eBOSS QSO Mock Challenge

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Colloque Dark Energy
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Overview

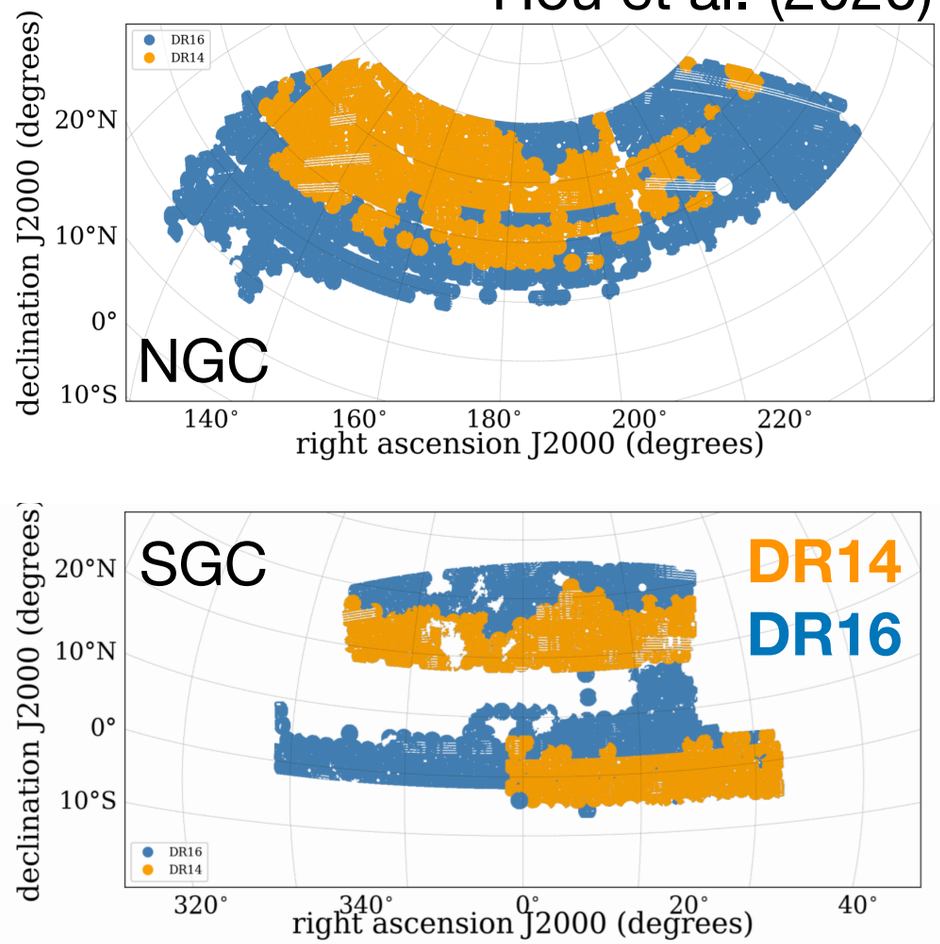
- eBOSS DR16 QSO sample
- QSO mock challenge:
  - Non-blind mocks
  - Blind mocks
  - Results
- Averaging over lines of sight
  - Correlation function uncertainties
  - Growth rate uncertainties
- Conclusions

QSO mock challenge: *arXiv:2007.09003*
Line of sight: *arXiv:2007.11417*

eBOSS DR16 QSO Sample

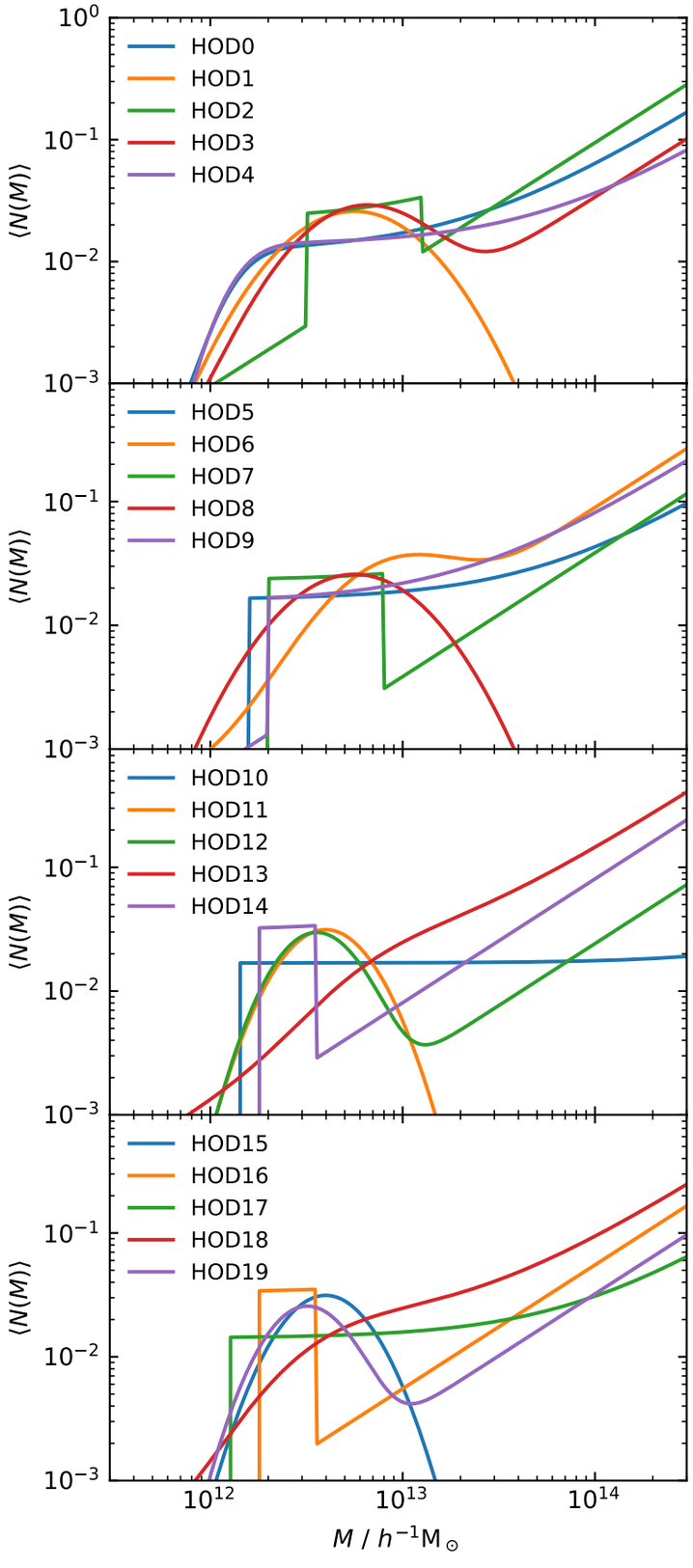
- DR16: ~350,000 QSOs between 0.8<z<2.2, covering ~4,000 sq deg
- Direct tracers of the matter density field
- Number doubled compared to DR14
- Clustering analysis: measure
  - $f\sigma_8$, $\alpha_\parallel$, $\alpha_\perp$
- Mock challenge:
  - Validate RSD models
  - Measure modelling systematic uncertainties
  - Aim: 3% for $f\sigma_8$ and 1% for $\alpha_\parallel$, $\alpha_\perp$
  - Include effects of HOD, z uncertainties (Non-blind)
    fiducial cosmology (Blind)

Hou et al. (2020)



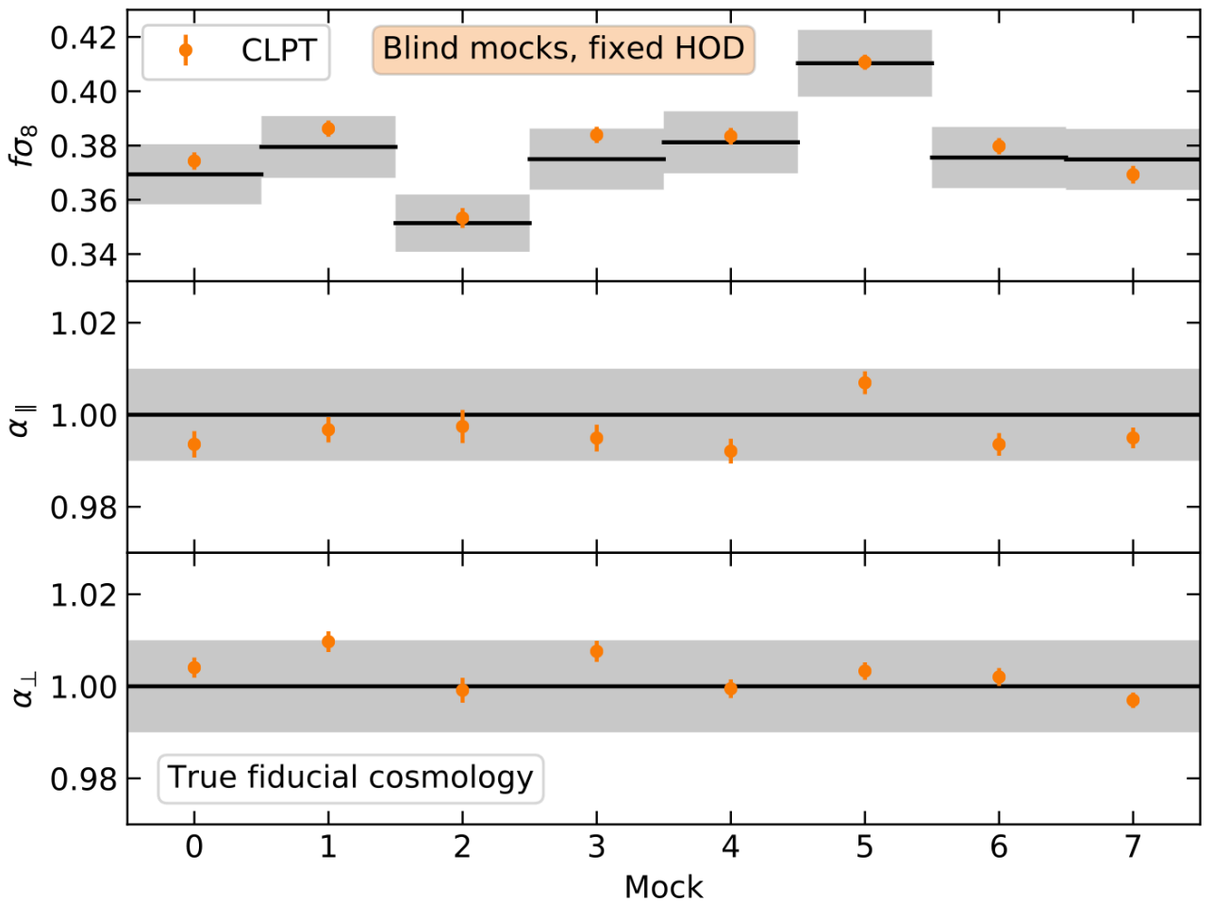
Non-blind mocks

- Mocks constructed from OuterRim simulation (3 Gpc/h), WMAP7 cosmology
- Snapshot at z=1.433
- Populated using a wide range of HODs
- HODs tuned to match clustering and number density of data
- 100 realizations of each HOD (QSO duty cycle ~1%)
- Include effects of redshift smearing and catastrophic redshifts (from data)
- Analysis done using known OuterRim fiducial cosmology



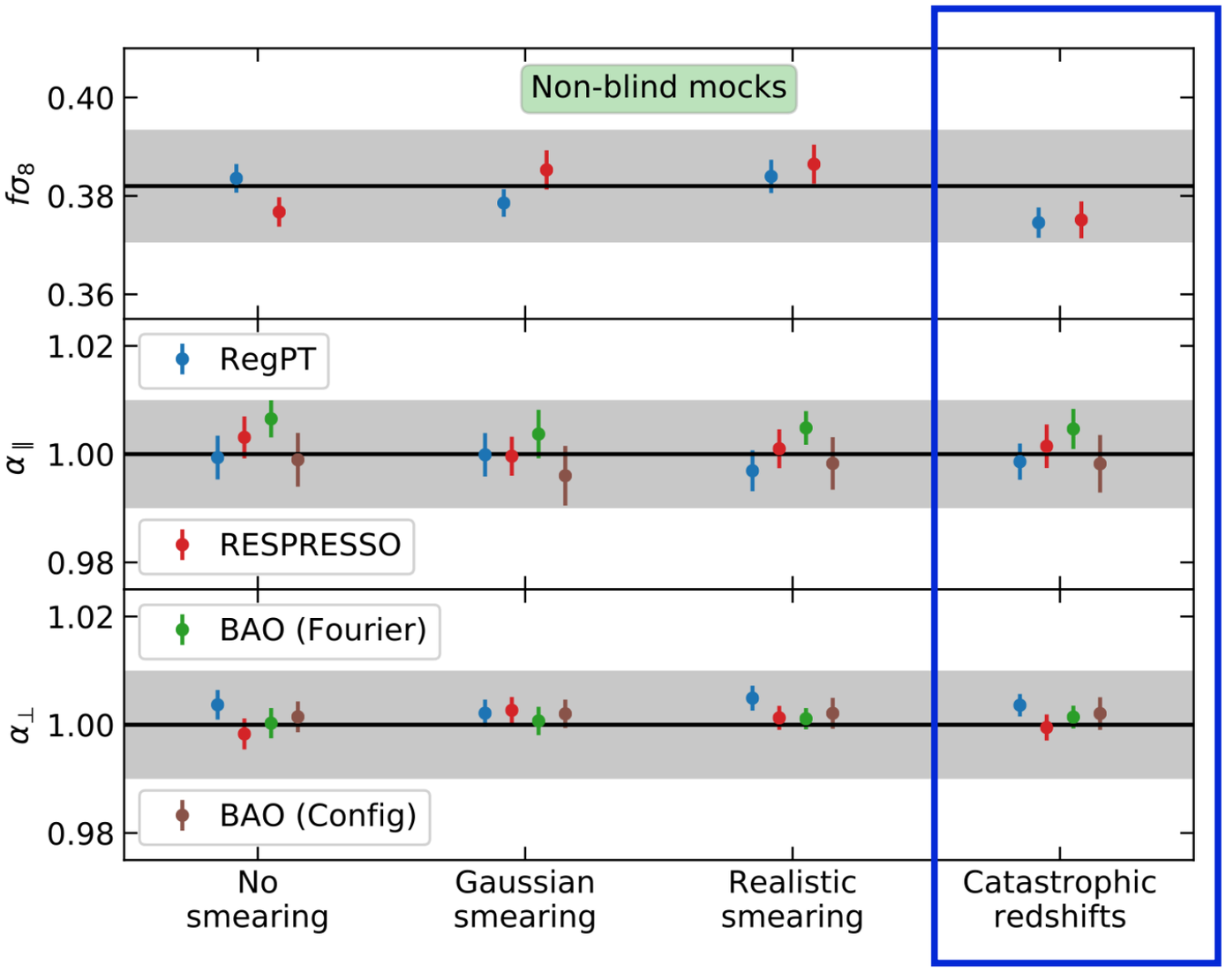
Blind mocks

- Method of Mead & Peacock 2014 to rescale OuterRim cosmology
- Modify the halo catalogue (at redshift z) to mimic a simulation of a different cosmology (at redshift z')
- **First part**: global scaling of simulation coordinates (position, velocity, mass) to match σ(M) of target cosmology
- **Second part**: use Zel'dovich approximation to match P(k) of target cosmology
- Rescaled to 8 new cosmologies (~5% shifts in cosmo params)
- Validated rescaling using CLPT model



Results

- Tested the models used in analysis of Hou (2020) and Neveux (2020)
- Non-blind results



RESPRESSO	RegPT
Hou (2020)	Neveux (2020)
Configuration space	Fourier space
TNS	TNS
RESPRESSO + Fitting function	RegPT (2 loop)

Non-blind systematics (from mocks which include redshift smearing and catastrophic redshifts)

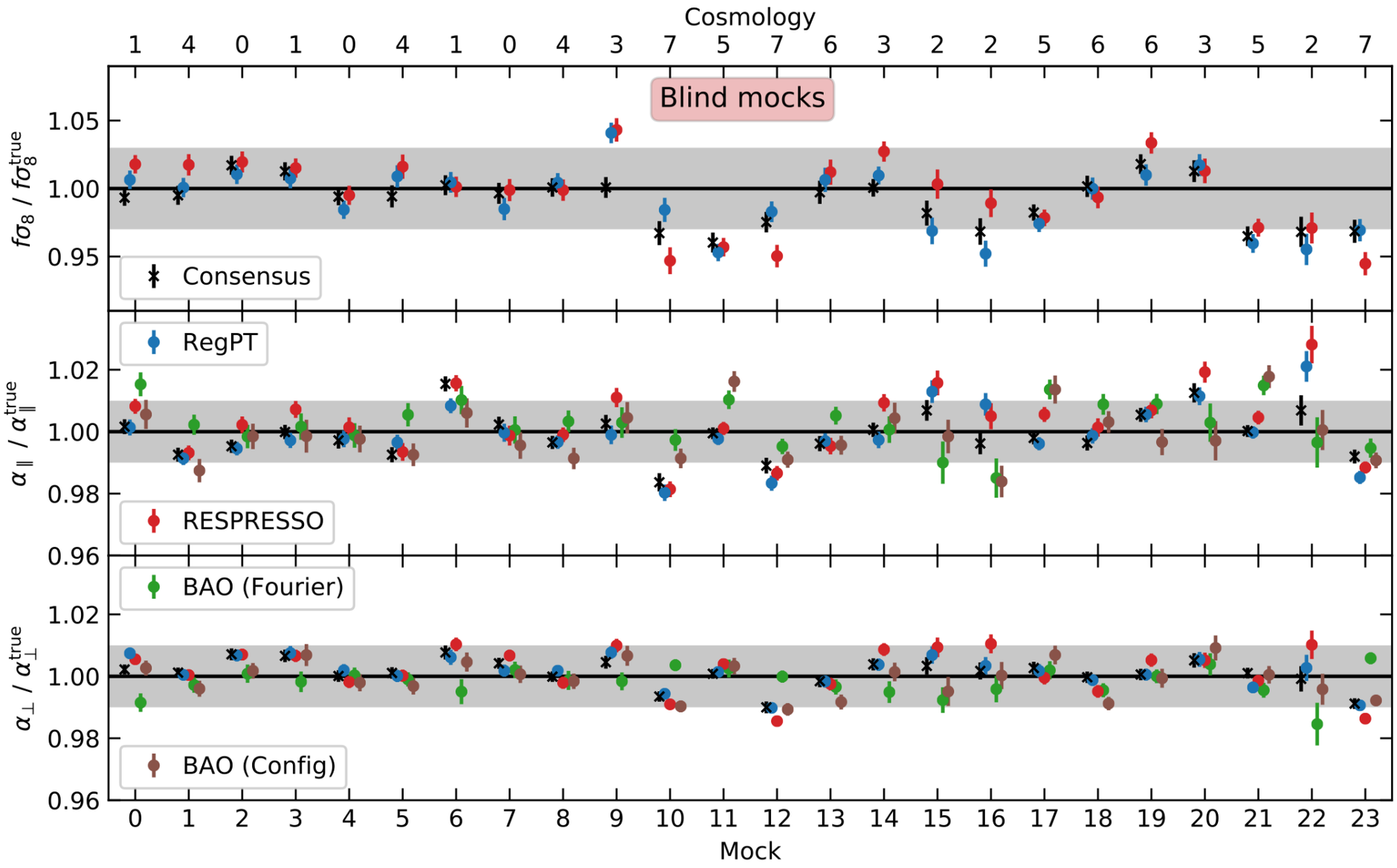
	RESPRESSO	RegPT
$f\sigma_8$	0.008	0.008
$\alpha_\parallel$	0.004	0.004
$\alpha_\perp$	0.004	0.003

Results

- Blind results (using OR fiducial cosmology)
- Largest variations when large difference between fiducial and true cosmology

Blind systematics

	RESPRESSO	RegPT
$f\sigma_8$	0.011	0.009
$\alpha_\parallel$	0.011	0.009
$\alpha_\perp$	0.007	0.005



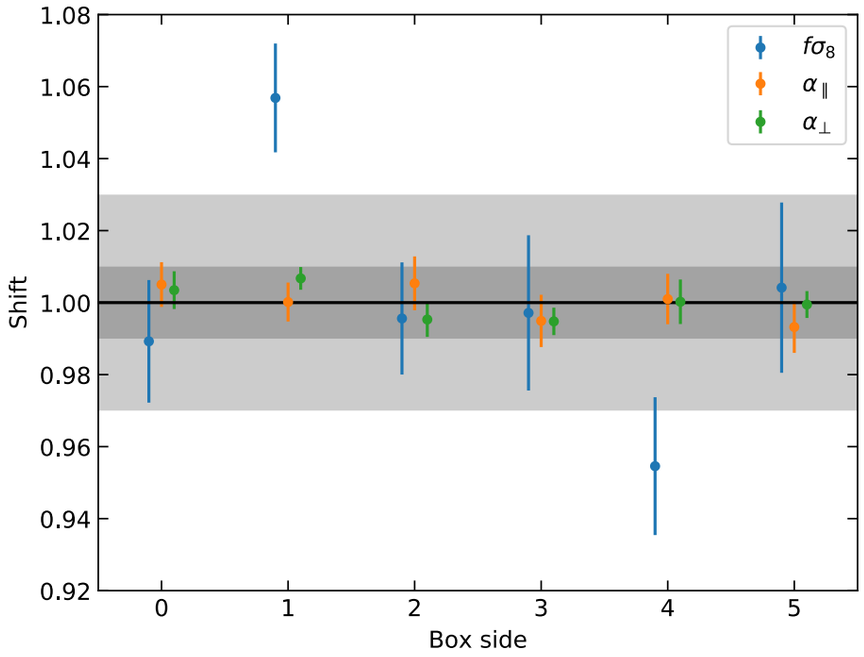
Results

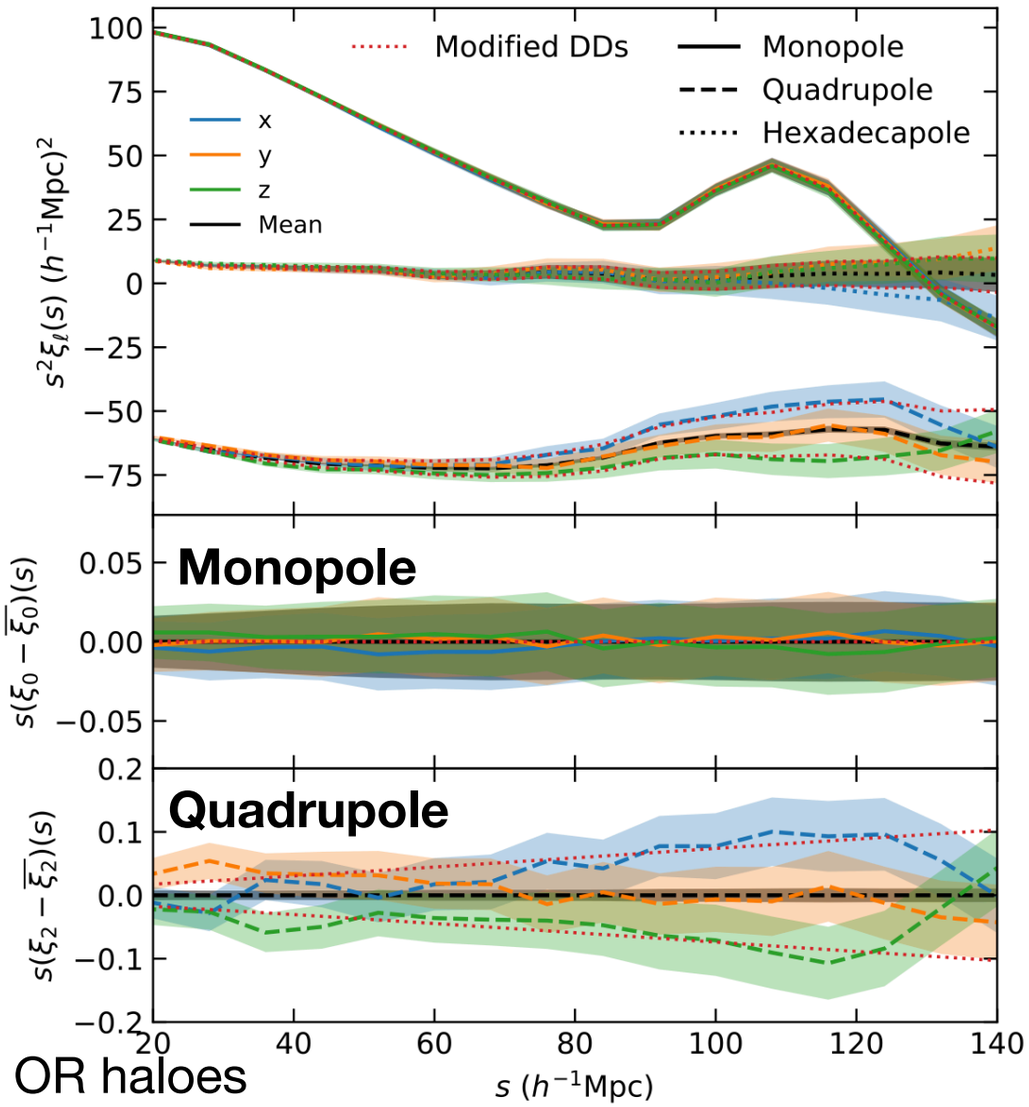
- Combine non-blind and blind results in quadrature
- Both models perform similarly well
- Take conservative modelling systematics for both models
  2.8% in $f\sigma_8$ 1.2% in $\alpha_\parallel$ 0.8% in $\alpha_\perp$
- ~30% of statistical error

	$f\sigma_8$	$\alpha_\parallel$	$\alpha_\perp$
RegPT	0.0123	0.0098	0.0066
RESPRESSO	0.0131	0.0117	0.0078
Consensus	0.0106	0.0079	0.0048
BAO (Fourier)	-	0.0098	0.0055
BAO (Configuration)	-	0.0102	0.0067

Line of Sight

- For different choices of observer position, $f\sigma_8$ varied by as much as ~5%
- Surprising, given 3 Gpc/h box



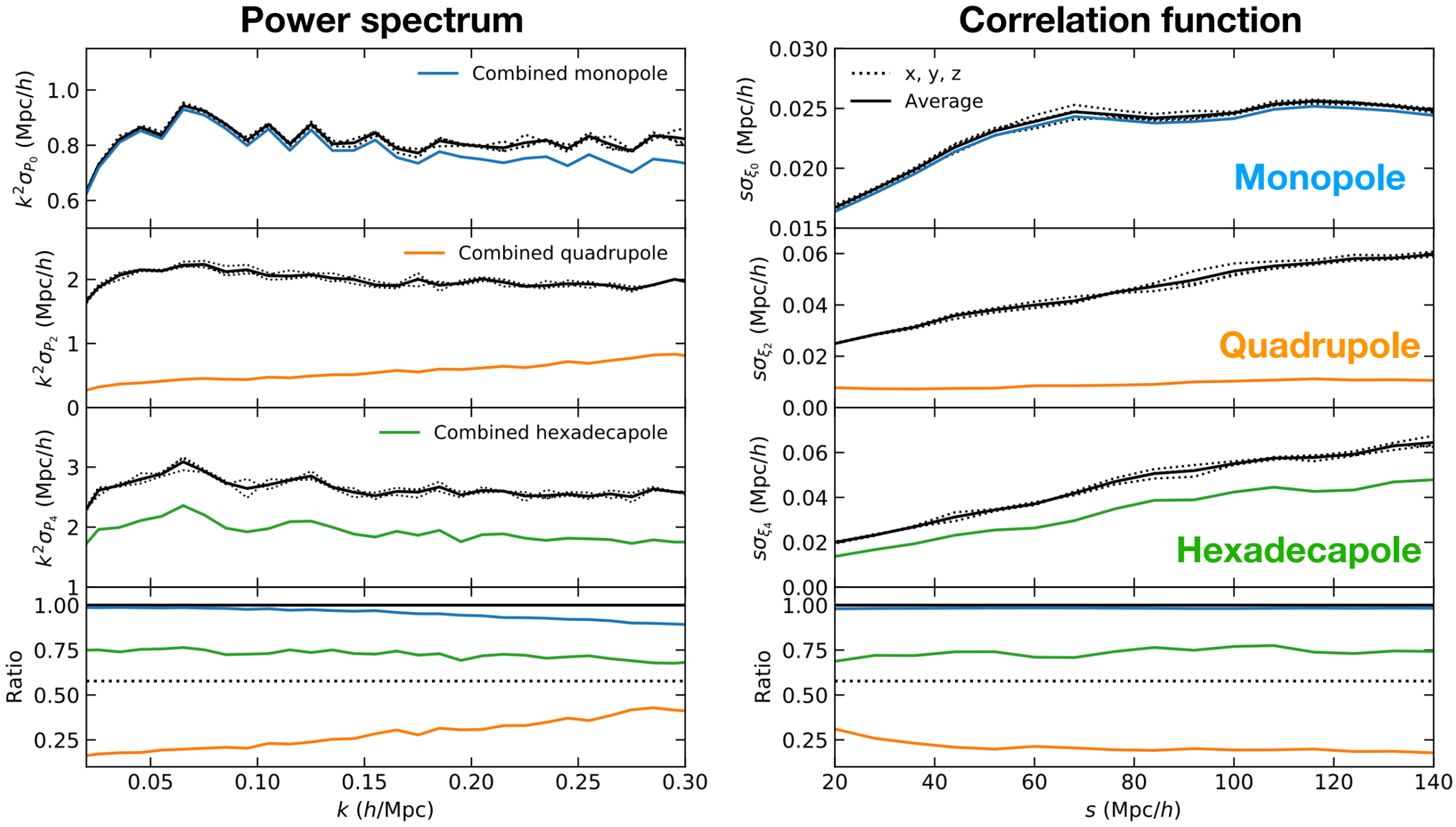


OR haloes
M>3e12 Msun/h

- Related to amplitude of quadrupole
- Large variations in quadrupole seen on large scales in halo catalogue
- Due to velocities along different LOS
- Tiny variations in velocity distributions strongly amplified in correlation function quadrupole

Averaging over LOS

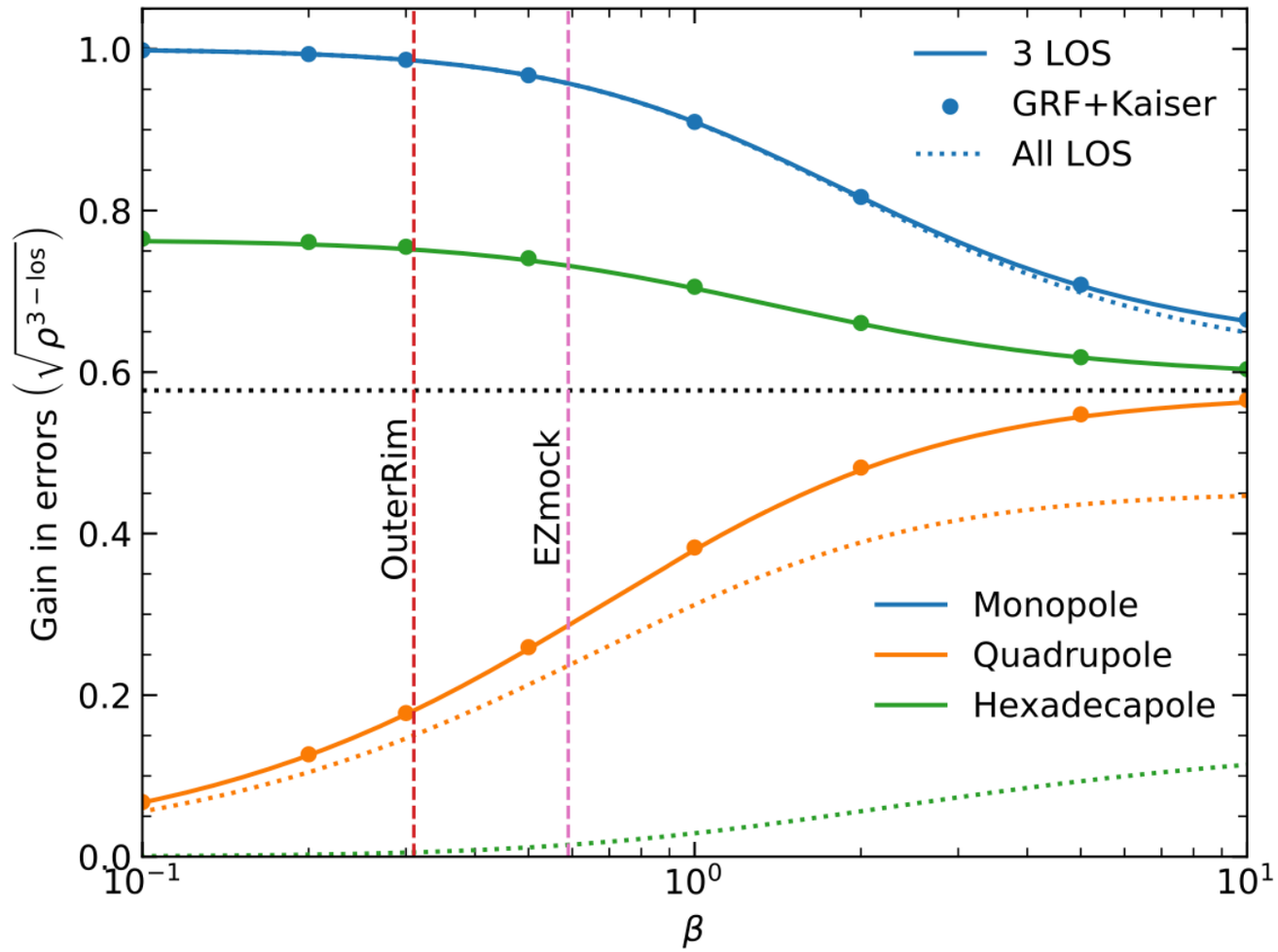
- Jackknife uncertainties from OuterRim halo catalogue
- When averaging over 3 orthogonal LOS, large gains in quadrupole uncertainty, much better than $\sqrt{1/3}$



Quadrupole anti-correlation

- Quadrupole measurements for 2 LOS are anti-correlated
- For orthogonal LOS, no shot noise, cross correlation (ρ^{xy}) only depends on $\beta=f/b$
- Averaging over 3 LOS, gain in errors

$$\rho^{3-\mathrm{los}} = \sqrt{\frac{1+2\rho^{xy}}{3}}$$



- For OR halo catalogue, predicted gains consistent with measurements (on large scales)

Growth rate anti-correlation

- We performed a full-shape analysis on the P(k) measurements from a set of 300 eBOSS ELG EZmocks
- When averaging over 3 orthogonal LOS, an anti-correlation is seen in the growth rate
- Even when small scales included, a weak anti-correlation is still seen
- Very important to average over LOS with 1 mock (like in mock challenge)

Large scales

	$[0.03, 0.12]h\mathrm{Mpc}^{-1}$	$f\,\sigma_8$
Cross-correlation	ρ^{xy}	-0.244 ± 0.016
	Prediction	-0.274
Gain in uncertainties	$\sqrt{\rho^{3-\mathrm{los}}}$	0.414 ± 0.013
	Prediction	0.388

Small scales

	$[0.03, 0.2]h\mathrm{Mpc}^{-1}$	$f\,\sigma_8$
Cross-correlation	ρ^{xy}	-0.076 ± 0.041
	Prediction	-0.035
Gain in uncertainties	$\sqrt{\rho^{3-\mathrm{los}}}$	0.532 ± 0.025
	Prediction	0.557

Conclusions

- Validated and measured modelling systematics for RSD models used in QSO DR16 clustering analysis
- Using Blind and Non-blind mocks from OuterRim simulation
- Include effects of HOD, redshift uncertainties, cosmology
- Results affected by choice of line of sight
- Anti-correlation in quadrupole (and growth rate) measurements for 2 LOS
- Large gains in uncertainties when averaging over LOS
- Important to do this for eBOSS mock challenge (1 simulation)
- In future, can help constrain models while require fewer simulations