Why we need you: confessions of a LSS end user

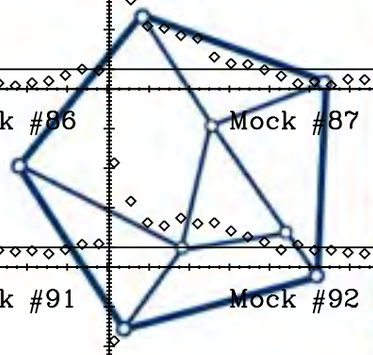
Eyal Kazin

In collaboration with:

Chris **Blake**, Ariel **Sánchez**

The **Wigglez** Dark Energy Survey

The SDSS-III **B**aryonic **O**scillation **S**pectroscopic **S**urvey



CAASTRO

ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

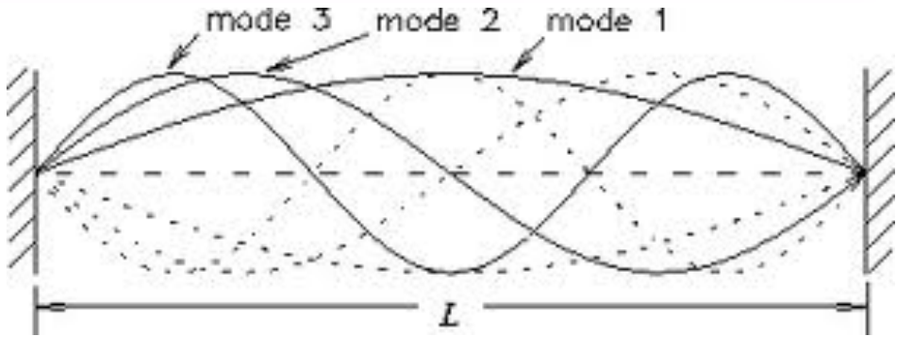
SWINBURNE UNIVERSITY OF TECHNOLOGY

Mock catalogs are essential to analyze the large-scale structure

- To build reliable covariance matrixes
- To test for cosmic variance
- To test for analysis systematics
- To test the technique of reconstruction of the baryonic acoustic feature

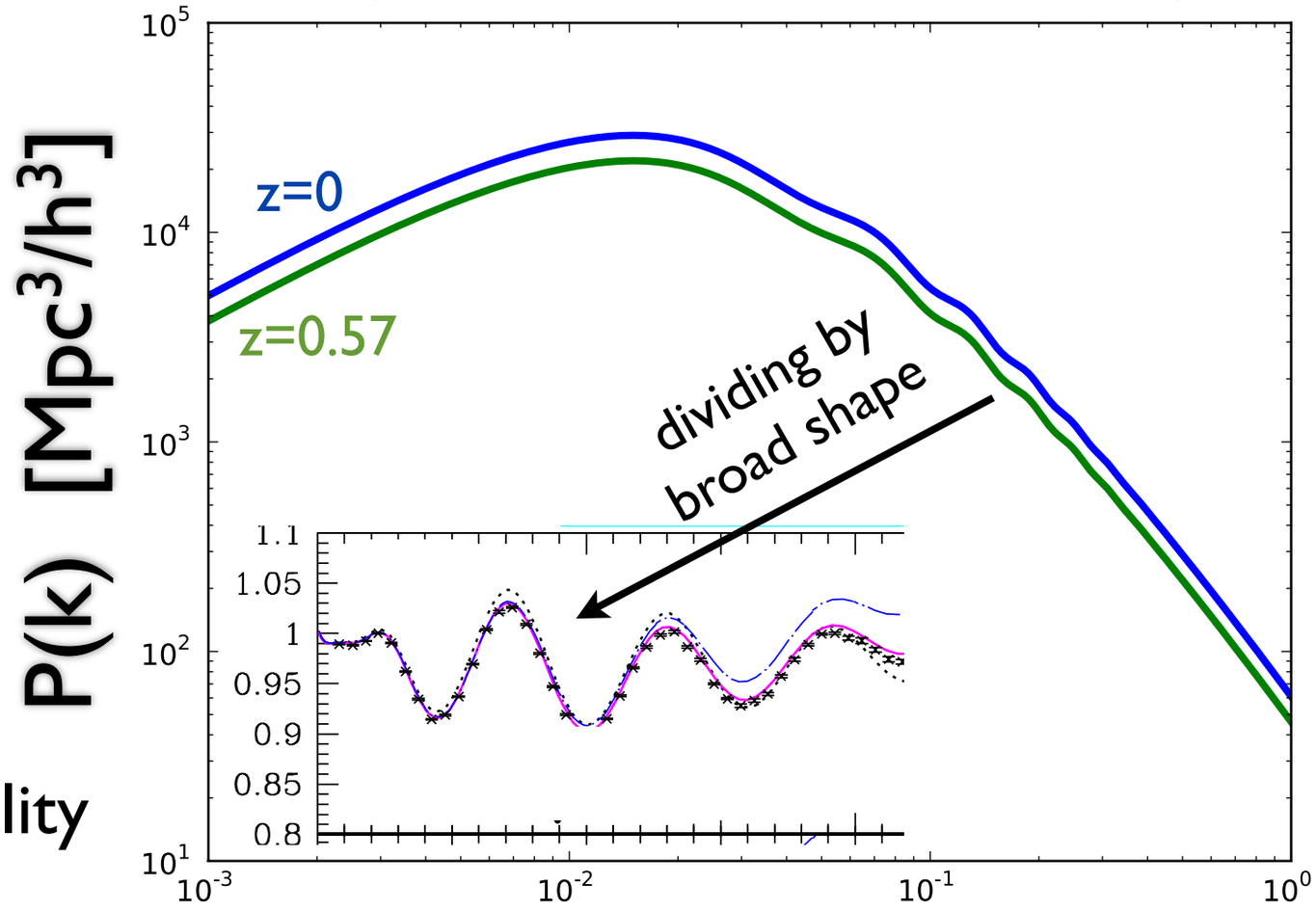
P(k): the executive summary

$P(k) \sim \langle \delta(k)^2 \rangle_{all\ modes}$



Sample variance: improves with volume *V*
Shot noise: improves with density *n*

$$\Delta P(k) \sim \frac{P(k)+n^{-1}}{k^{3/2}\sqrt{V}}$$

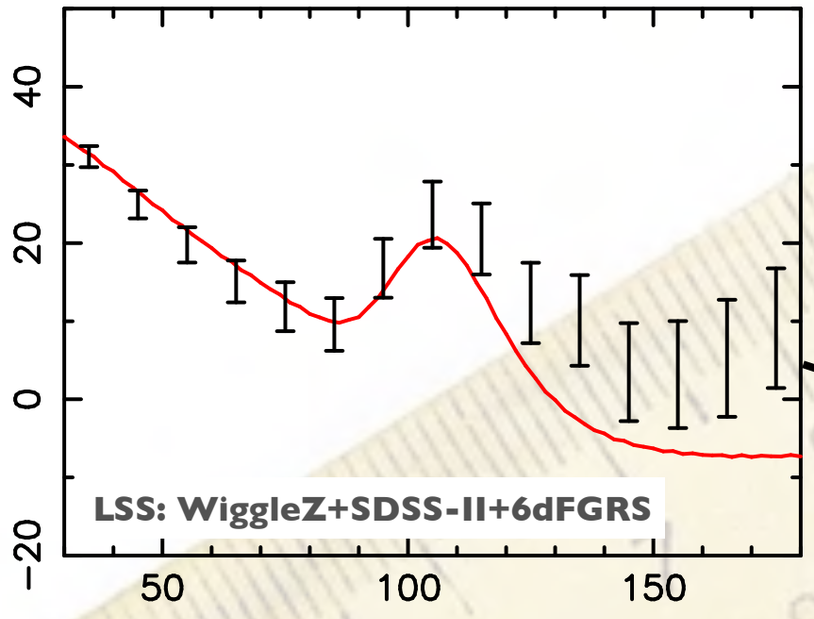


Information encoded:

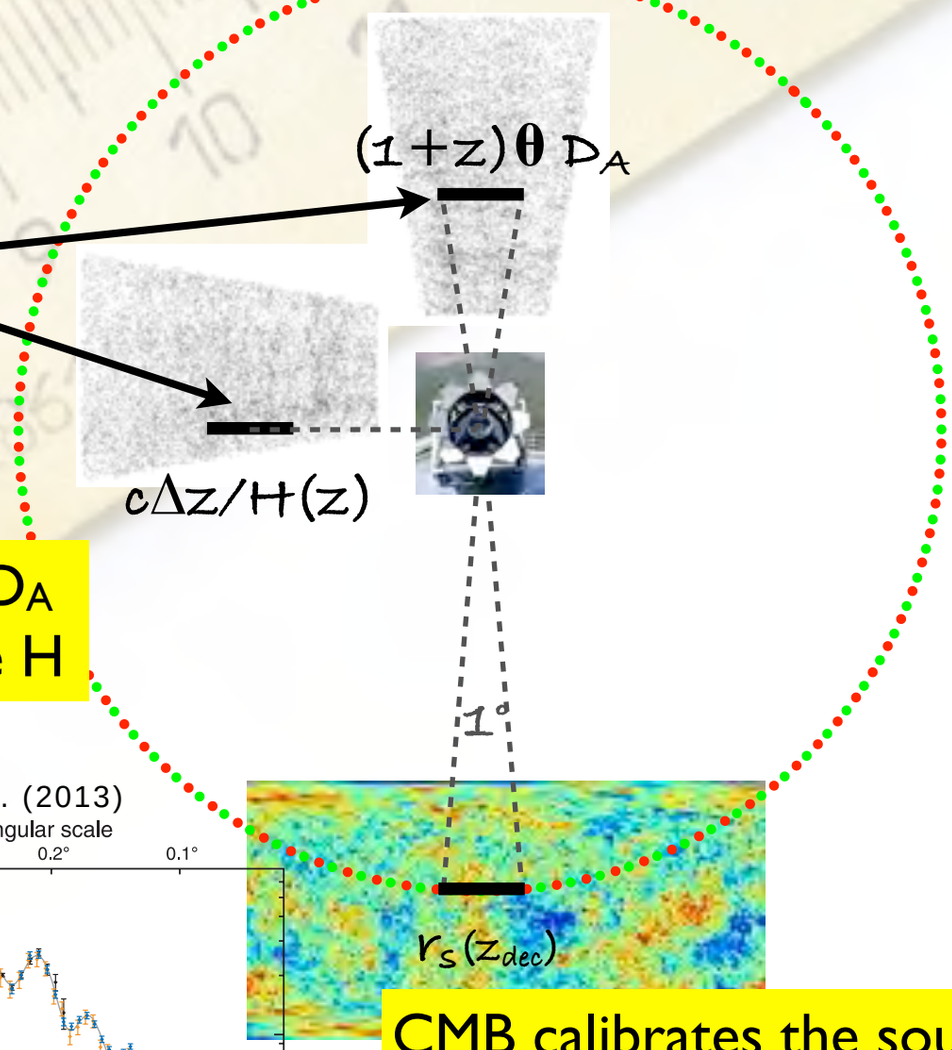
- gravity
- z_{eq} radiation and matter equality
- geometry

BA Feature as a Standard Ruler

Blake, Kazin, Beutler & WiggleZ (2011)

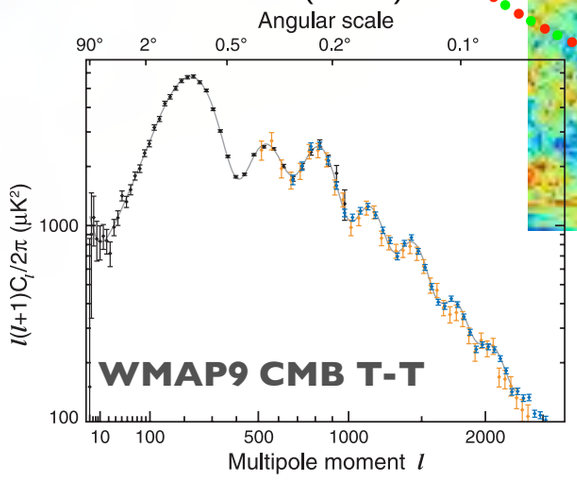


Surface of last scattering
z~1100 (not to scale...)



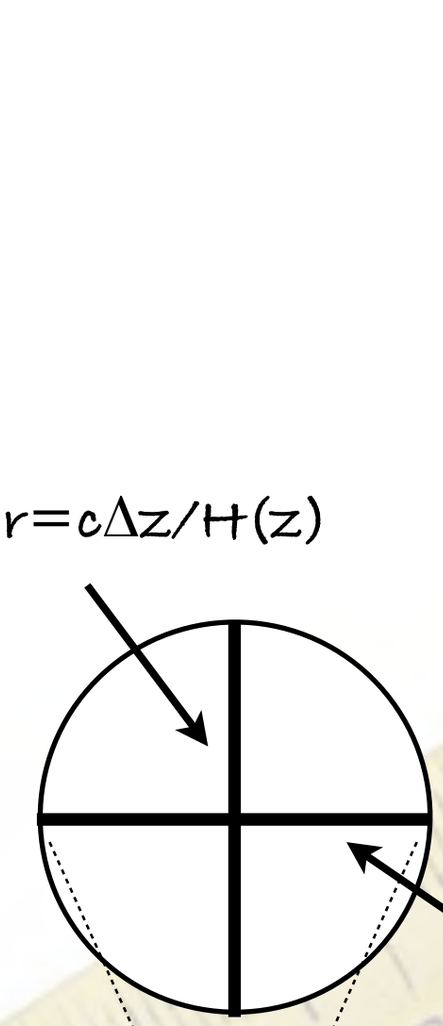
Transverse clustering modes measure D_A
Line-of-sight clustering modes measure H

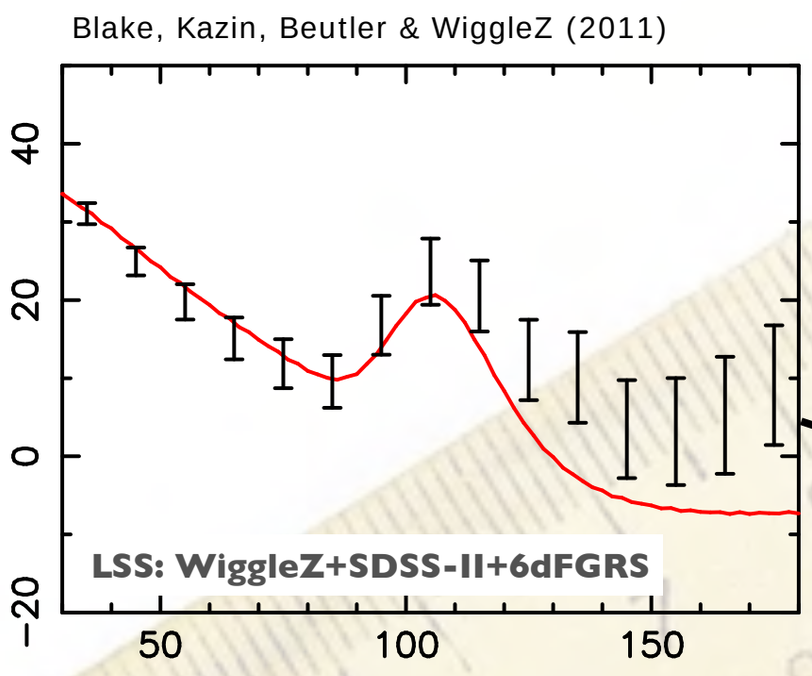
Hinshaw et al. (2013)



CMB calibrates the sound horizon r_s to 0.4% accuracy
(Planck Collaboration XVI)

BA Feature as a Standard Ruler





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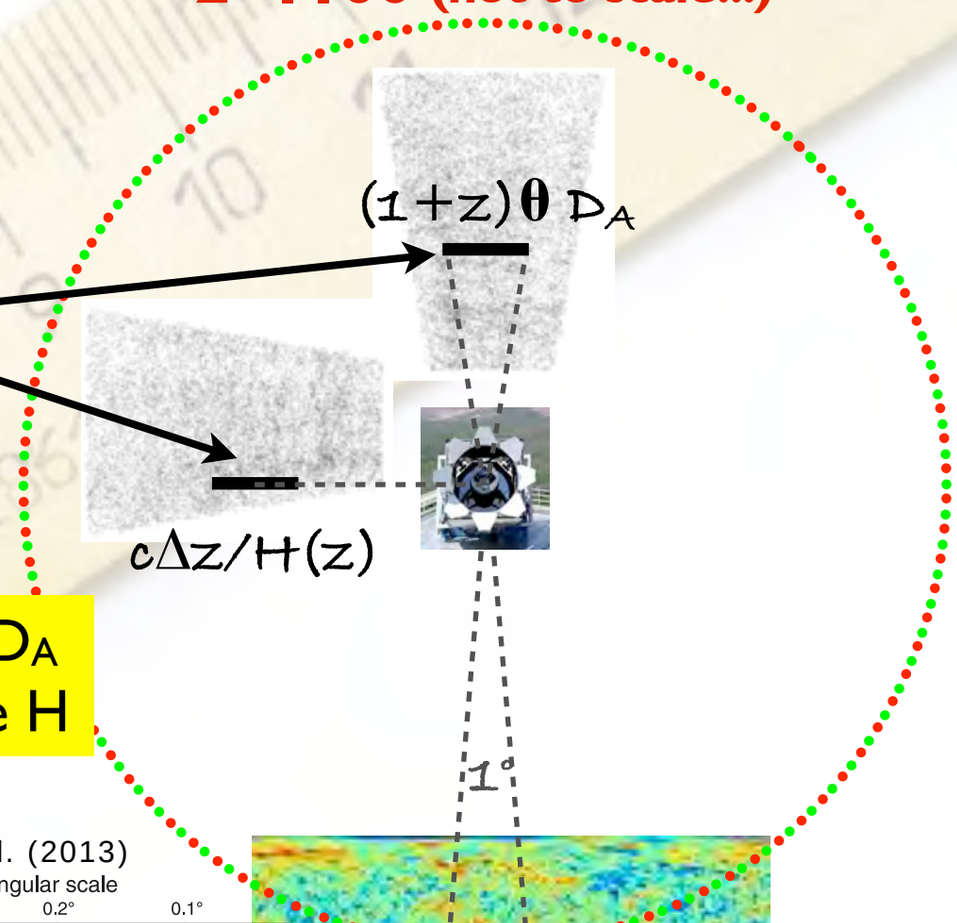

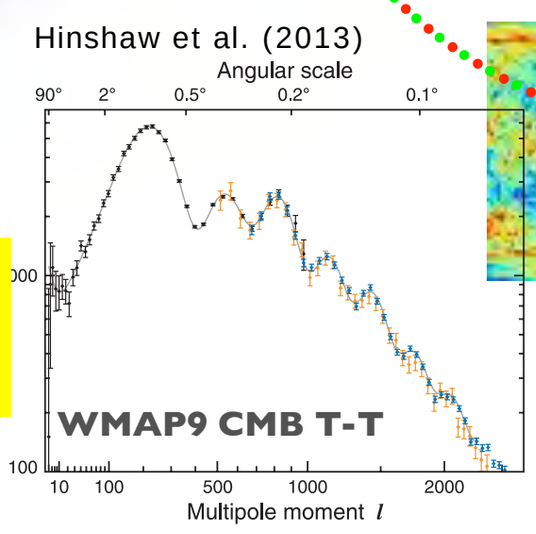

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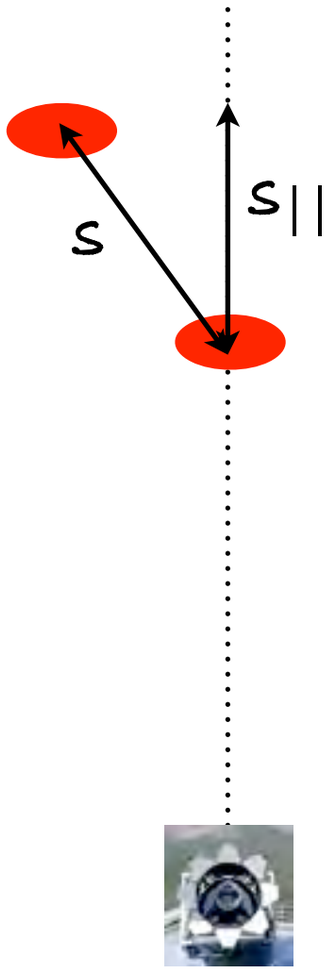
Standard Sphere!

Clustering Anisotropies: because two peaks are better than one



Averaging 160 LasDamas (SDSS-II LRG volume) simulations

$\xi_\perp \rightarrow D_A$

``yard stick"

$\xi_{||} \rightarrow H$

``speedometer"

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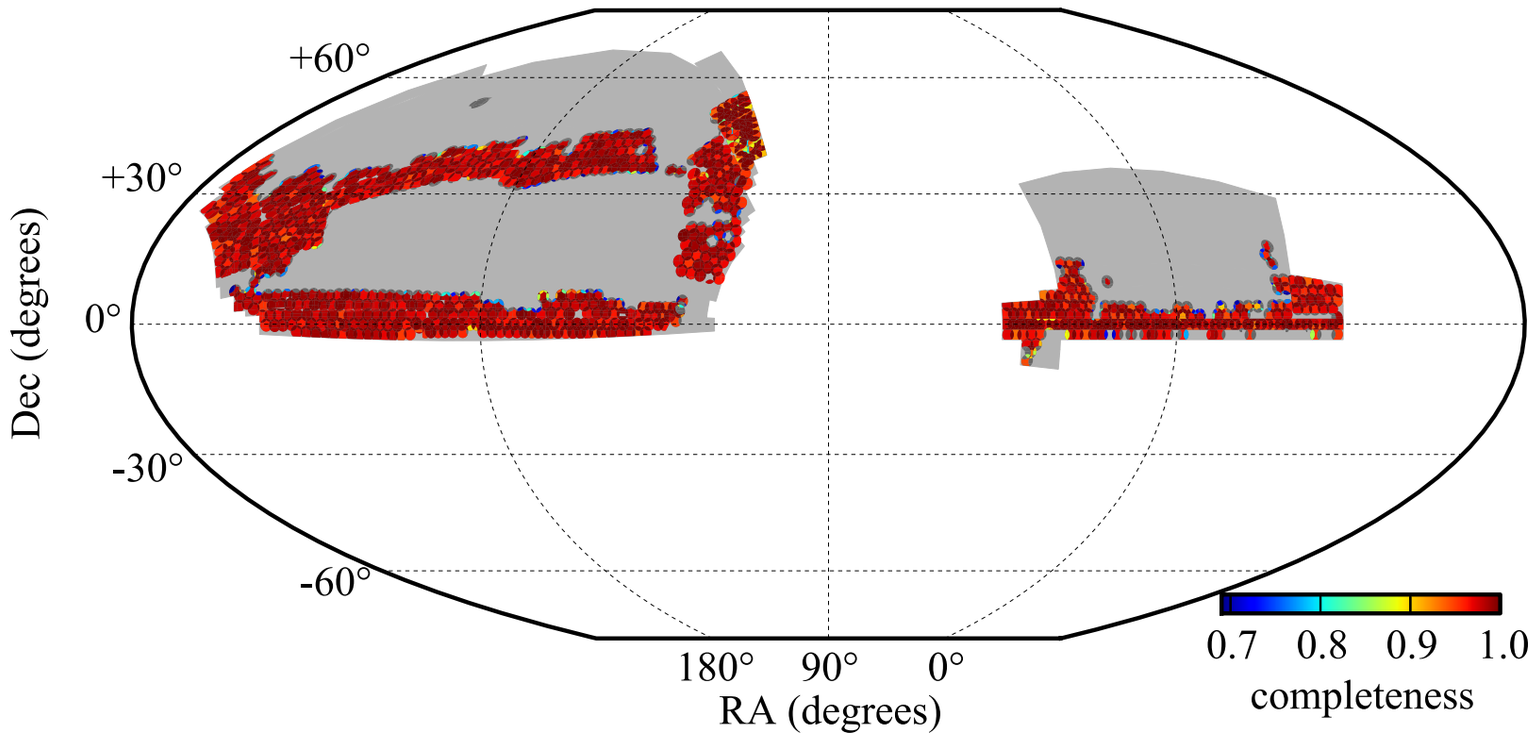
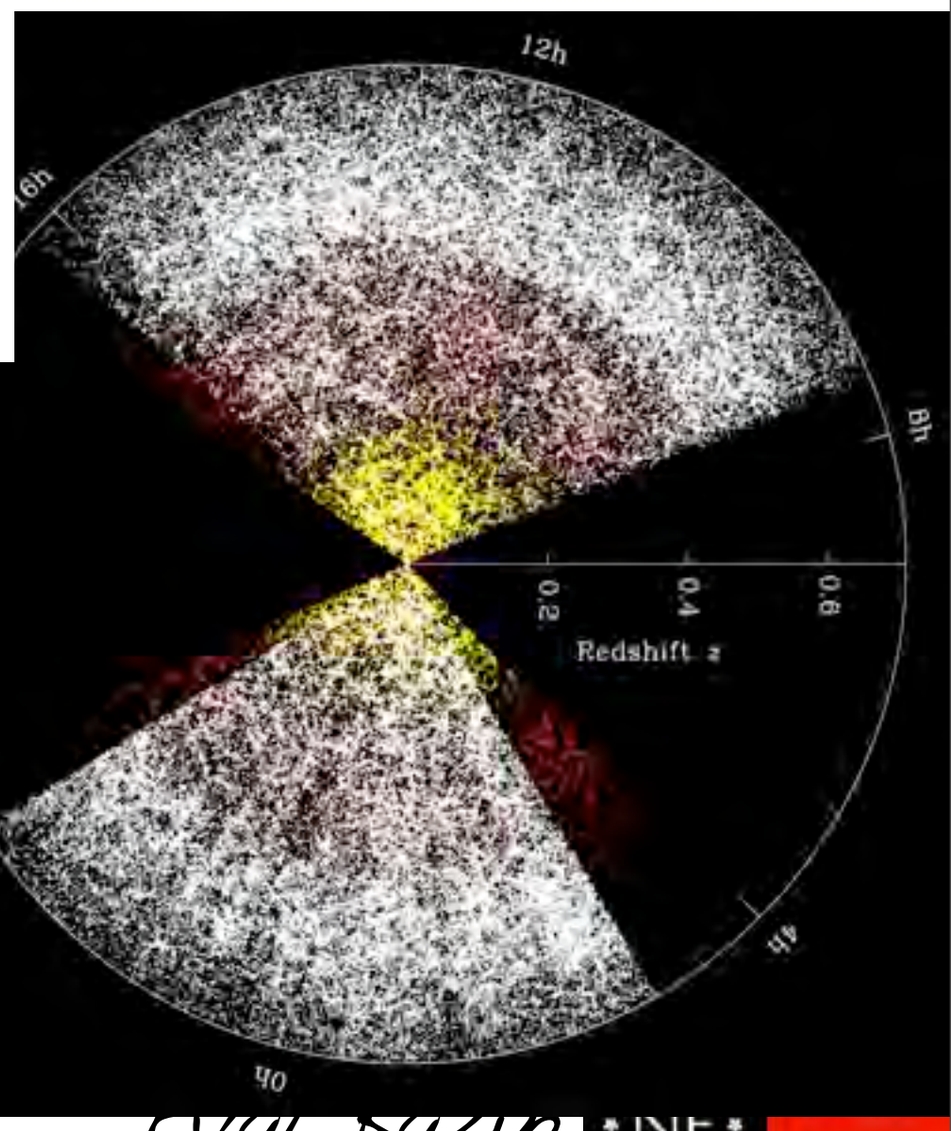
the SDSS-III BOSS



CMASS sample:

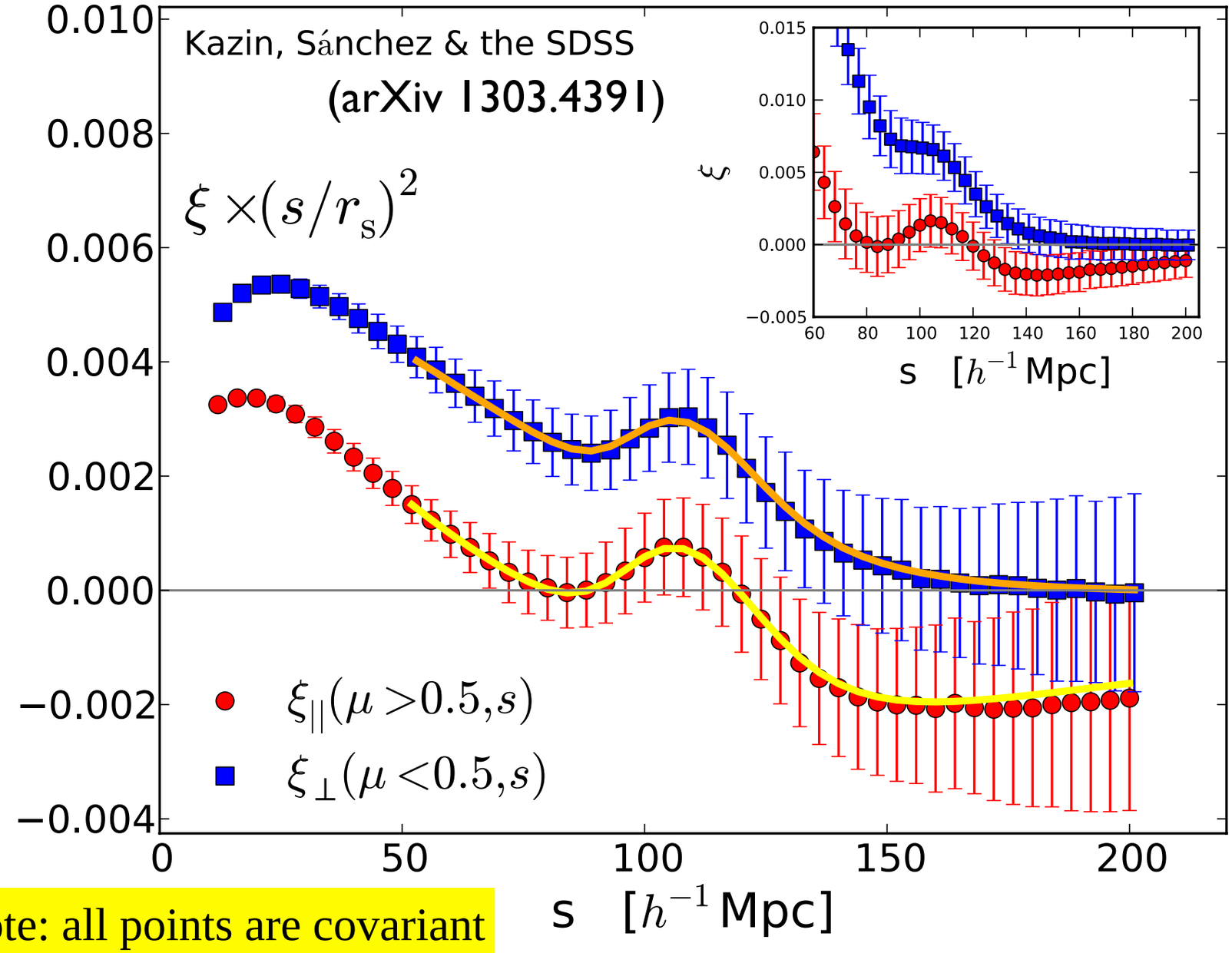
- 264,000 massive galaxies
- $0.43<z<0.7$ $\langle z\rangle=0.57$
- Volume of 2.2 Gpc^3
- density ~ $3\cdot10^{-4} h^3 Mpc^{-3}$



Apache Point NM, USA

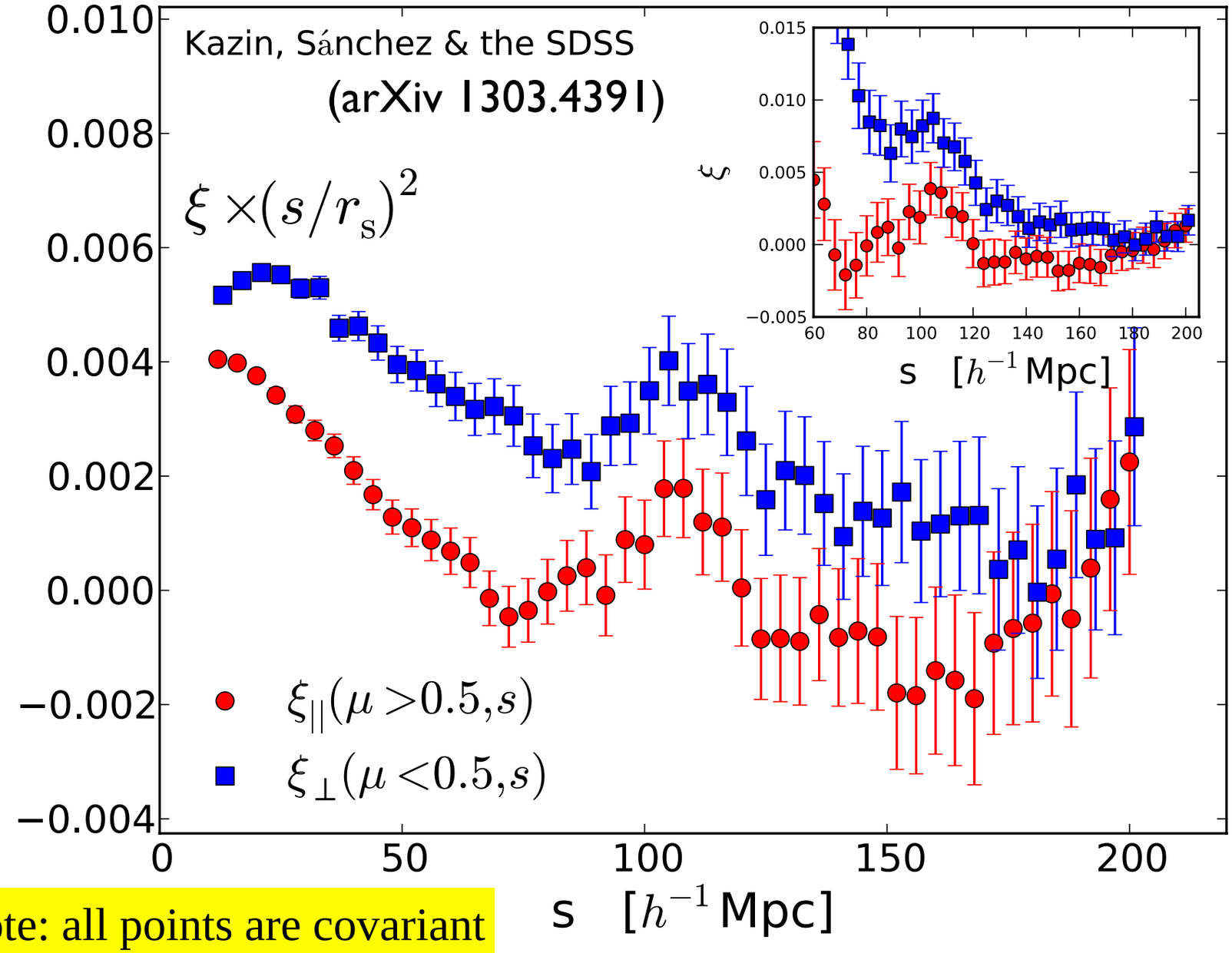
BOSS Results: Simulated Data

Averaging 600 PTHalo BOSS volumes by Manera et al. (2012)



Note: all points are covariant

BOSS Results: Data



Note: all points are covariant

BOSS BA Feature: Measuring H(z), D_A(z) from BA Feature only

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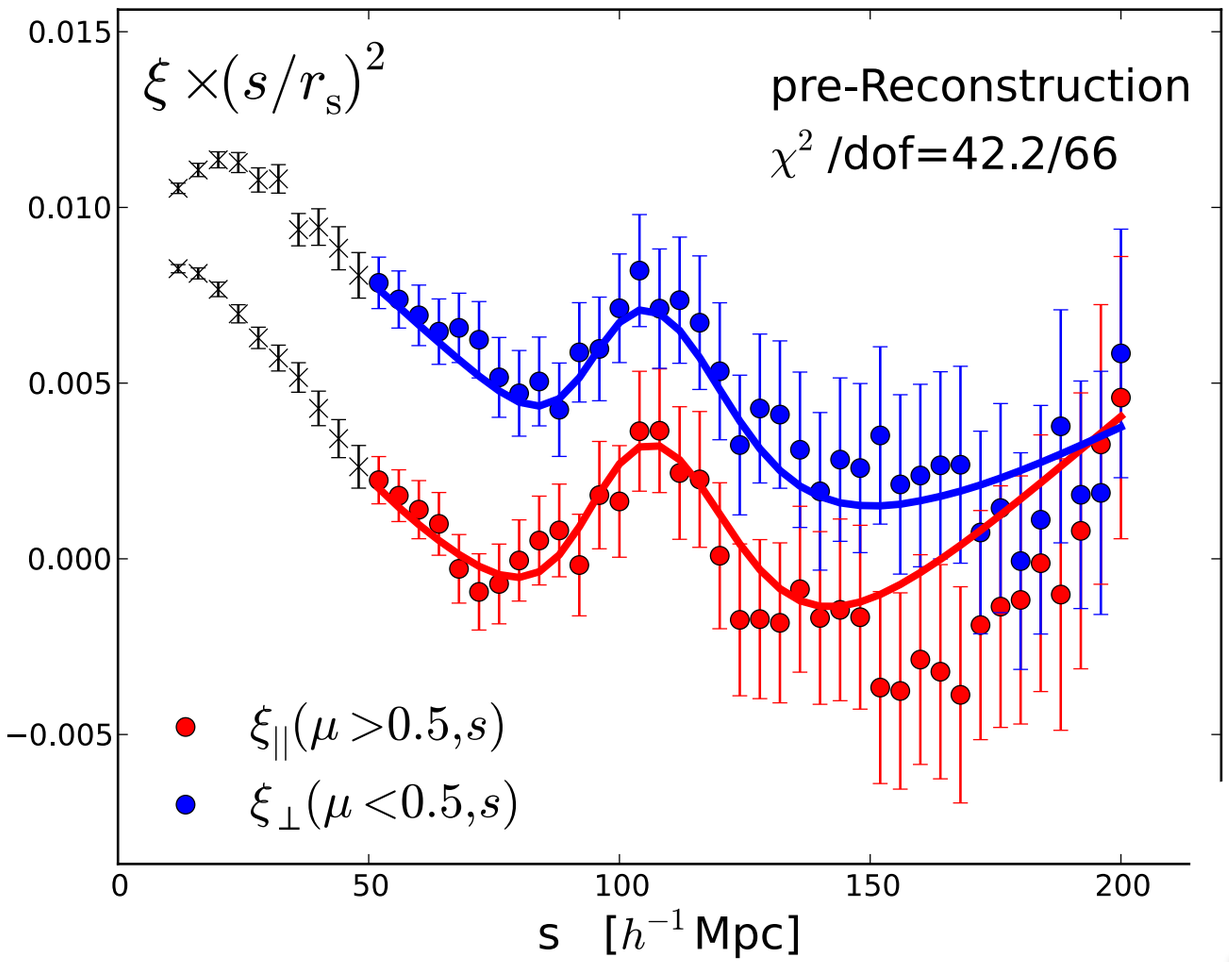
Model independent constraints:

$\Delta H/H \sim 6.5\%$

$\Delta D_A/D_A \sim 3\%$



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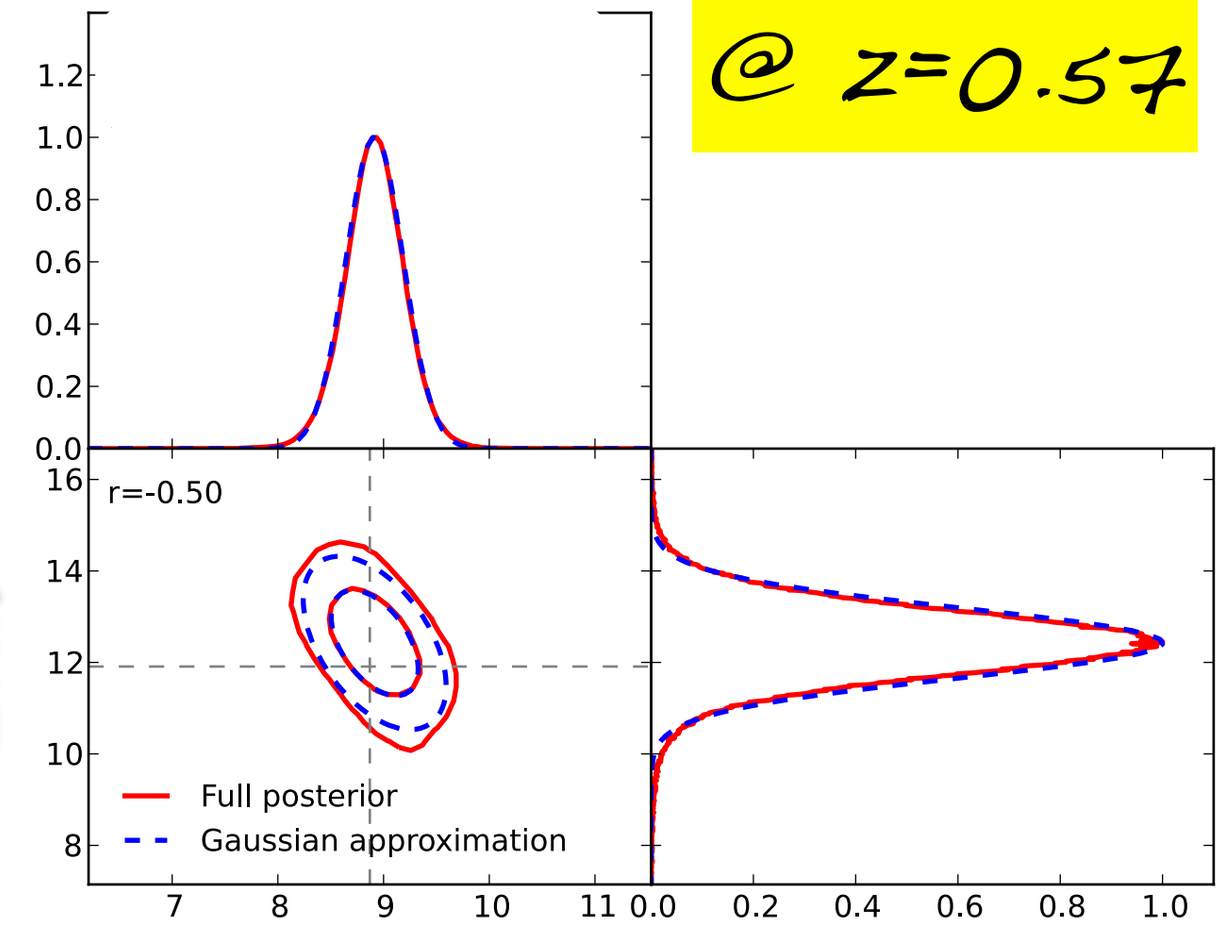

Kazin, Sánchez & SDSS (arXiv 1303.4391)

Is this measurement reliable?

DR9 $H(z)$, $D_A(z)$ expectations pre -Rec from mock catalogs

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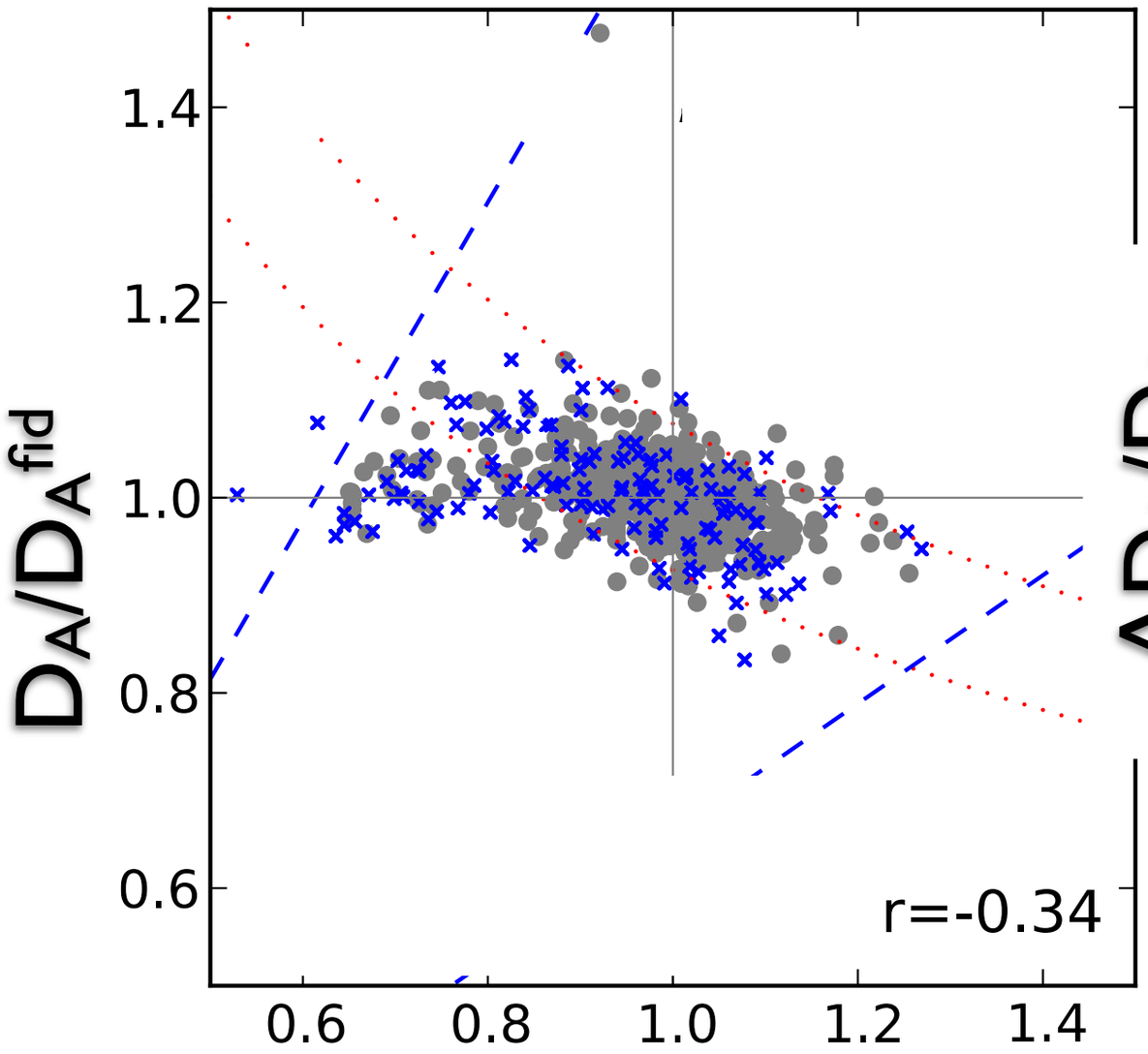
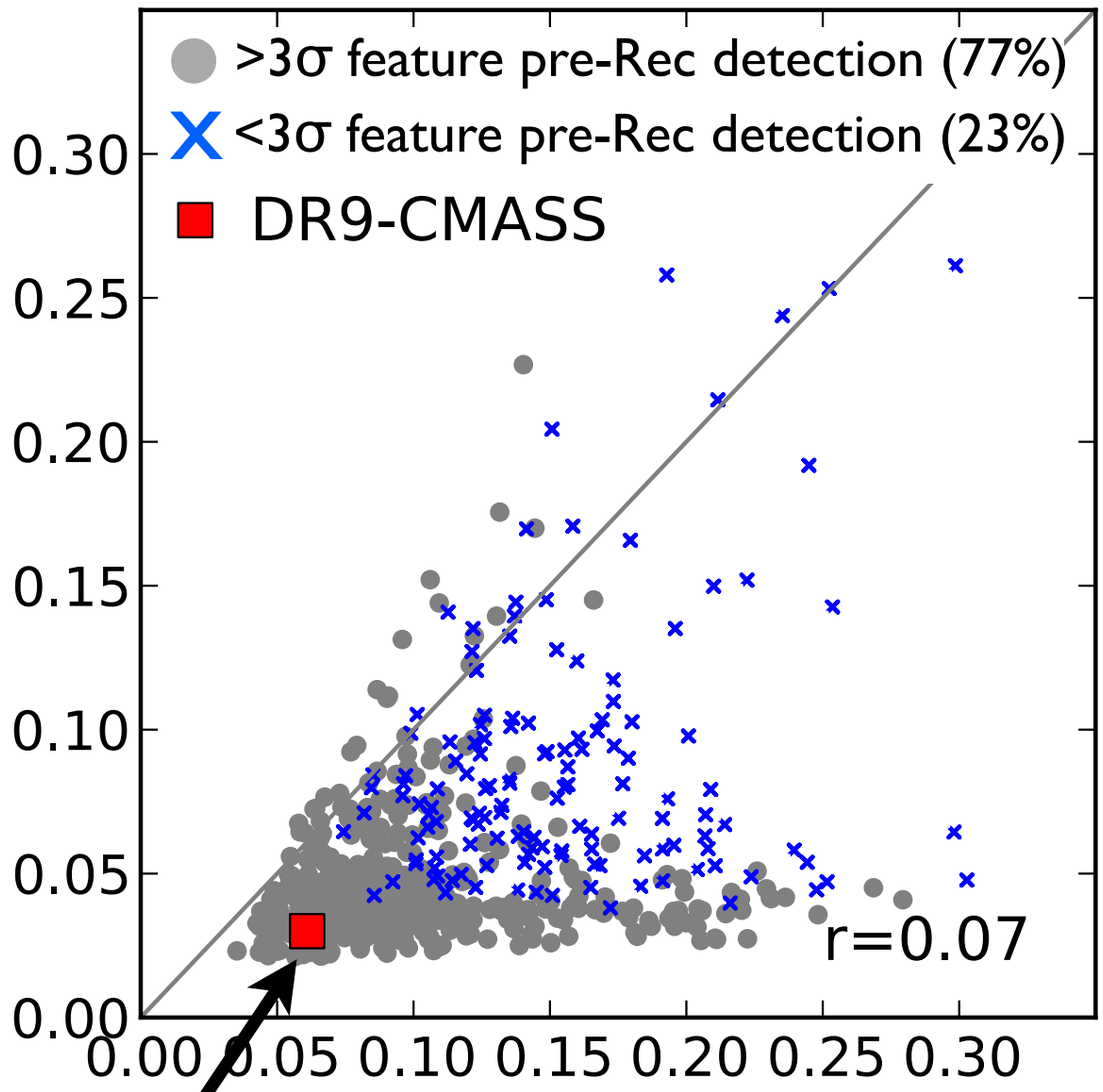
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

Testing for bias



Constraining power



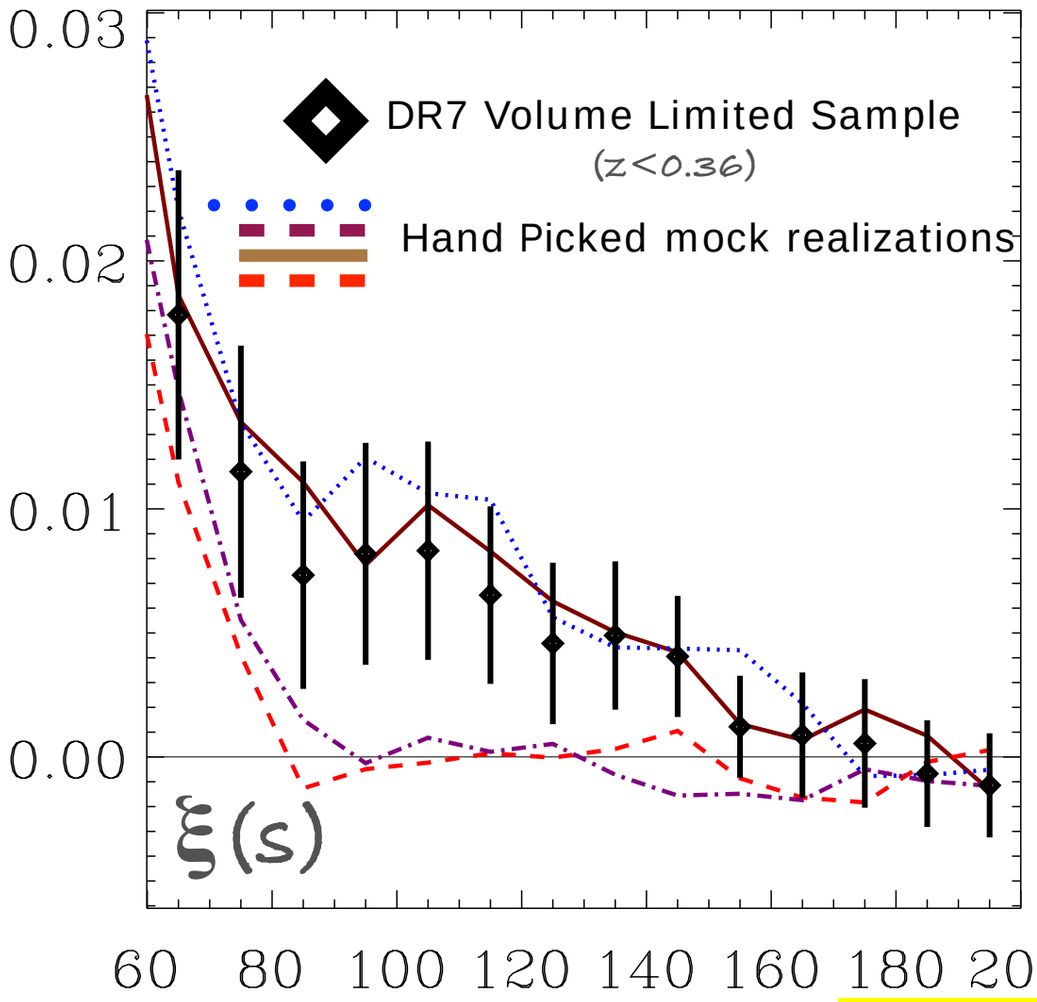
Our result

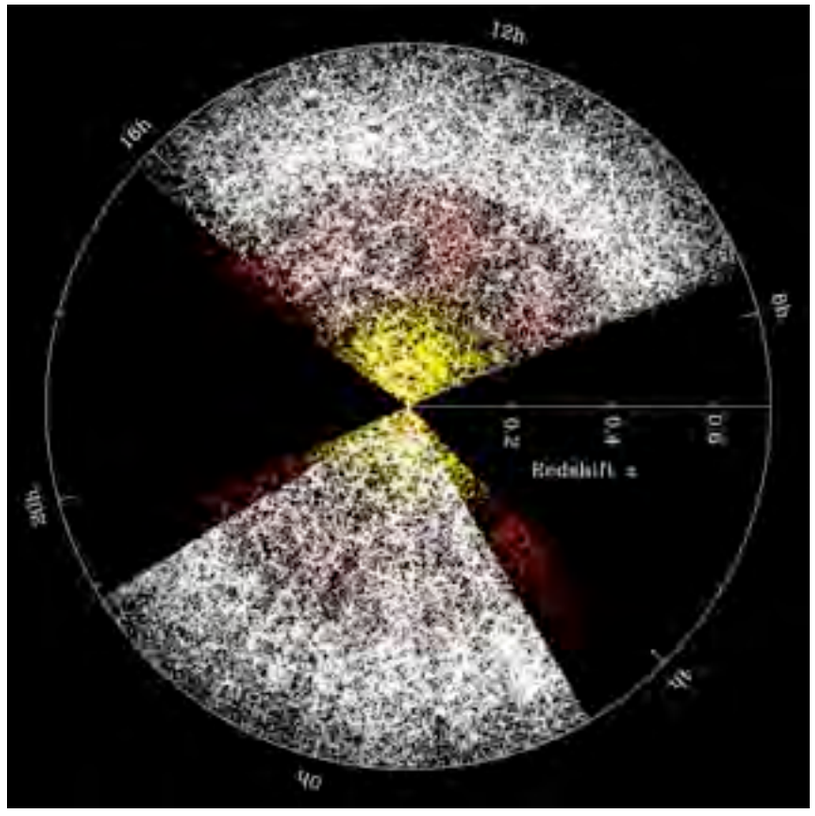
Kazin, Sánchez & the SDSS (arXiv 1303.4391)

Baryonic acoustic feature in a smaller data set: SDSS-II LRGs

- SDSS-II volume mock catalogs indicate a >10% chance of not detecting an apparent signature

  -based on mock catalogs provided by LasDamas (McBride et al.; in prep) and Horizon-Run mocks (Kim et al. 2009)-





Note: all points are covariant

- ~45% (75 of 160) of realizations do show indication of a clear peak
- SDSS-II LRGs **do** reveal a Baryonic Acoustic Feature in various redshifts and luminosity cuts

Kazin et al. (2010)

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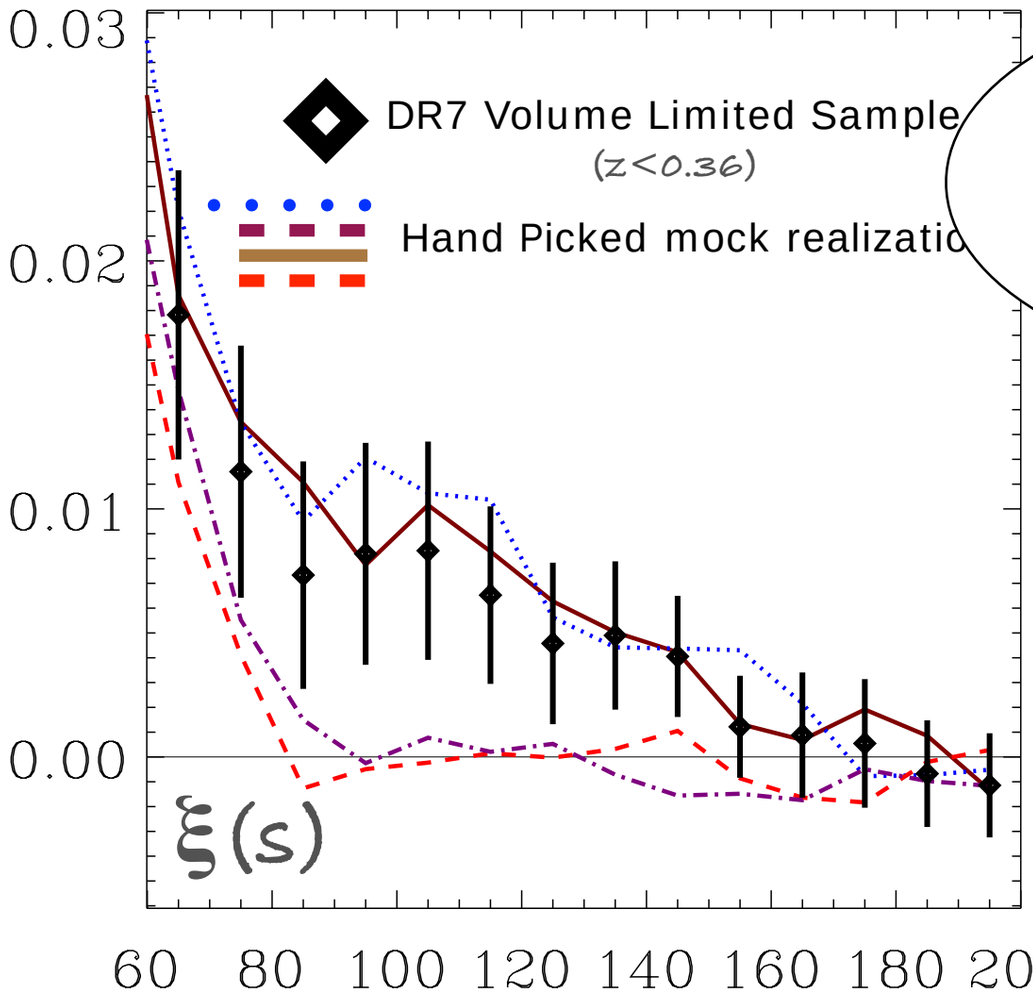

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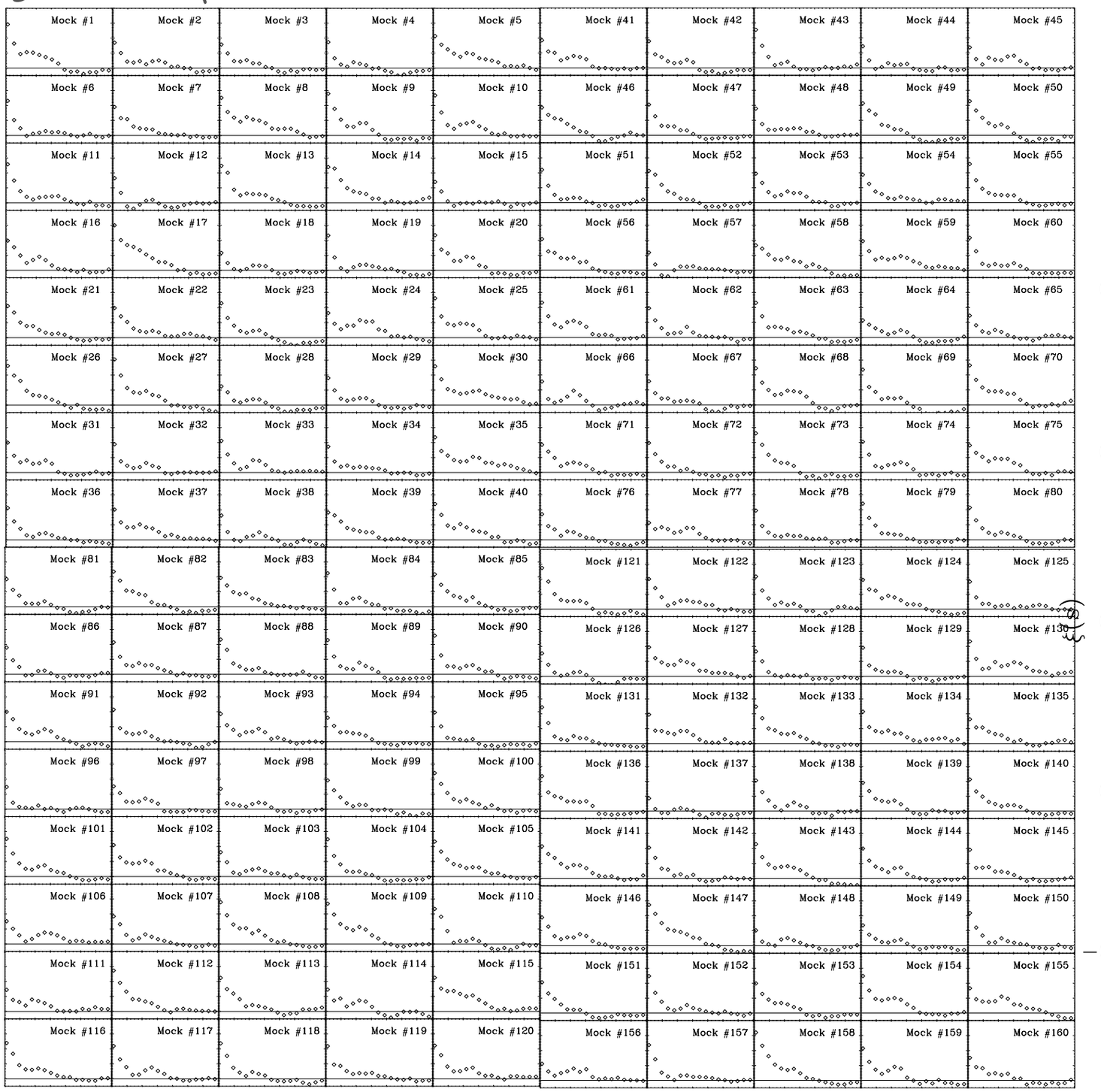
Kazin et al. (2010)

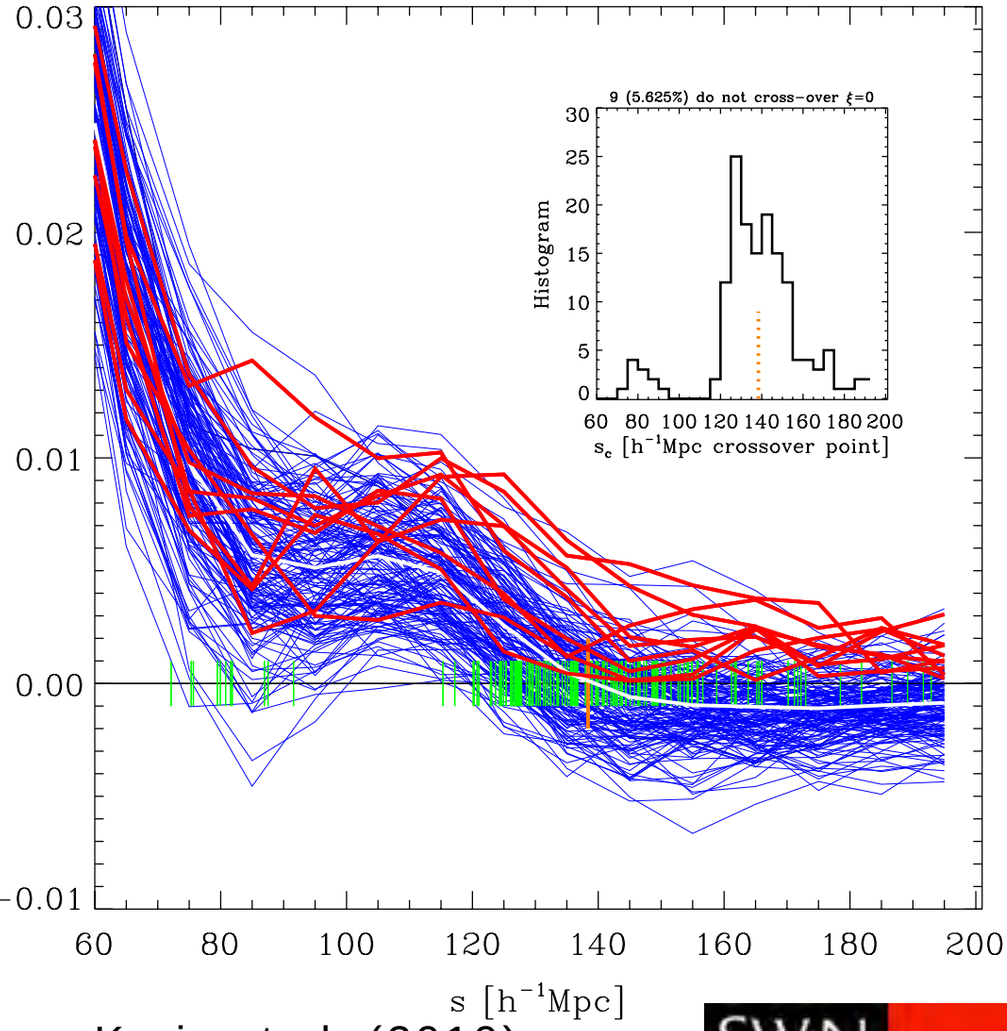
Mocking, mocking, mocking

ξ(s~ BA feature scale)



s [h⁻¹Mpc]

We test hundreds of mock catalogs for systematics - LasDamas realisations



Kazin et al. (2010)

Reconstruction - sharpening the baryonic acoustic feature

Results can be *substantially* improved
by reducing non-linear effects

Mock catalogs are essential to test systematics

Damping of the Baryonic Acoustic Feature

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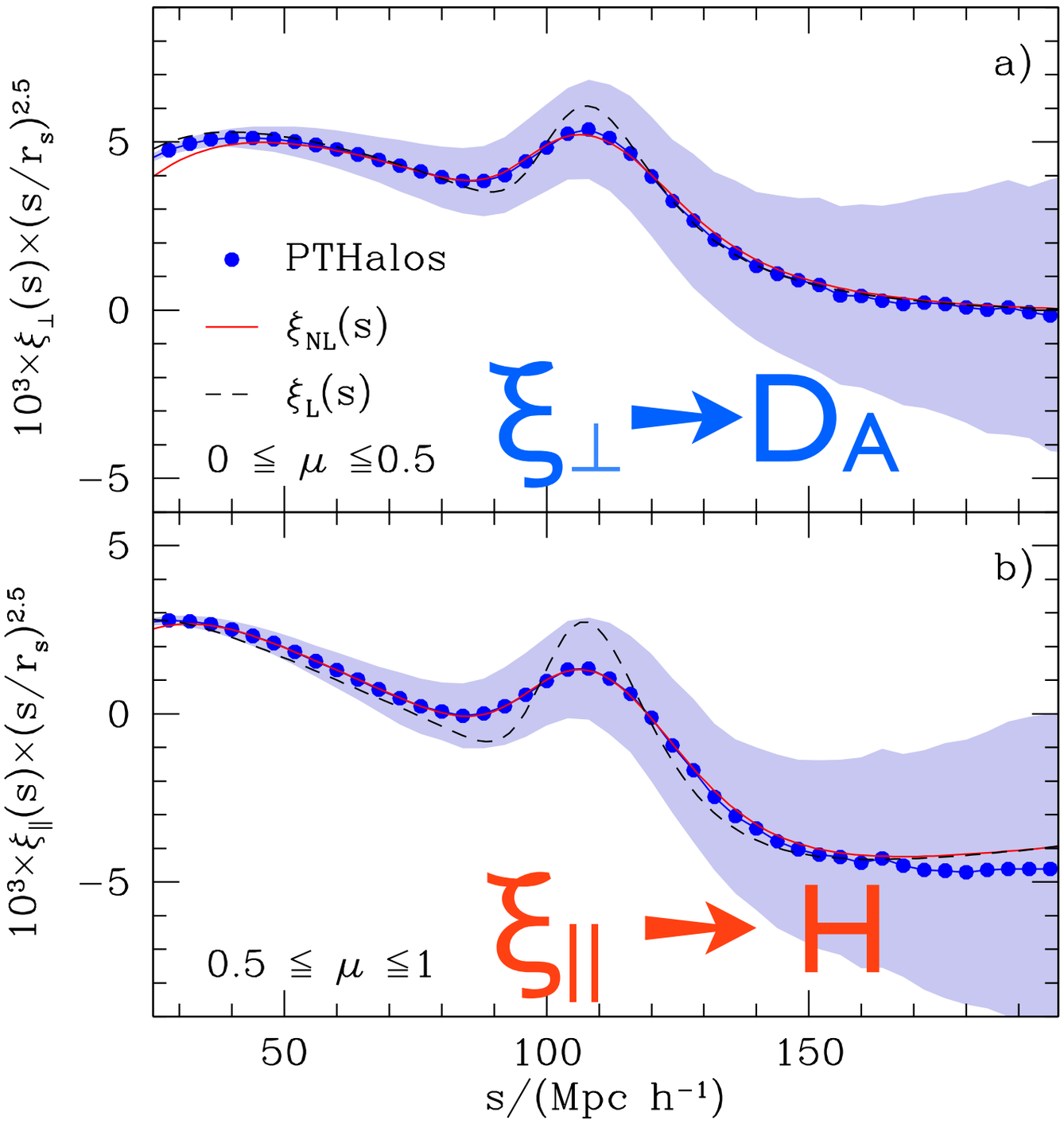
Sánchez, Kazin & the SDSS (arXiv 1303.4396)



PTHalo signal

PTHalo r.m.s region

linear theory

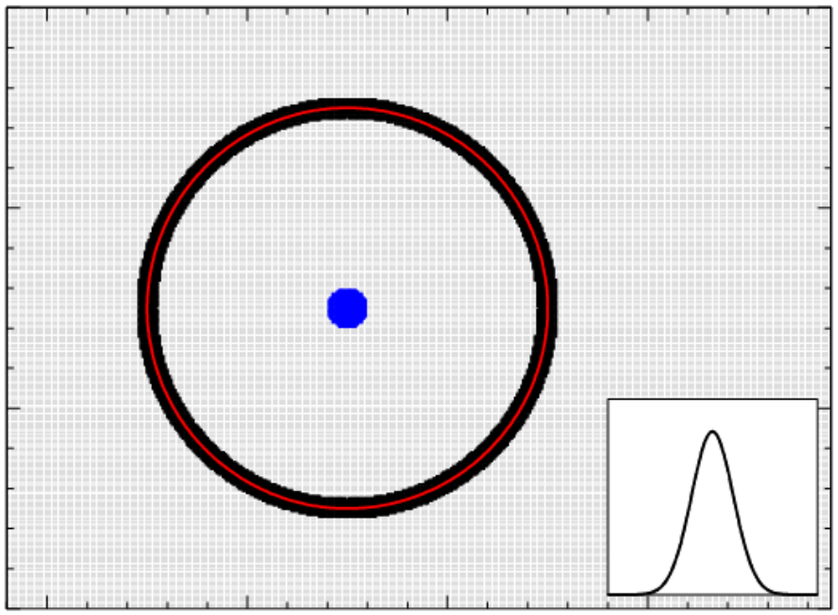
non-linear (damped)

- Bulk flows cause non linearities that push galaxies by 3-10 Mpc.
- This weakens the usage of baryonic acoustic feature as a standard ruler/sphere
- *This can be remedied!*

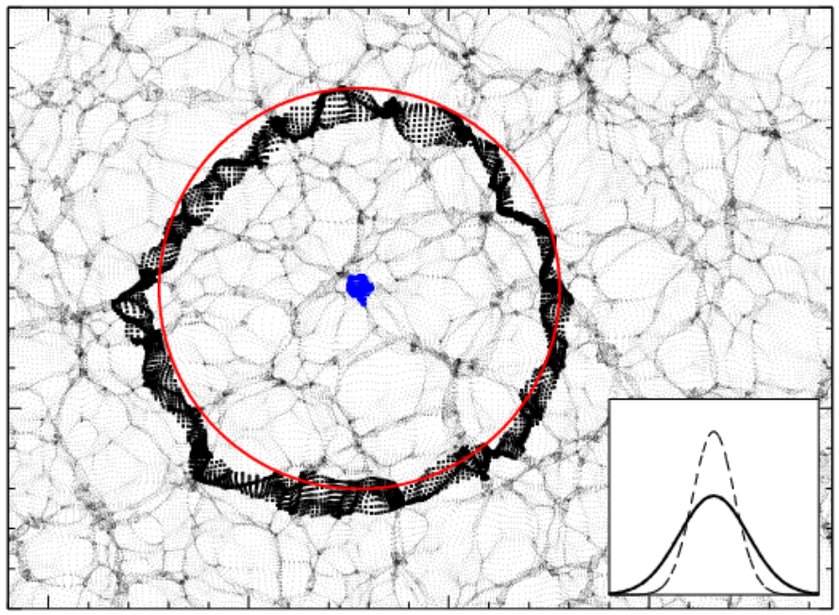
Reconstruction Technique

insets:
rms of
highlighted
galaxies

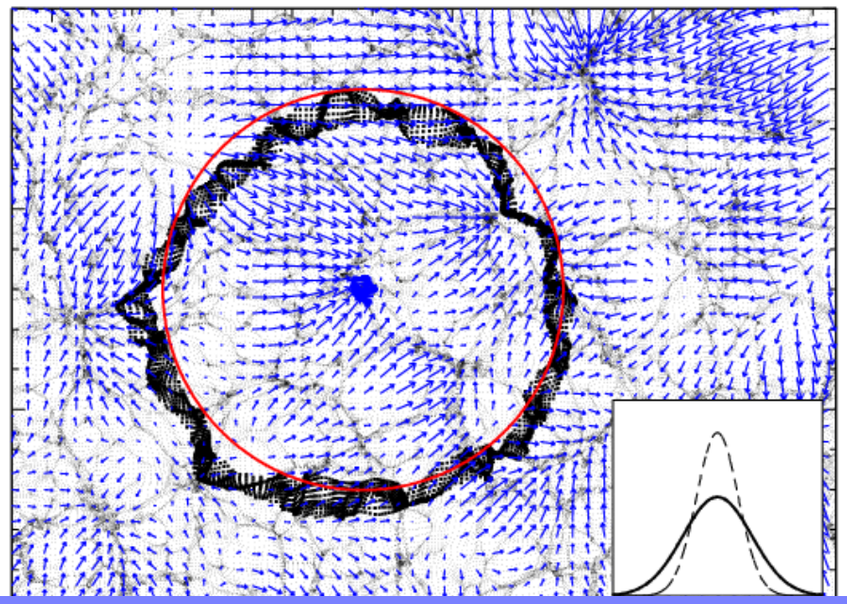
Initial Field



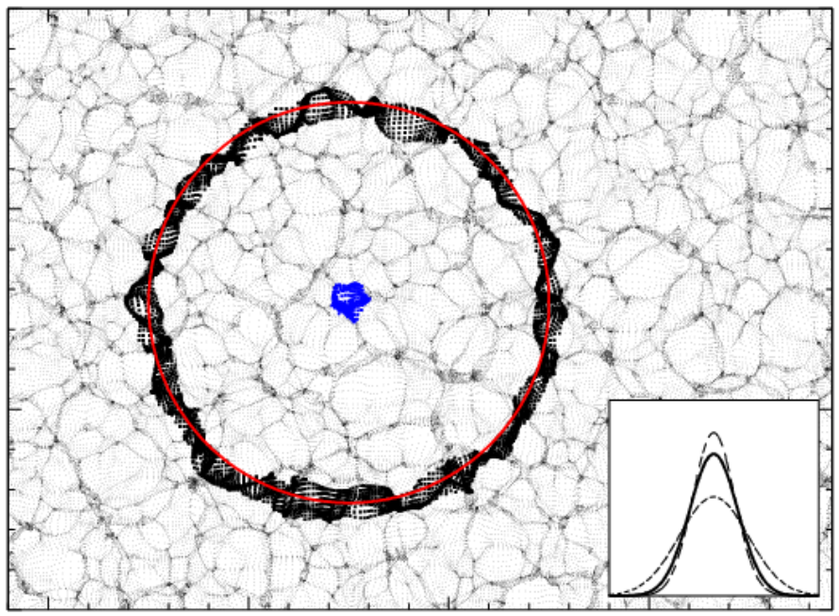
Present Field



Present Field



Present Reconstructed Field

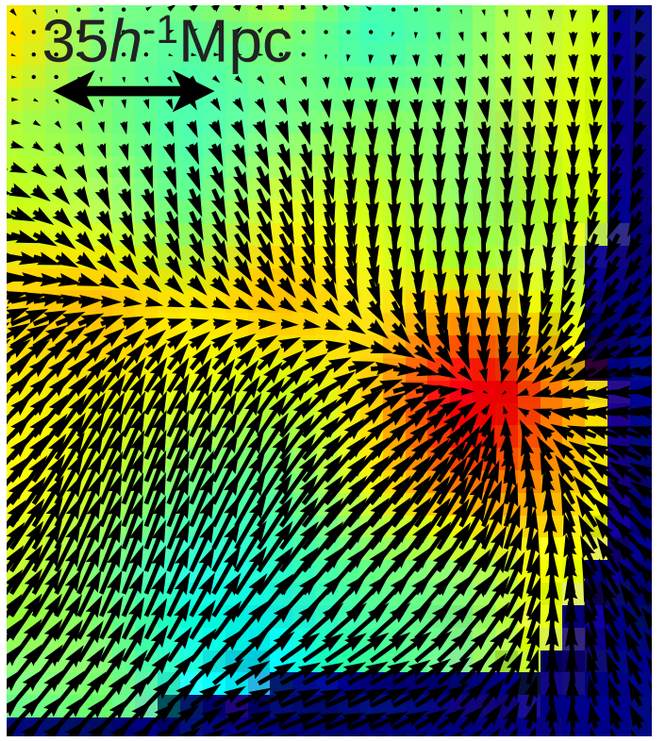


with displacement vectors

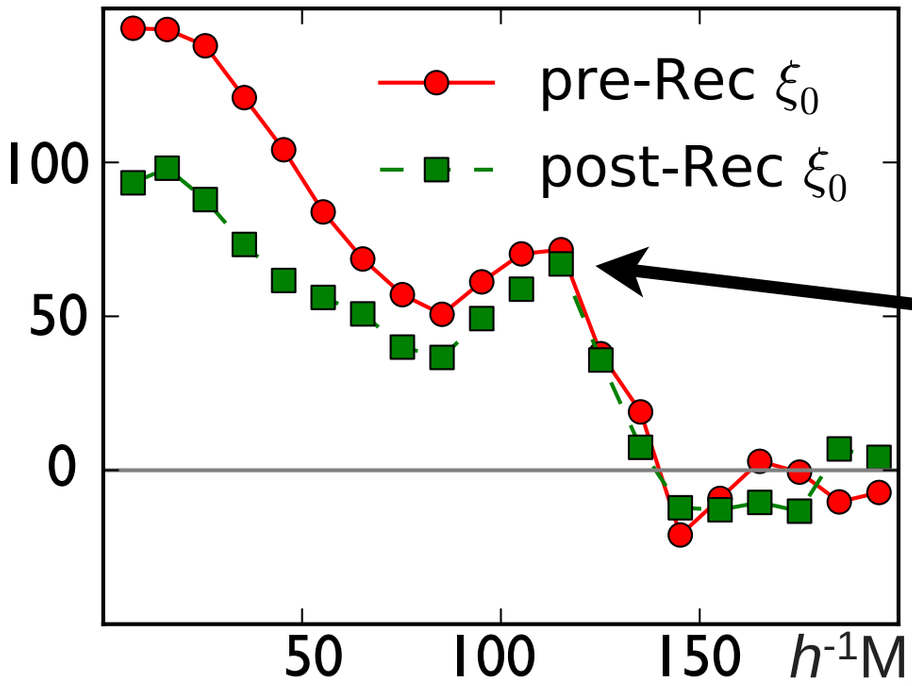
Padmanabhan + EK et al. (2012)

Reconstruction on simulations

Simulated field and displacement vectors

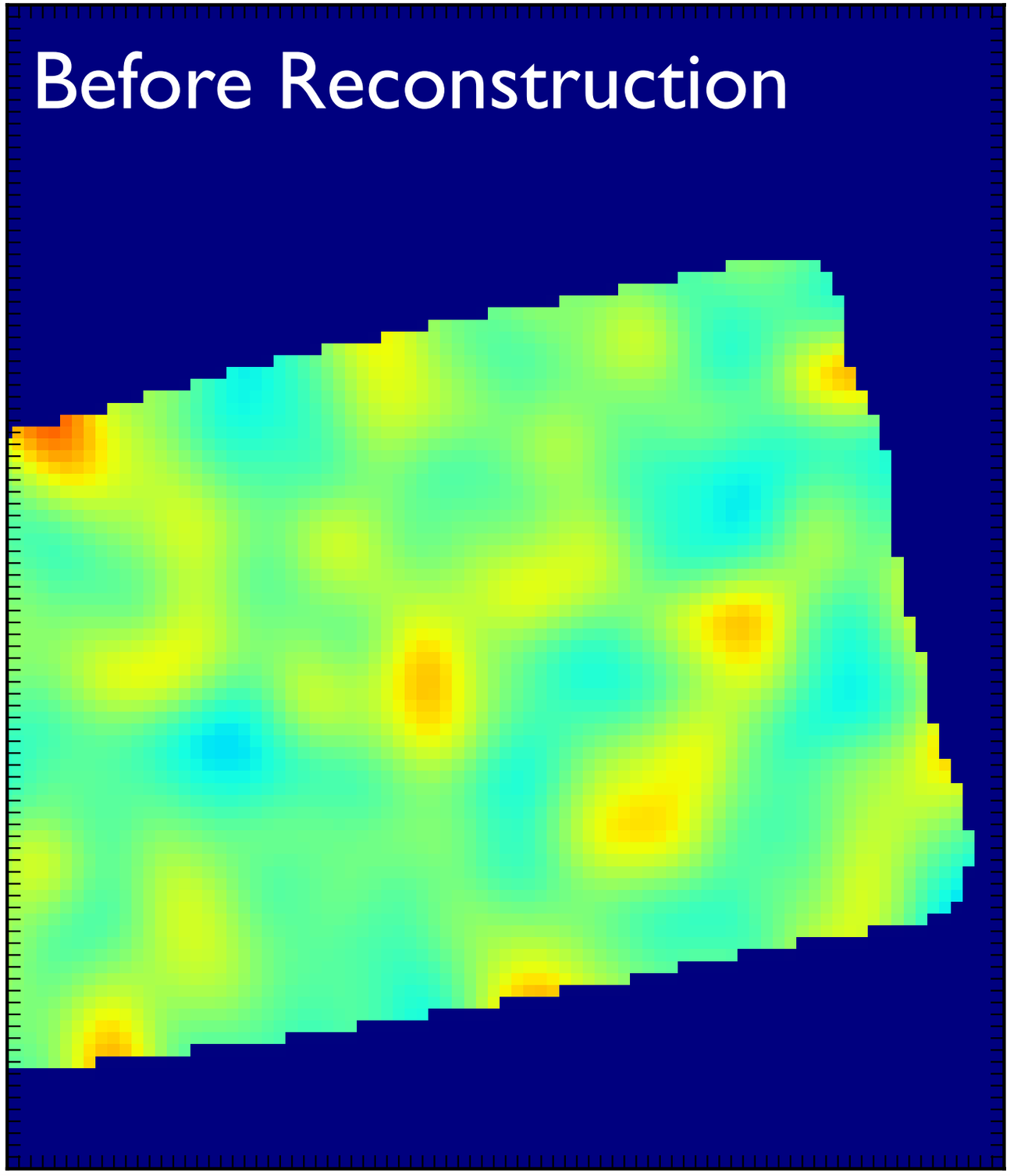


Simulated results (GiggleZ)



acoustic signature sharpened!

Reconstruction Technique: WiggleZ



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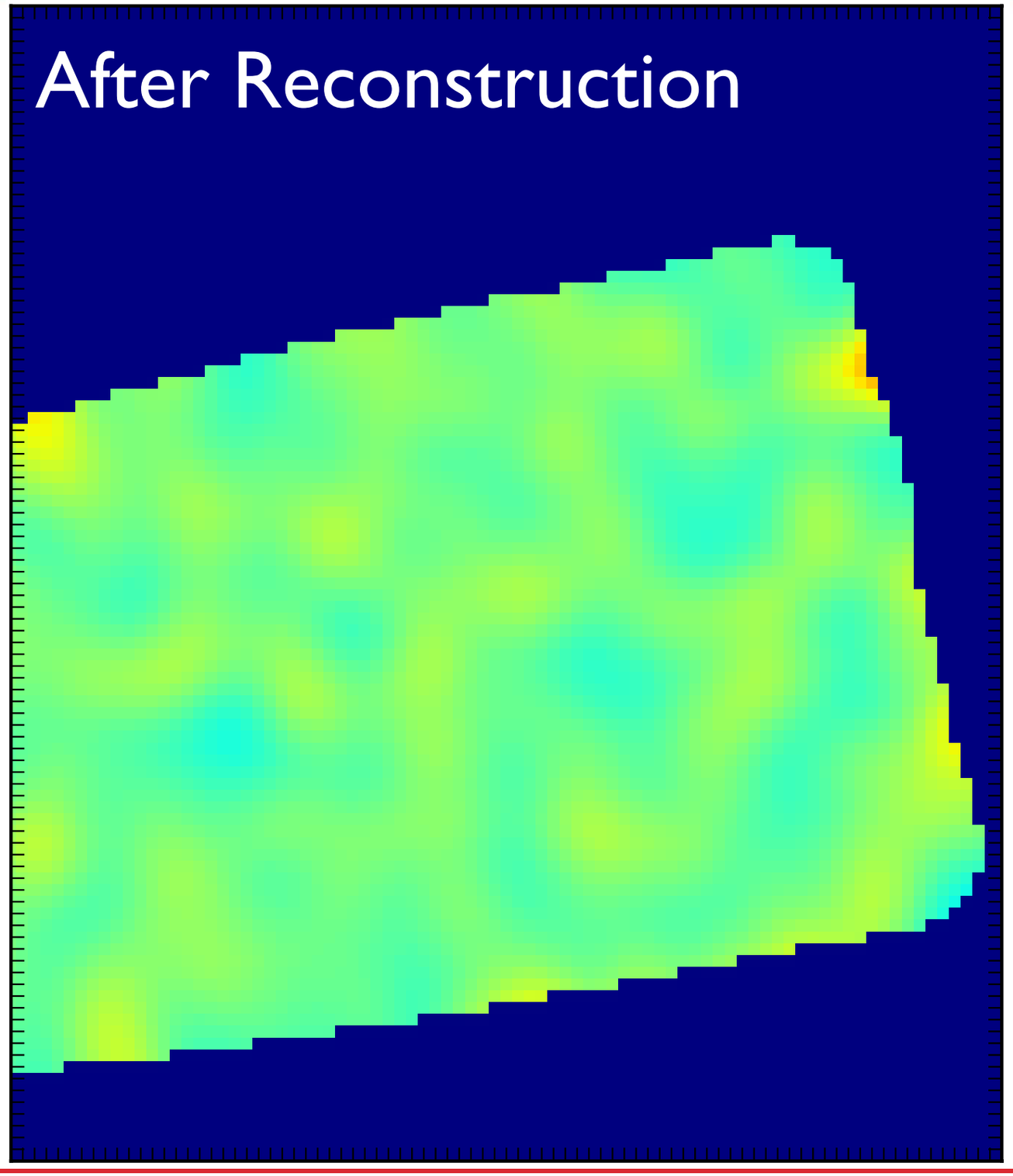
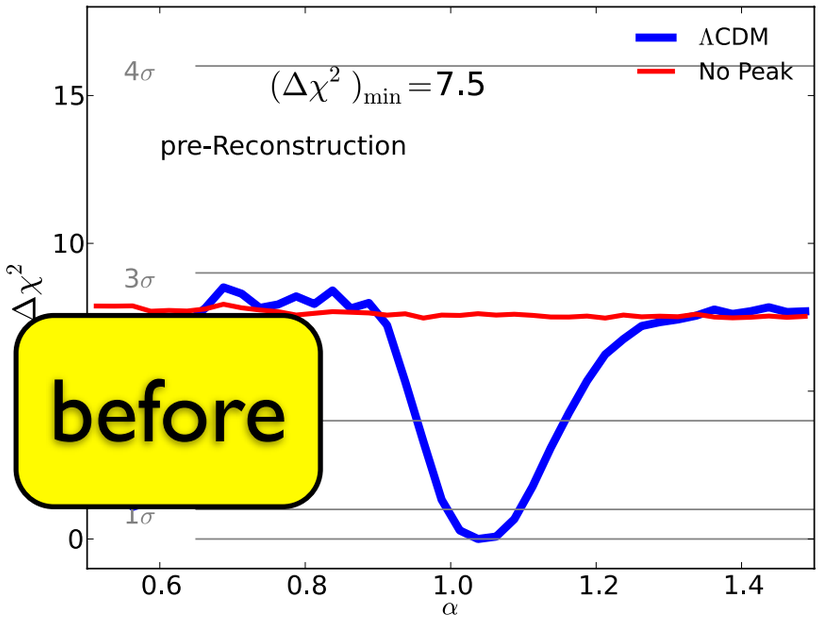
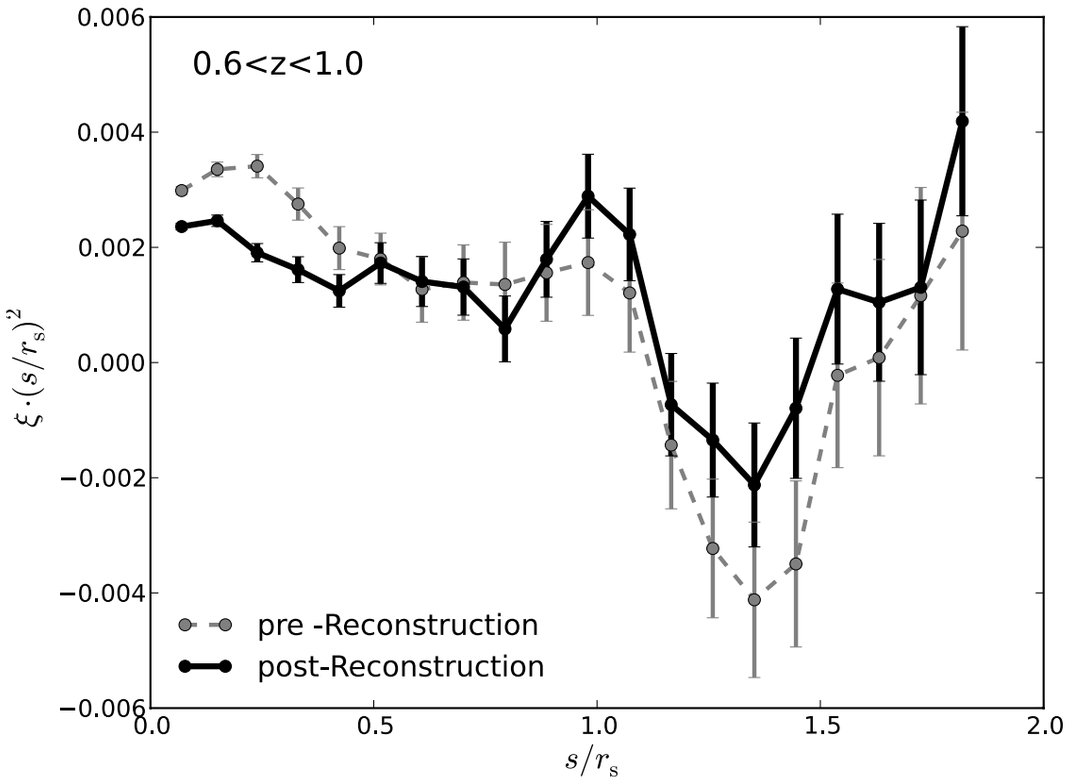
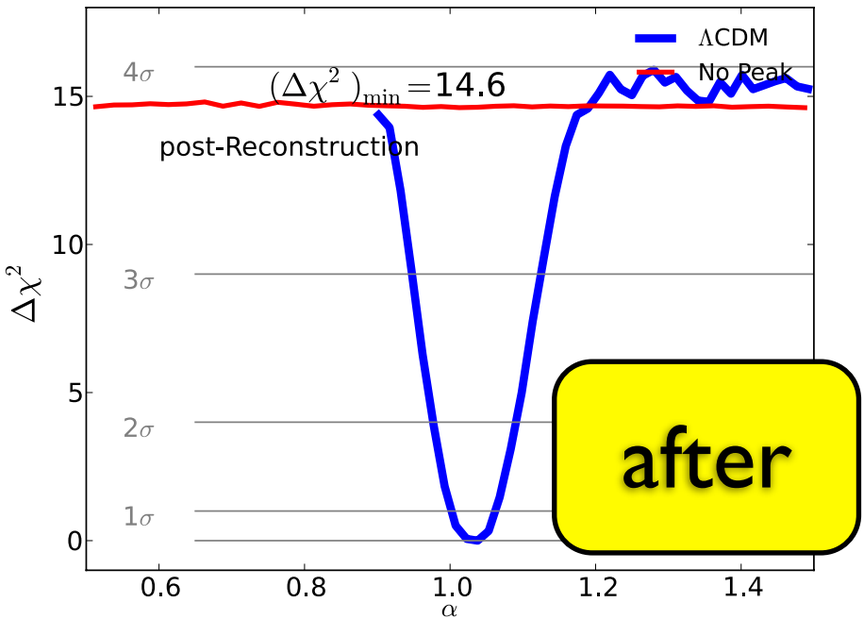


Reconstructed WiggleZ yields substantial improvements



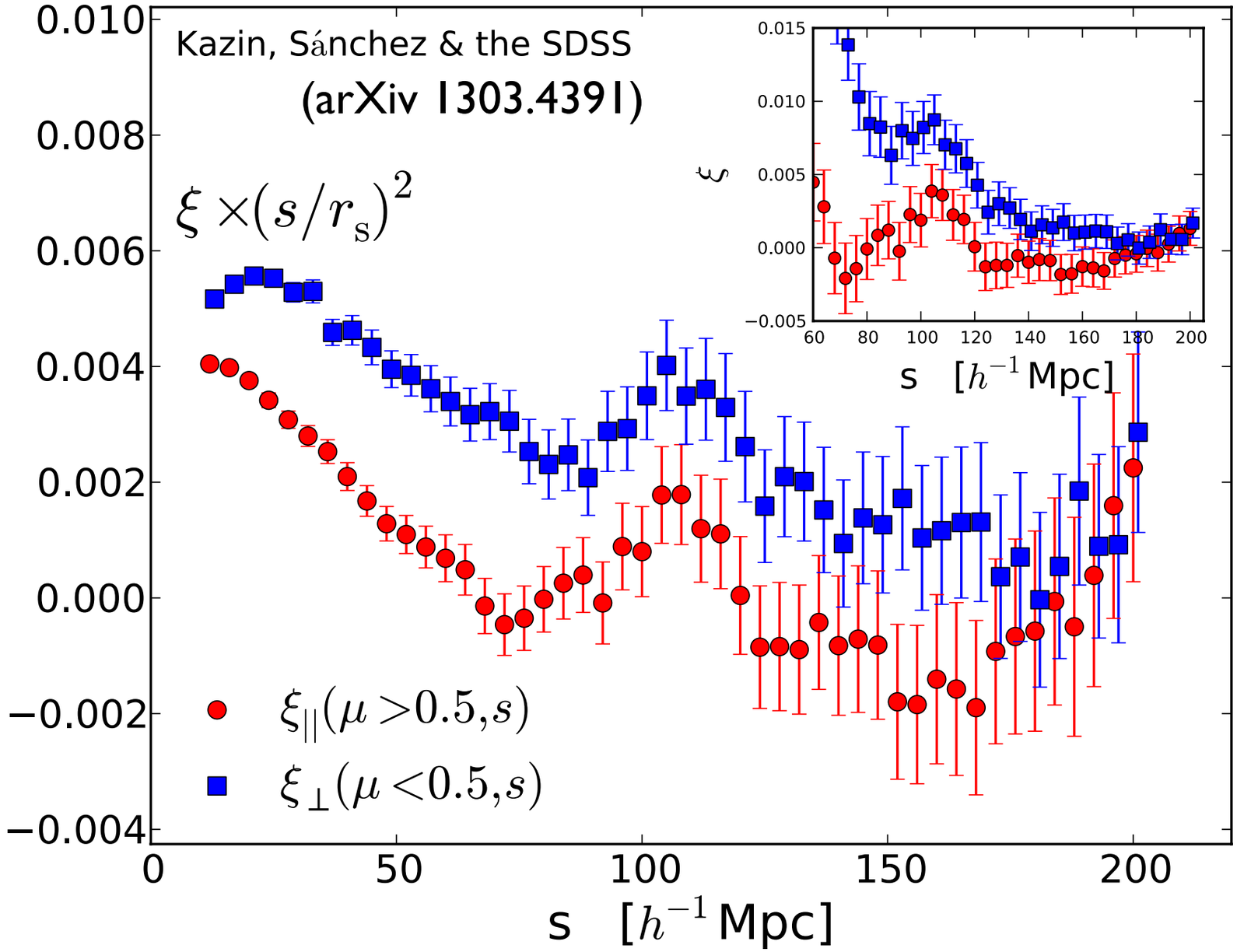




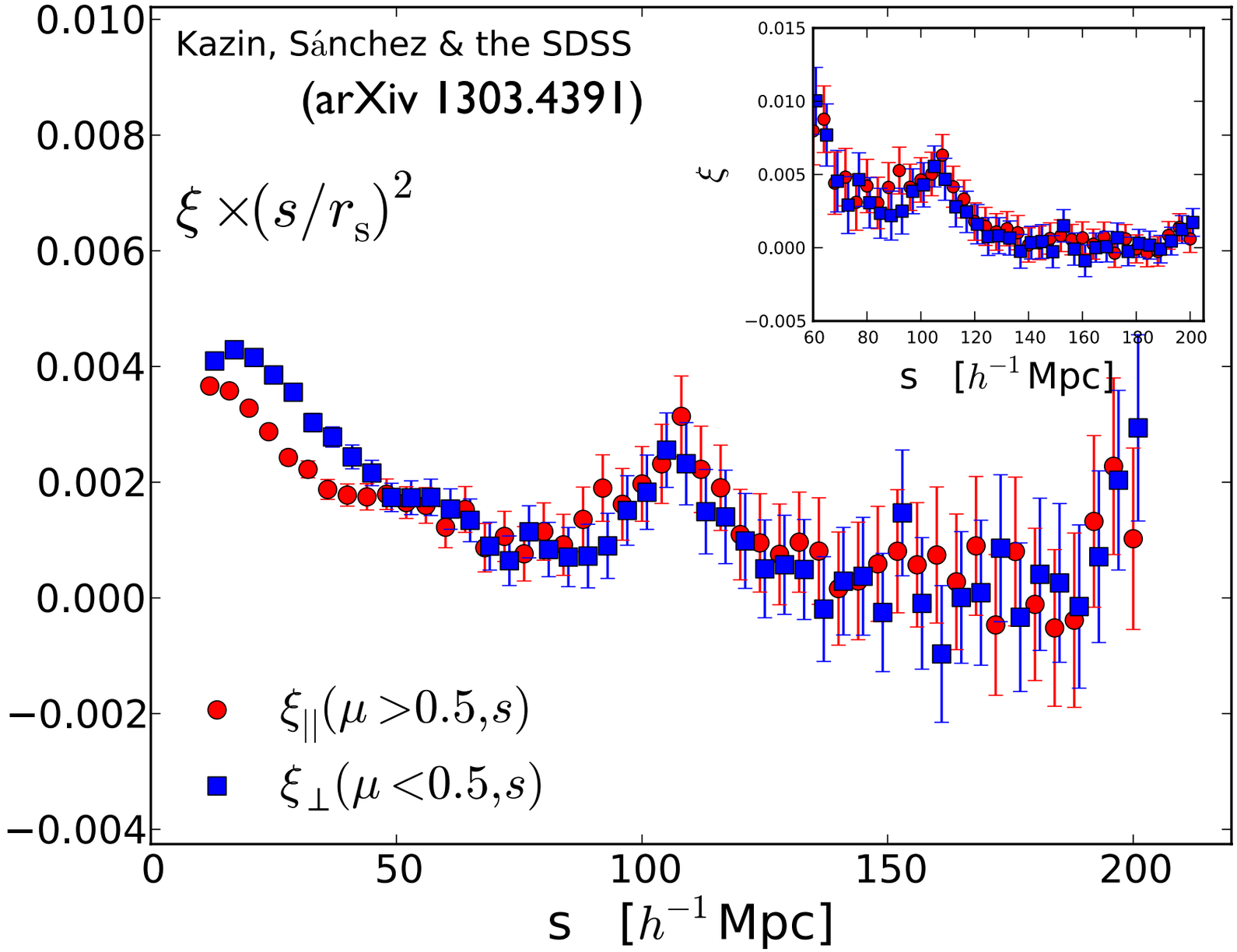
The distance measure to 0.7 should improve from ~6% to sub 3%!!

To appreciate these improved results, we need to test mock realizations!

BOSS Results: pre- Reconstruction Data



BOSS Results: post-Reconstruction Data



DR9 $H(z)$, $D_A(z)$ expectations pre -Rec from mock catalogs

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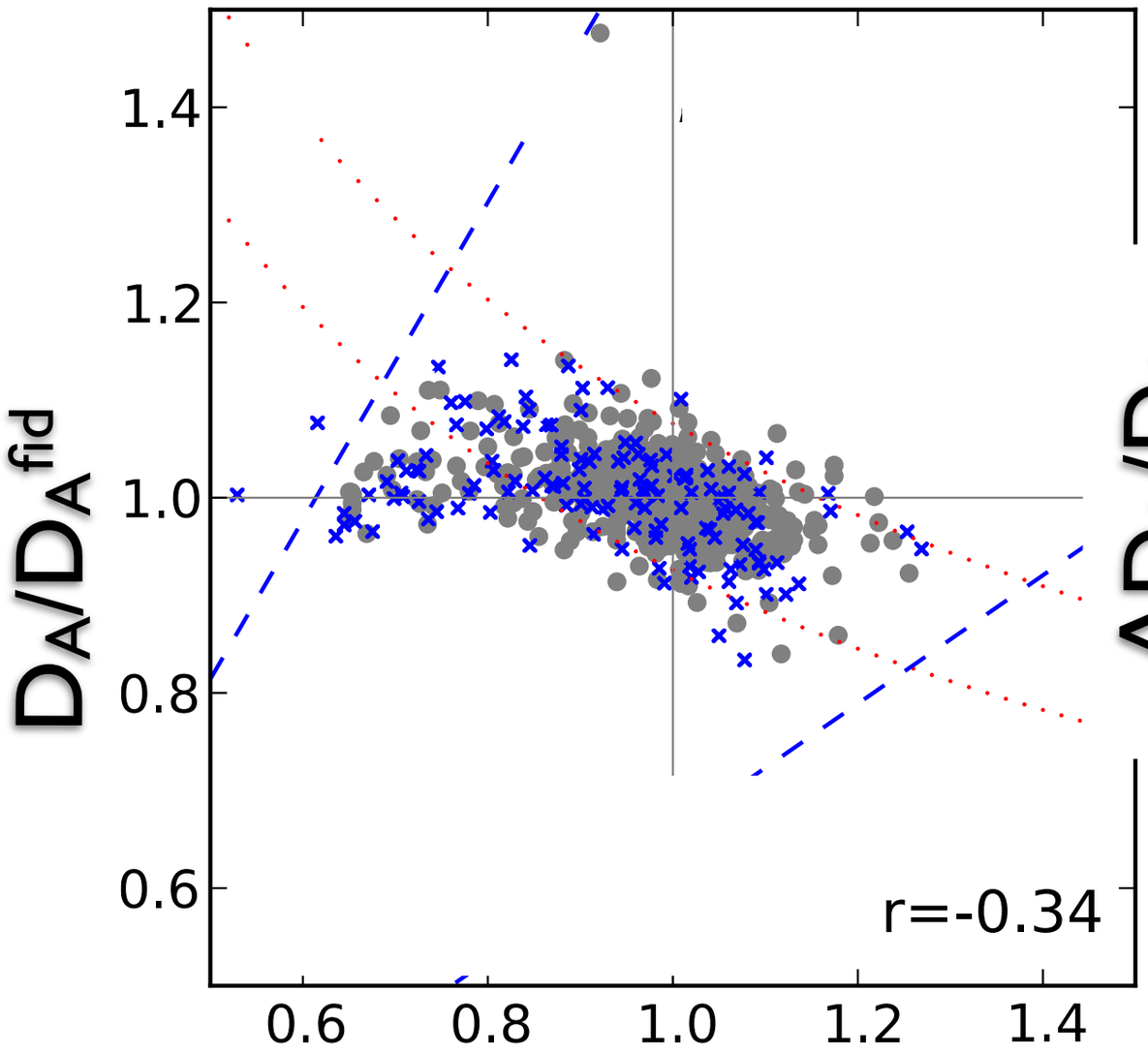
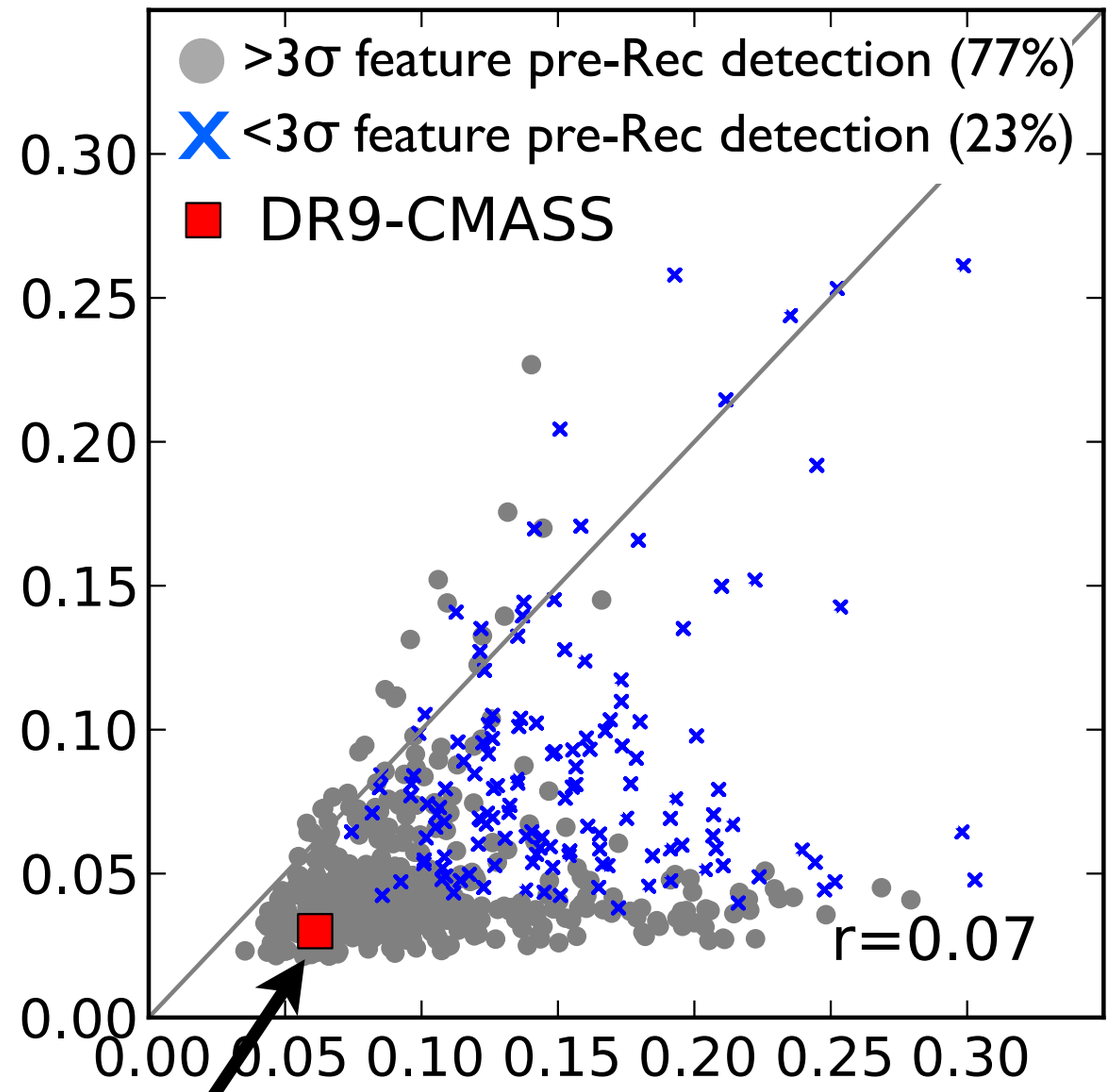
Testing for bias



Constraining power



Our result

Kazin, Sánchez & the SDSS (arXiv 1303.4391)

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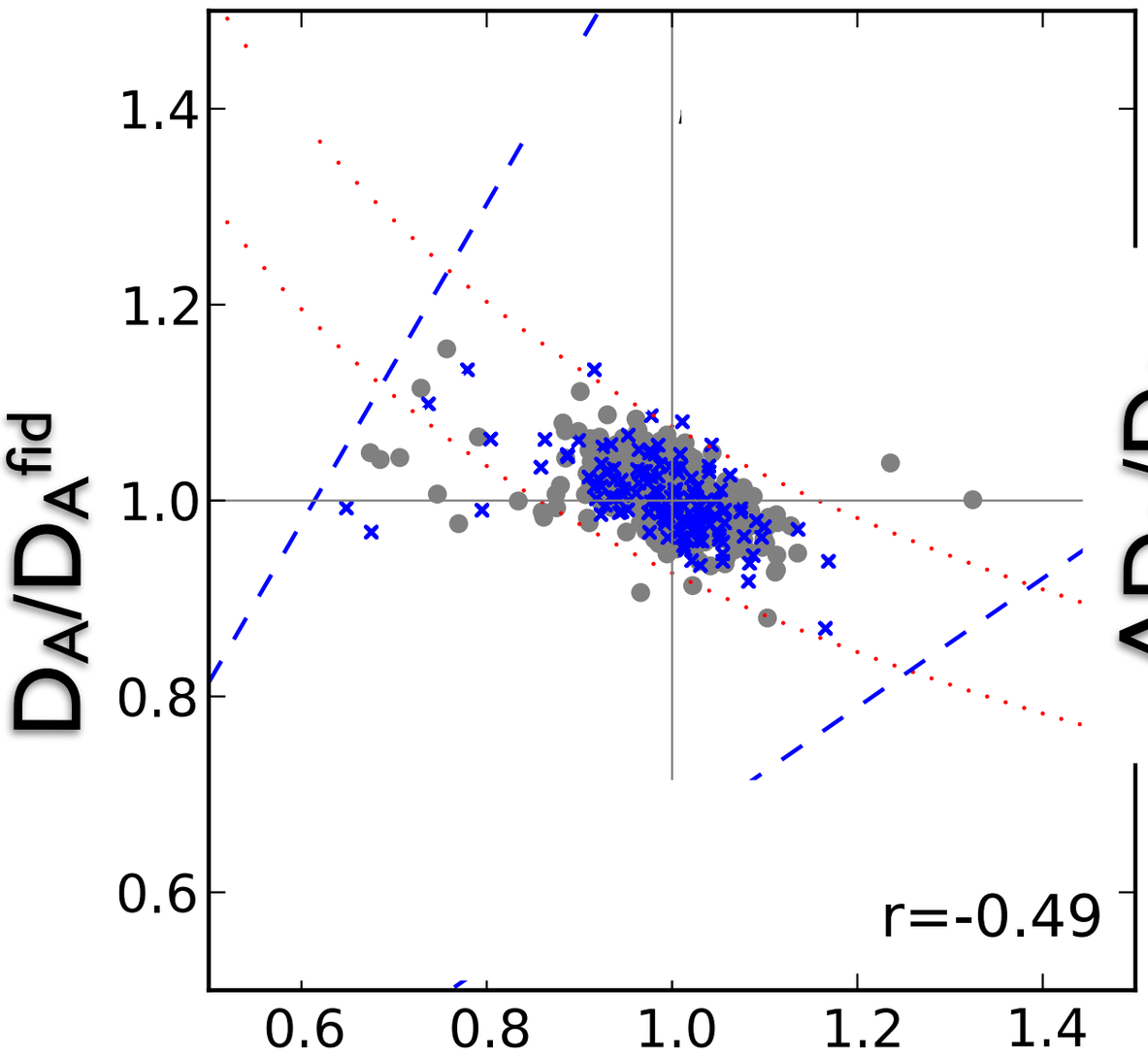

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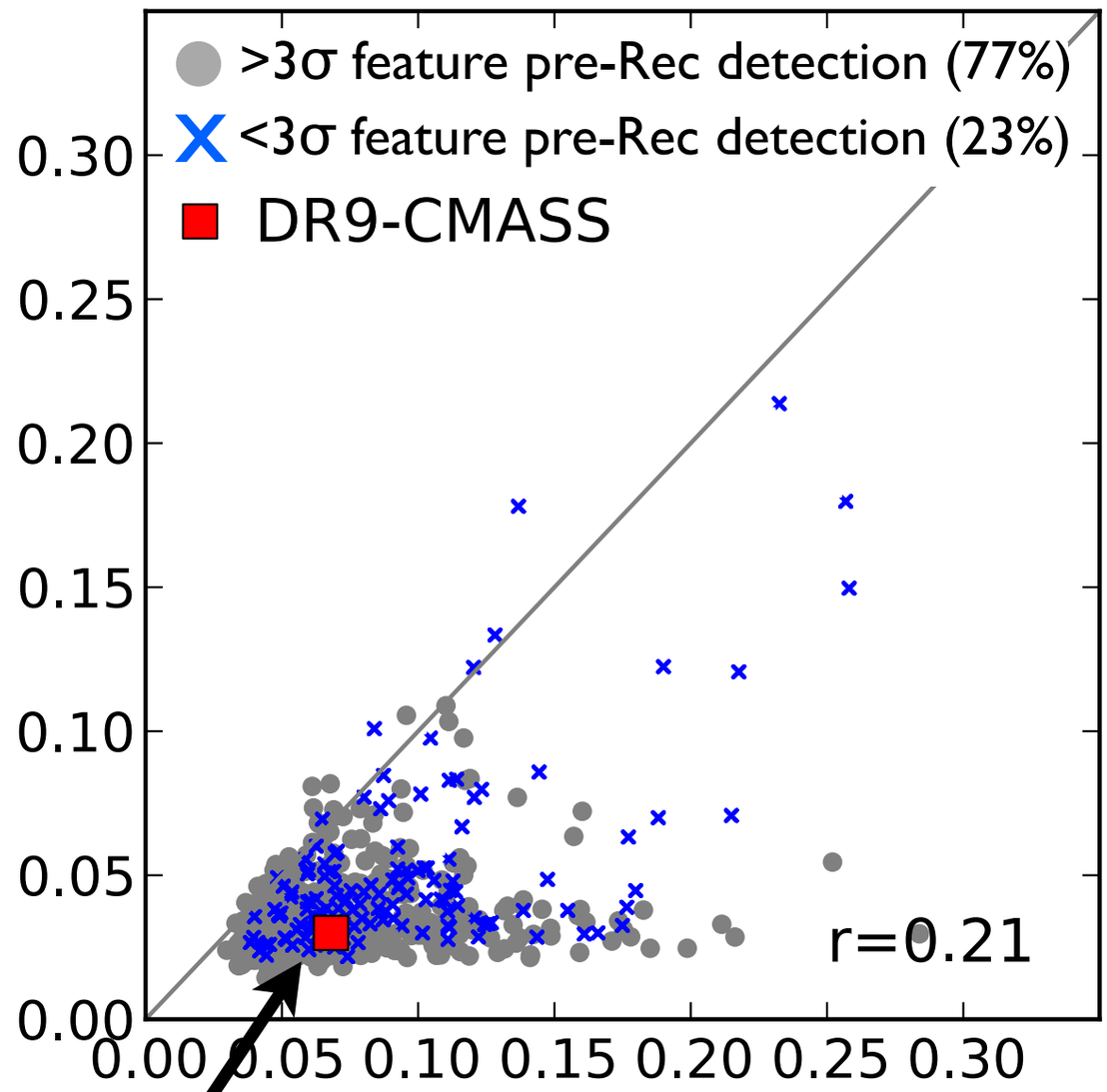


Our result

On average, Reconstruction improves constraints by 30%

Kazin, Sánchez & th

Synthetic Universes

Techniques to improve cost effectiveness of many mocks for LSS analysis

(talk to Jun Koda for details!)

PTHalos (Manera et al.):
Works fine for high mass galaxies,
but not so well for low mass galaxies

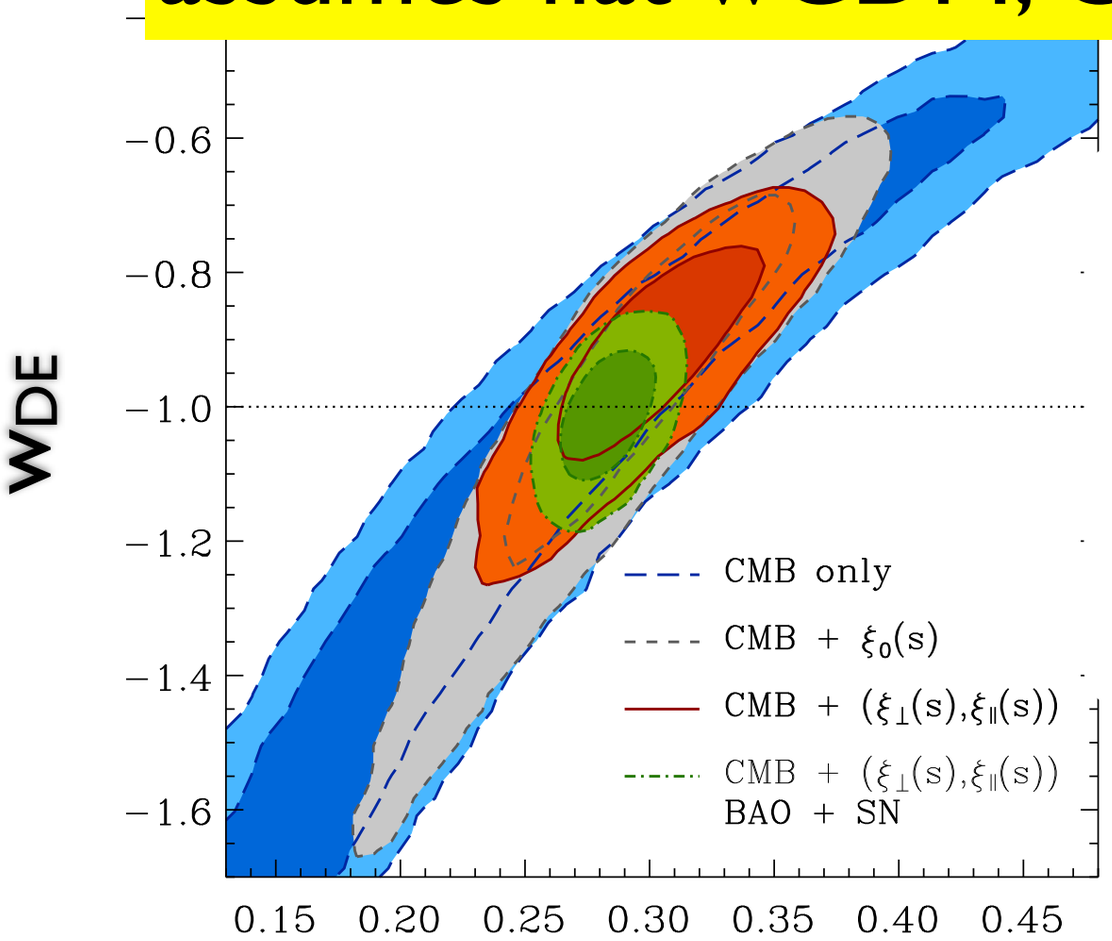
COLA- COmoving Lagrangian Acceleration

(Tassev, Zaldarriaga, Eisenstein):

Trades small scale accuracy for speed without sacrificing large-scale accuracy

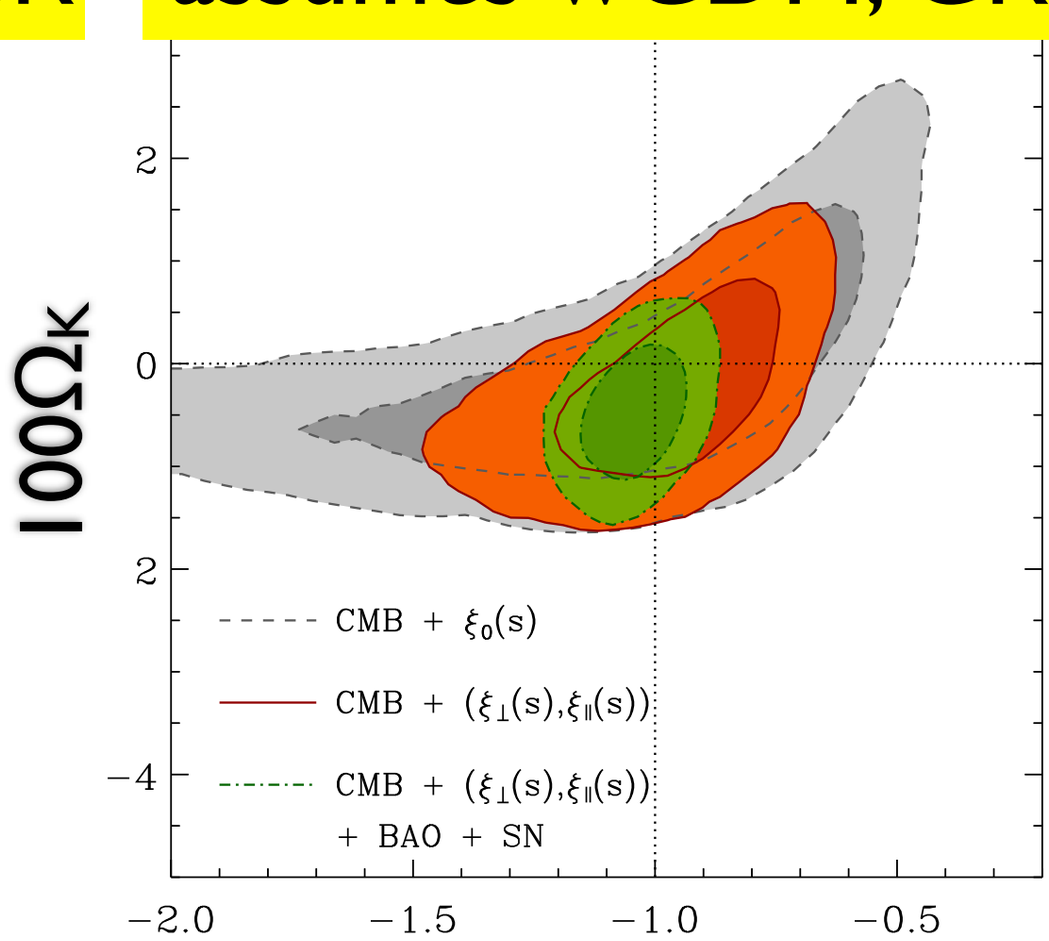
Cosmology from BOSS
tightest (pre-Planck) constraints

assumes flat wCDM, GR



Ω_M

assumes wCDM, GR



w_{DE}

clear improvement,
when using LSS 2D signal

from:
WMAP9, +(BOSS isotropic)
+BOSS anisotropic, +
SN & other LSS isotropic

Sánchez, Kazin & the SDSS (arXiv 1303.4396)

Cosmology from BOSS
tightest (pre-Planck) constraints

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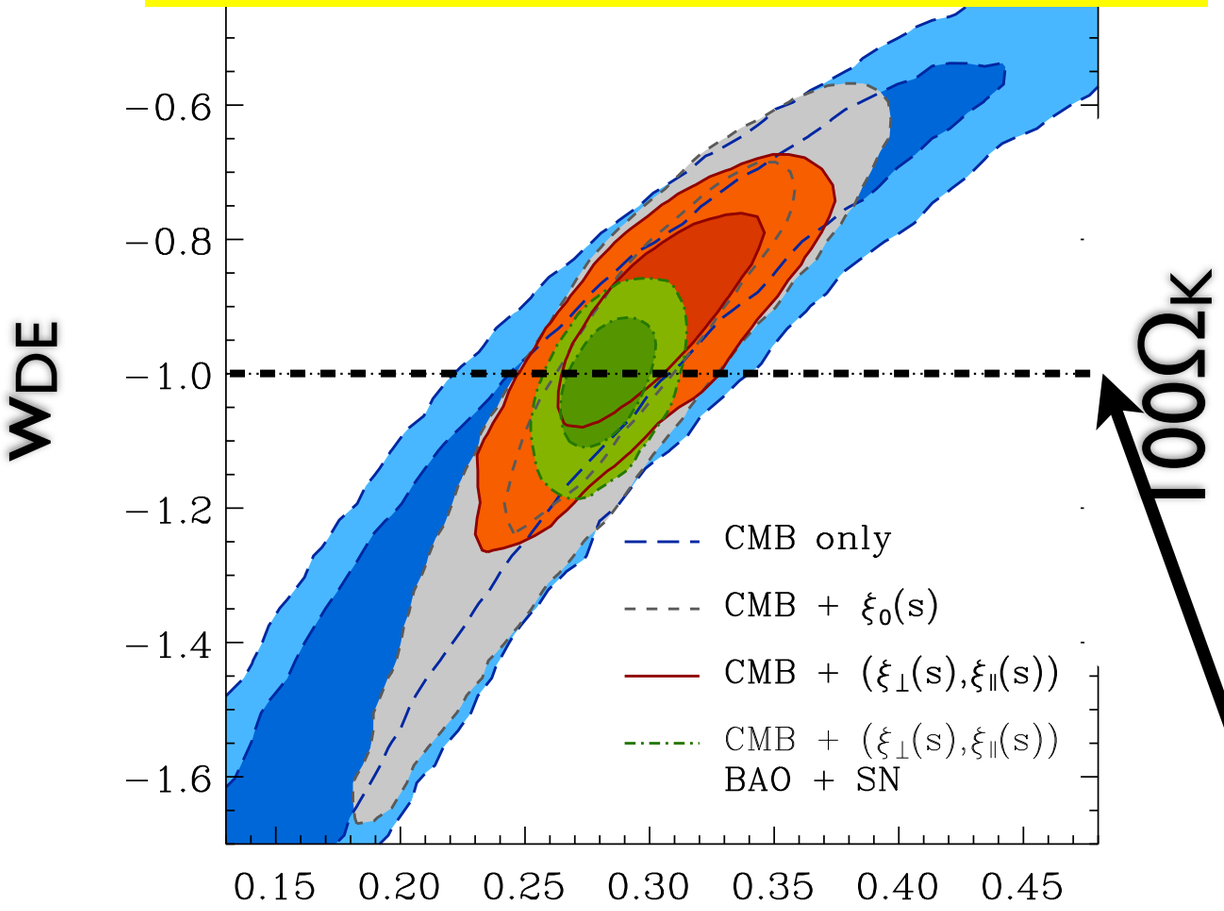

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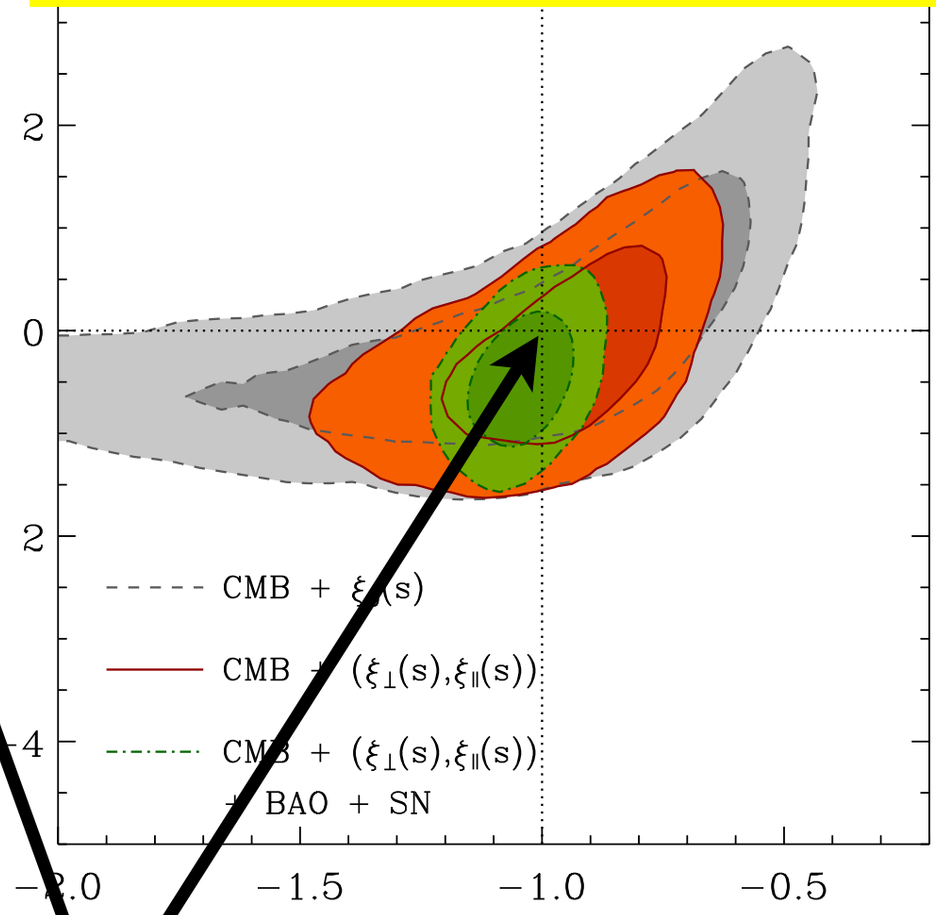

fro
W
+B
SN & other LSS isotropic

clear improvement,
when using LSS 2D signal

flat ΛCDM is still a non-ridiculous theory (according to observations)

Sánchez, Kazin & the SDSS (arXiv 1303.4396)

Summary

Take aways:

- Many (hundreds) of >1 Gpc^3 mock realizations are essential for analysis and interpretation of LSS measurements
- In particular they yield invaluable insights to cosmic variance and performance of the reconstruction of the BA feature technique.
- When planning a survey, ensure resources for dedicated people to prepare simulated data.

What the (LSS) end users require:

- >1 Gpc^3 mock realizations which
  - cover various cosmologies (i.e, f_{NL} and other exotic models)
  - within a cosmology vary parameter values
  - scores in each (for C_{ij}, examination of cosmic variance and reconstruction)