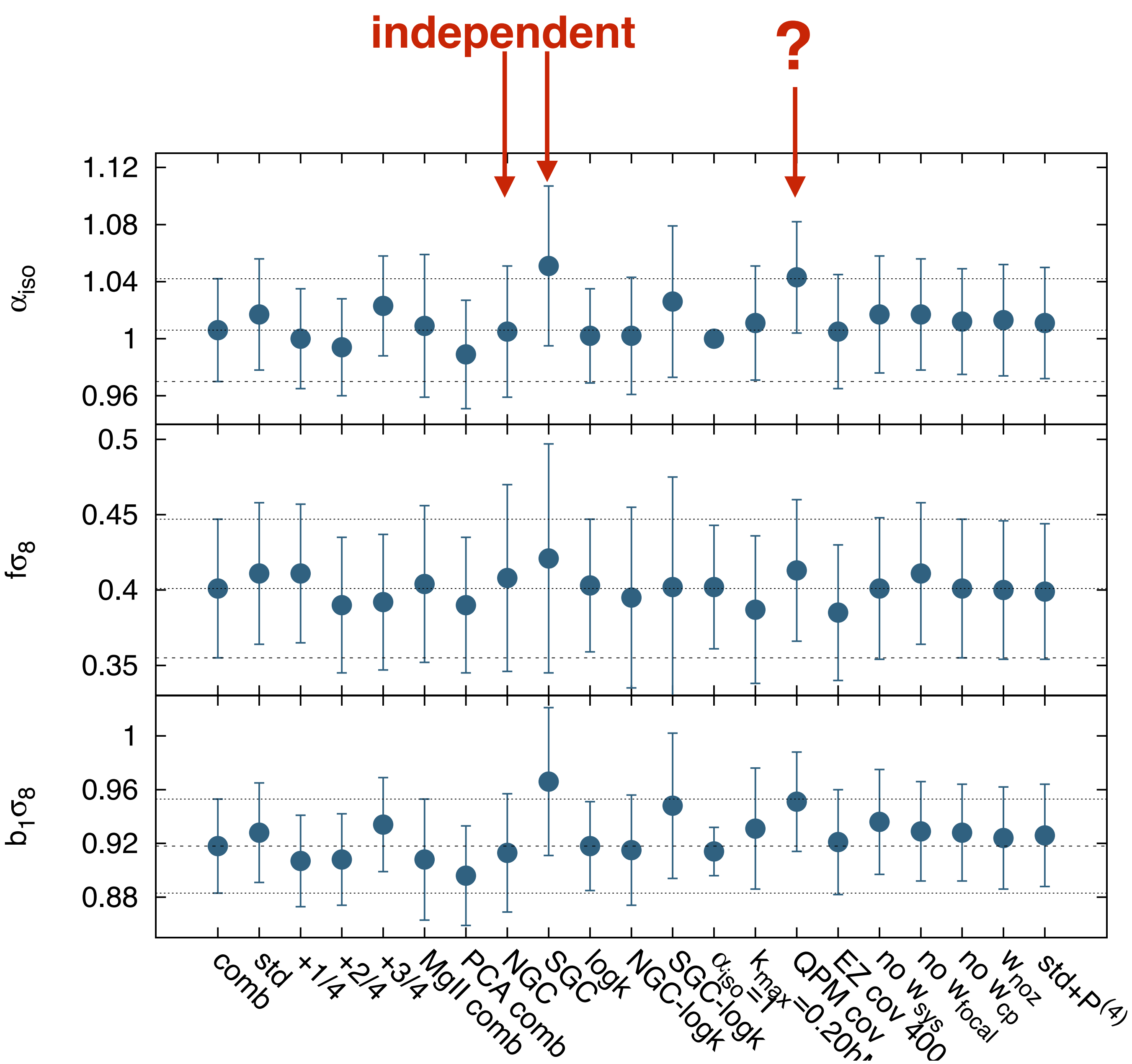
χ^2_{P0}=26/(28-7)
χ^2_{P2}=24/(28-6)
χ^2_{P4}=28/(28-4)

QSO mocks performance



Consistency results on the data

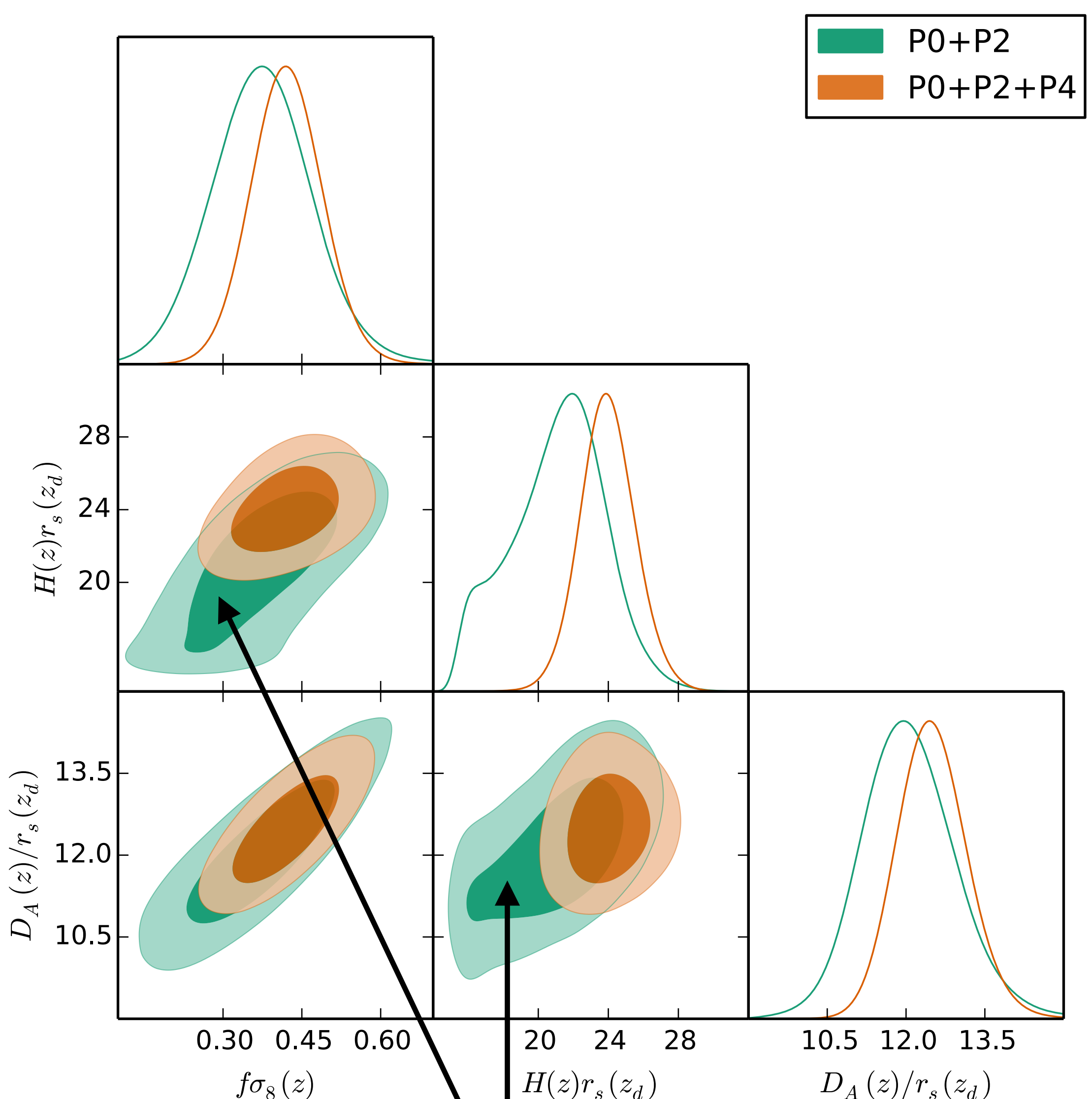
We re-analyze the data using different prescriptions (bin position/size, sample, etc., and study how the cosmological parameters change

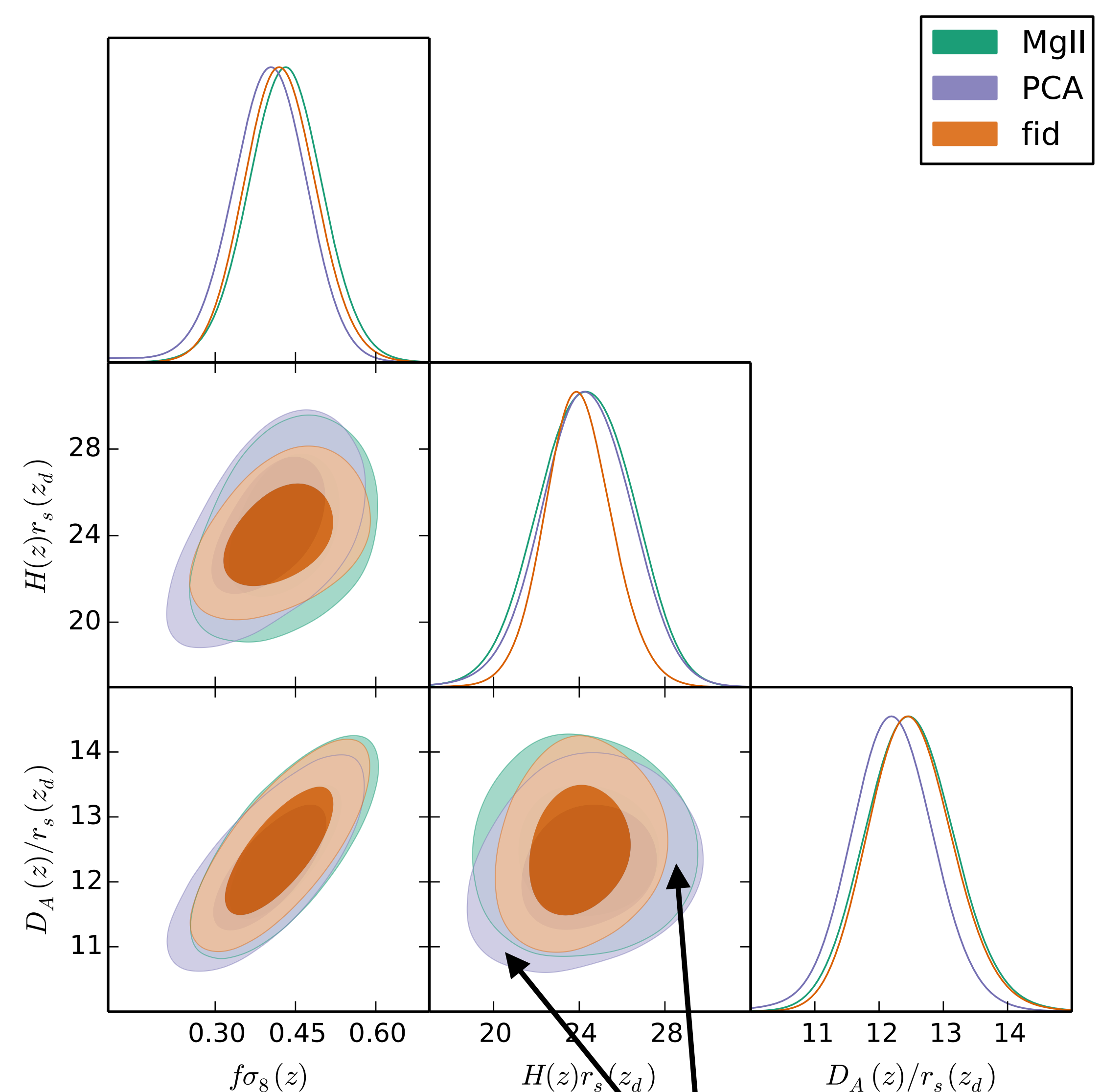


- QPM-choice shifts 0.67σ the $b_1\sigma_8$ and αiso wrt the 'std' case.
- 14% of the mocks present such behaviour
- It is expected that if we look at several properties, at least one of them deviate ~1σ

Consistency results on the data

Test the effect of adding/removing the hexadecapole
Test the effect of redshift estimates on the cosmological parameters



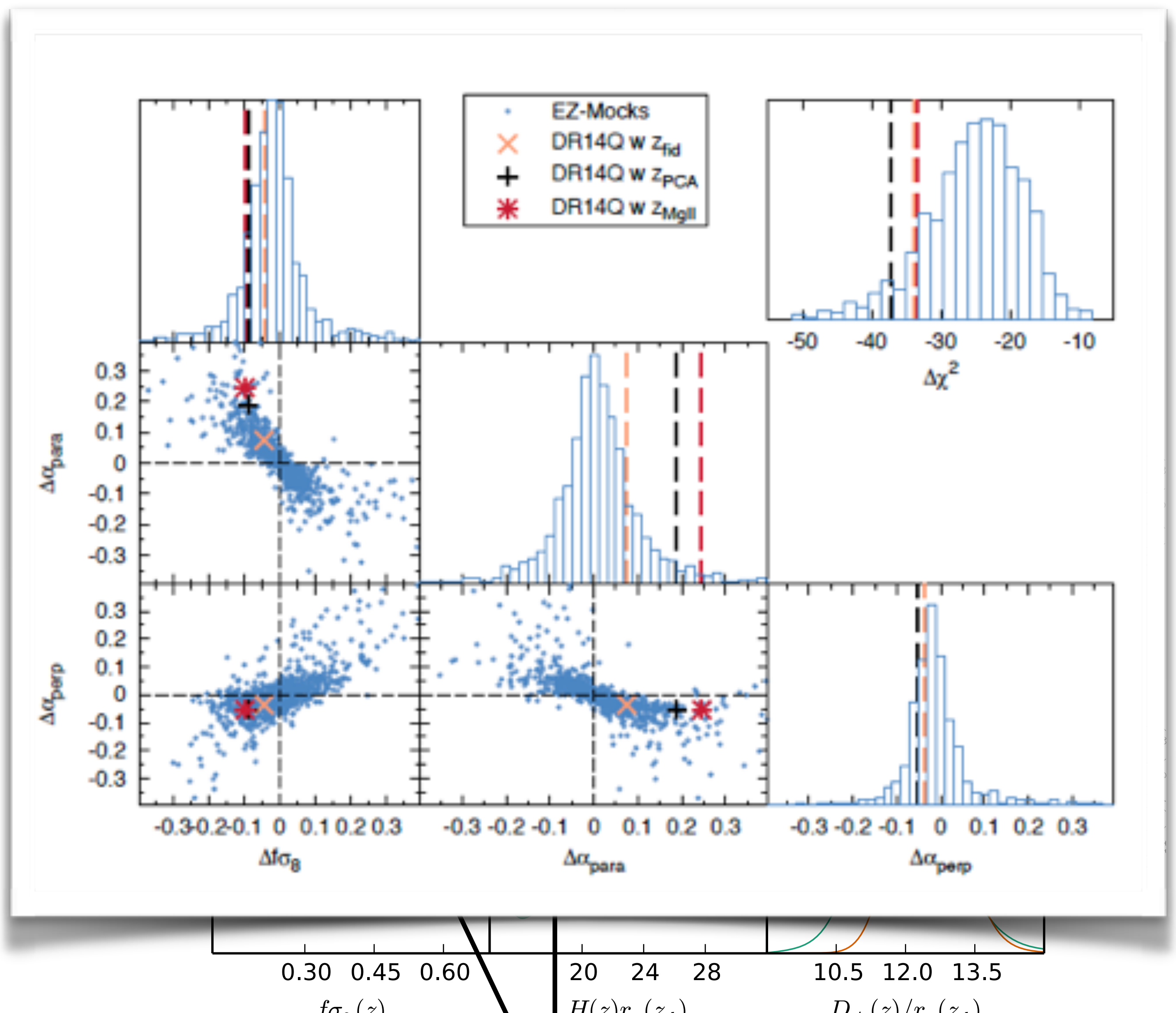


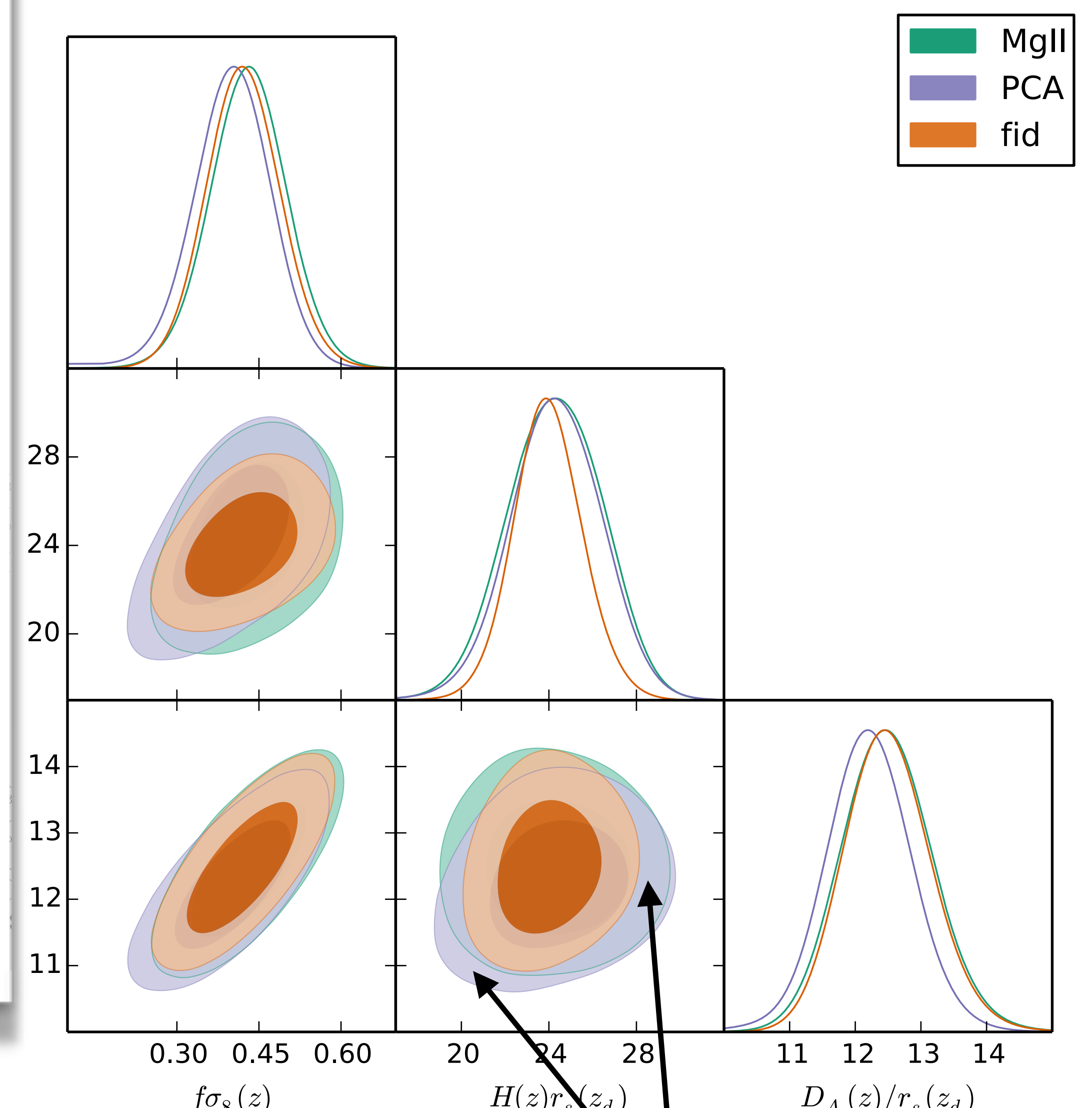
Hexadecapole helps to break H vs. fσ_8 and D_A vs H degeneracies

z_{PCA} larger tails

Consistency results on the data

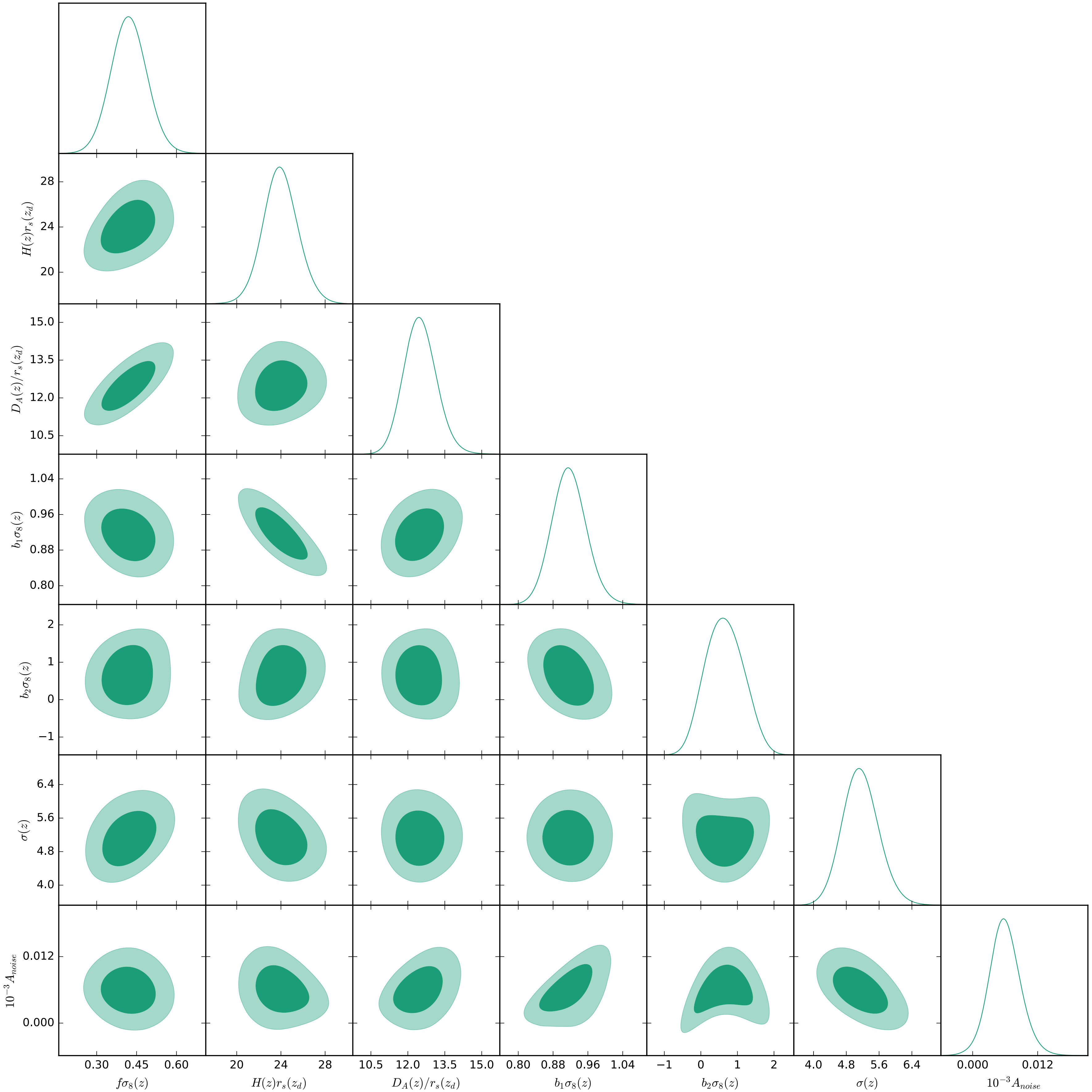
Test the effect of adding/removing the hexadecapole
Test the effect of redshift estimates on the cosmological parameters





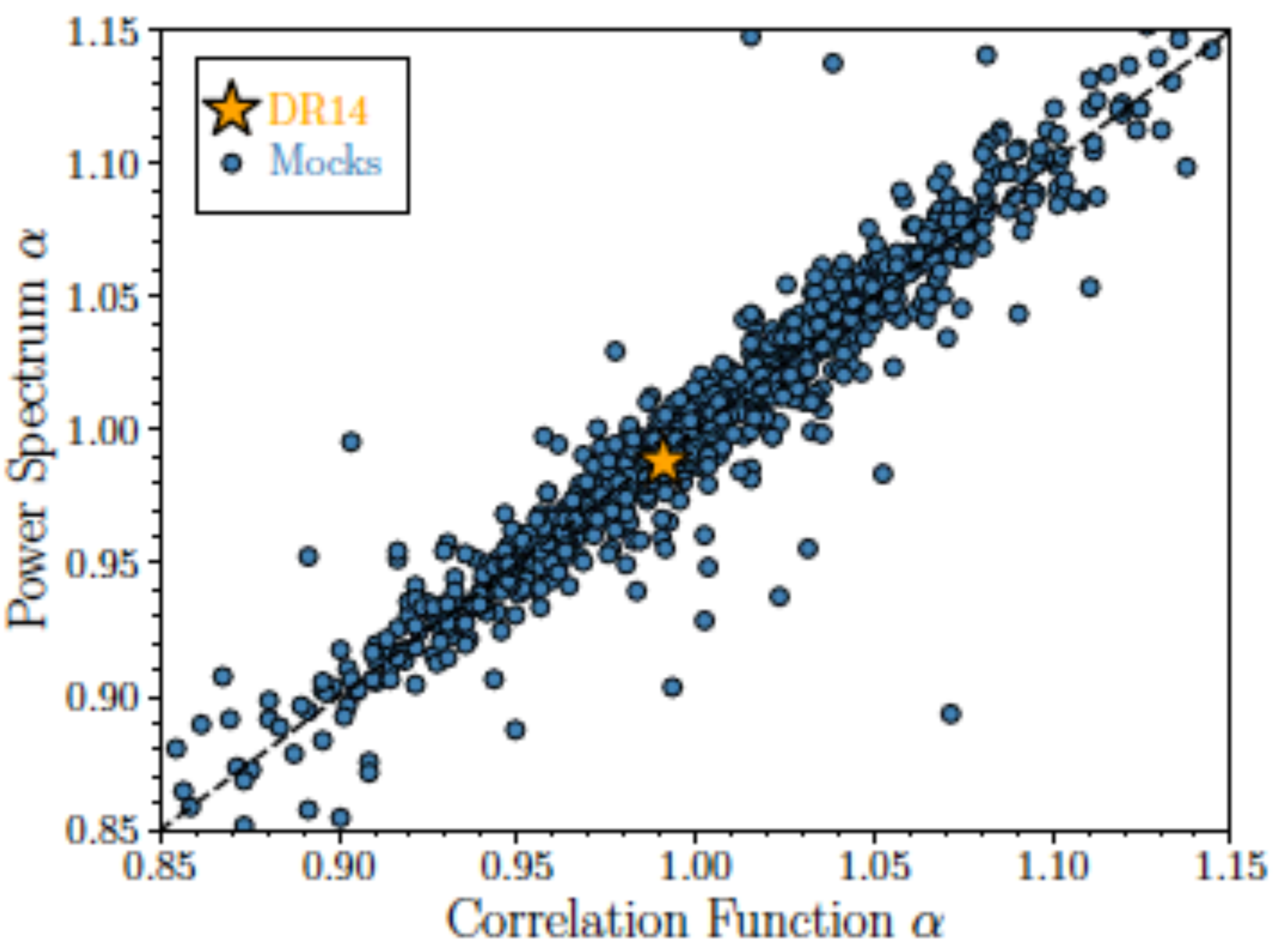
Hexadecapole helps to break H vs. $f\sigma_8$ and D_A vs H degeneracies

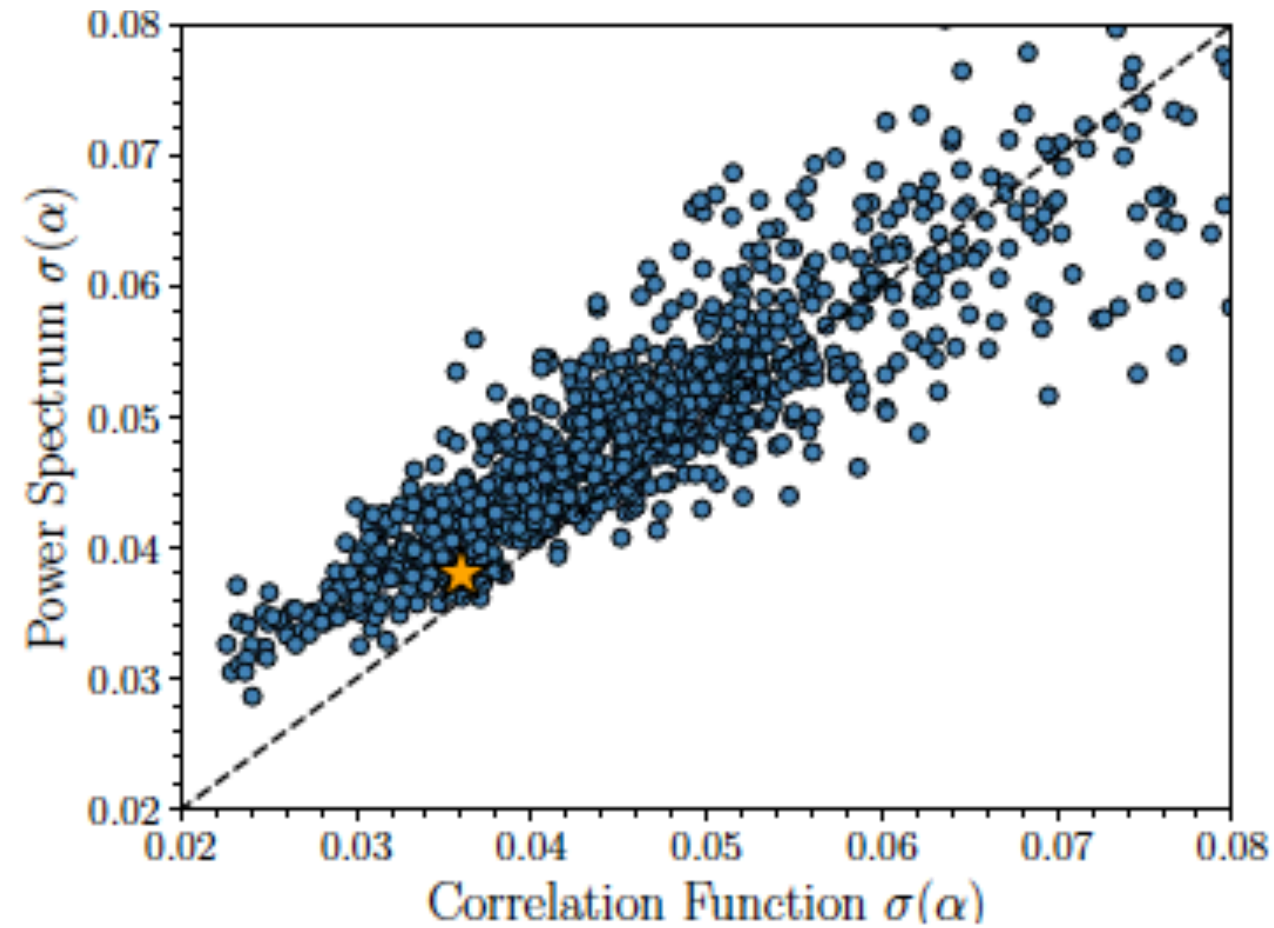
z_{PCA} larger tails



28
24
20
$H(z)r_s(z_d)$
15.0
13.5
12.0
10.5
$D_A(z)/r_s(z_d)$
1.04
0.96
0.88
0.80
$b_1\sigma_8(z)$
2
1
0
−1
$b_2\sigma_8(z)$
6.4
5.6
4.8
4.0
$\sigma(z)$
0.012
0.000
$10^{-3}A_{noise}$
0.30 0.45 0.60
$f\sigma_8(z)$
20 24 28
$H(z)r_s(z_d)$
10.5 12.0 13.5 15.0
$D_A(z)/r_s(z_d)$
0.80 0.88 0.96 1.04
$b_1\sigma_8(z)$
−1 0 1 2
$b_2\sigma_8(z)$
4.0 4.8 5.6 6.4
$\sigma(z)$
0.000 0.012
$10^{-3}A_{noise}$

Test on Mocks





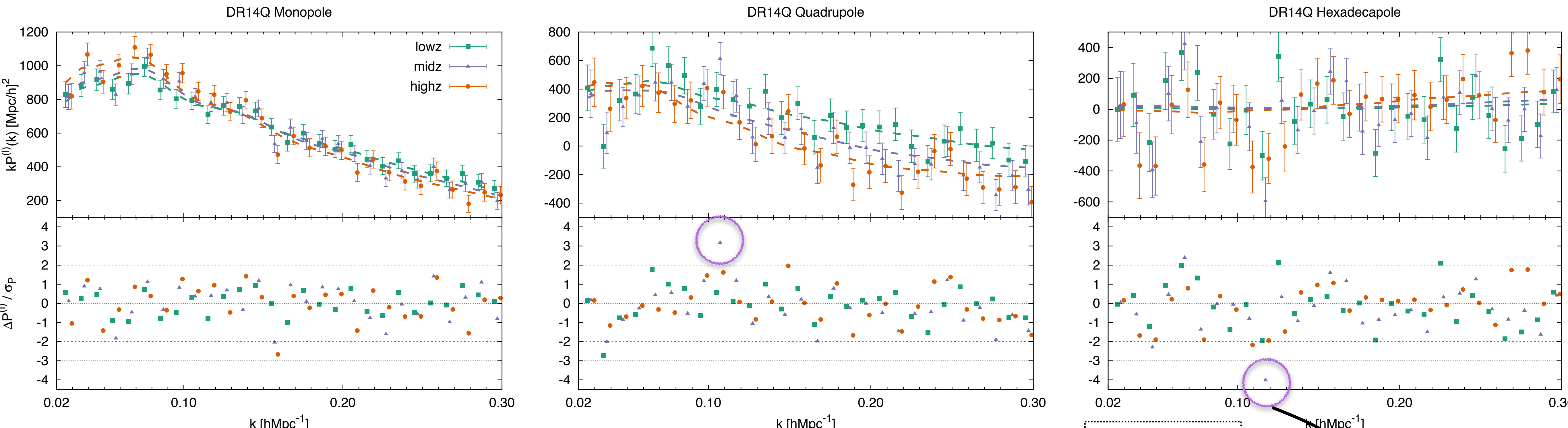
- 1000 mocks used to,

1. Compute the covariance matrix of the data
2. Test the BAO pipeline and compare it to the data

- Selection function on P(k) ⟶ extra damping on BAO

Split the 0.8<z<2.2 in 3 overlapping z-bins

- We individually fit the 3 redshift bins
- The covariance among parameters is computed through the ez-mocks



2σ in NGC
2.6σ in SGC

lowz 0.8<z<1.5
midz 1.2<z<1.8
highz 1.5<z<2.2

- higher Kaiser boost at high z
- higher damping at high z
- Non-understood outliers on midz → χ^2=122/(84-7) (highest mock 107)

χ^2_{MgII}=103/(84-7)

χ^2_{PCA}=107/(84-7)