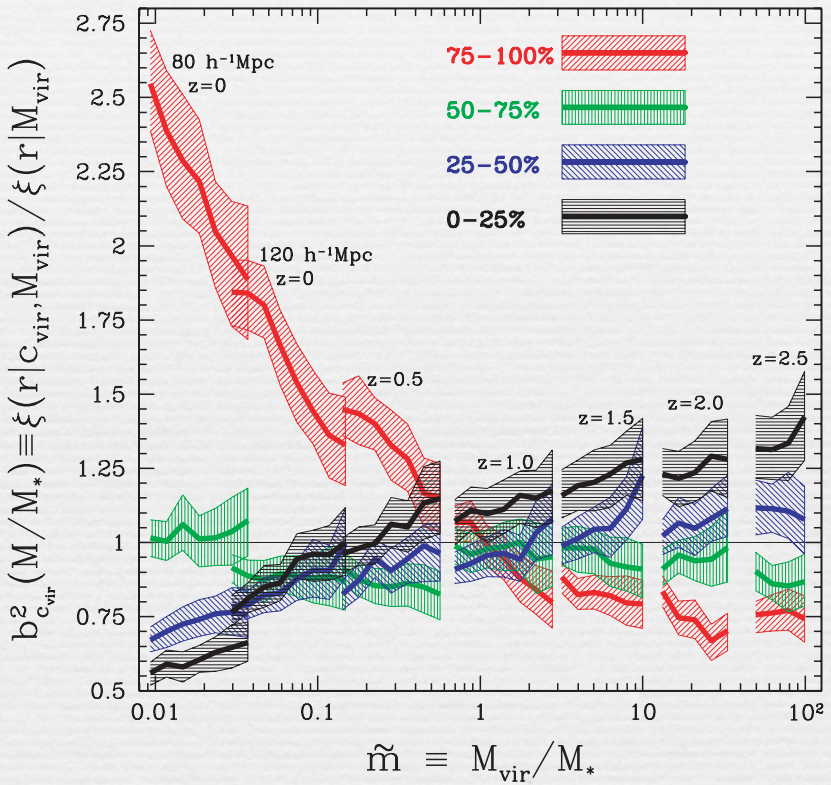
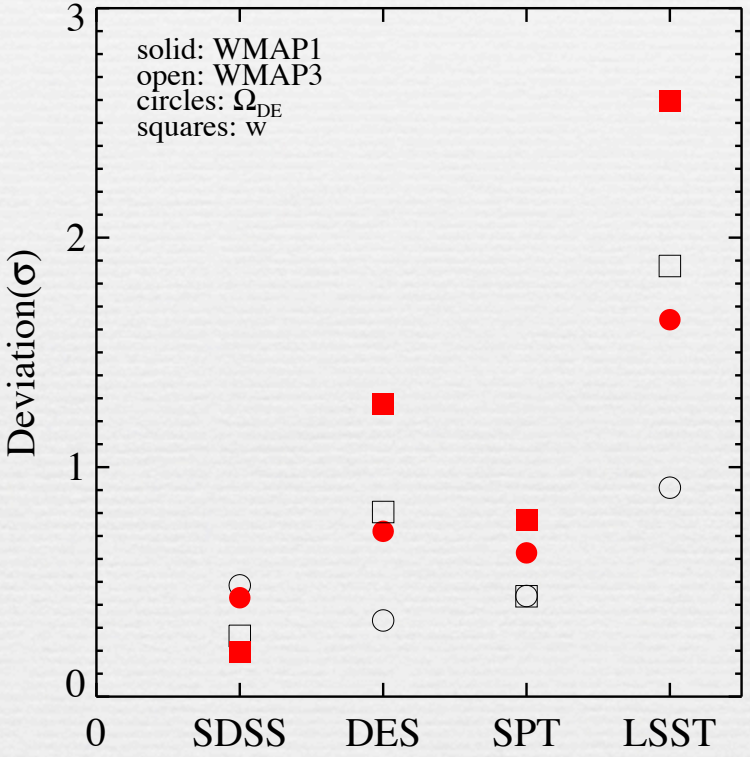
Measuring Halo Bias in Galaxy Cluster Surveys: What Will We Learn About Halo Assembly and Cosmology?

Heidi Wu (KIPAC/Stanford)
in collaboration with Risa Wechsler, Michael Busha,
Oliver Hahn, and Jeremy Tinker

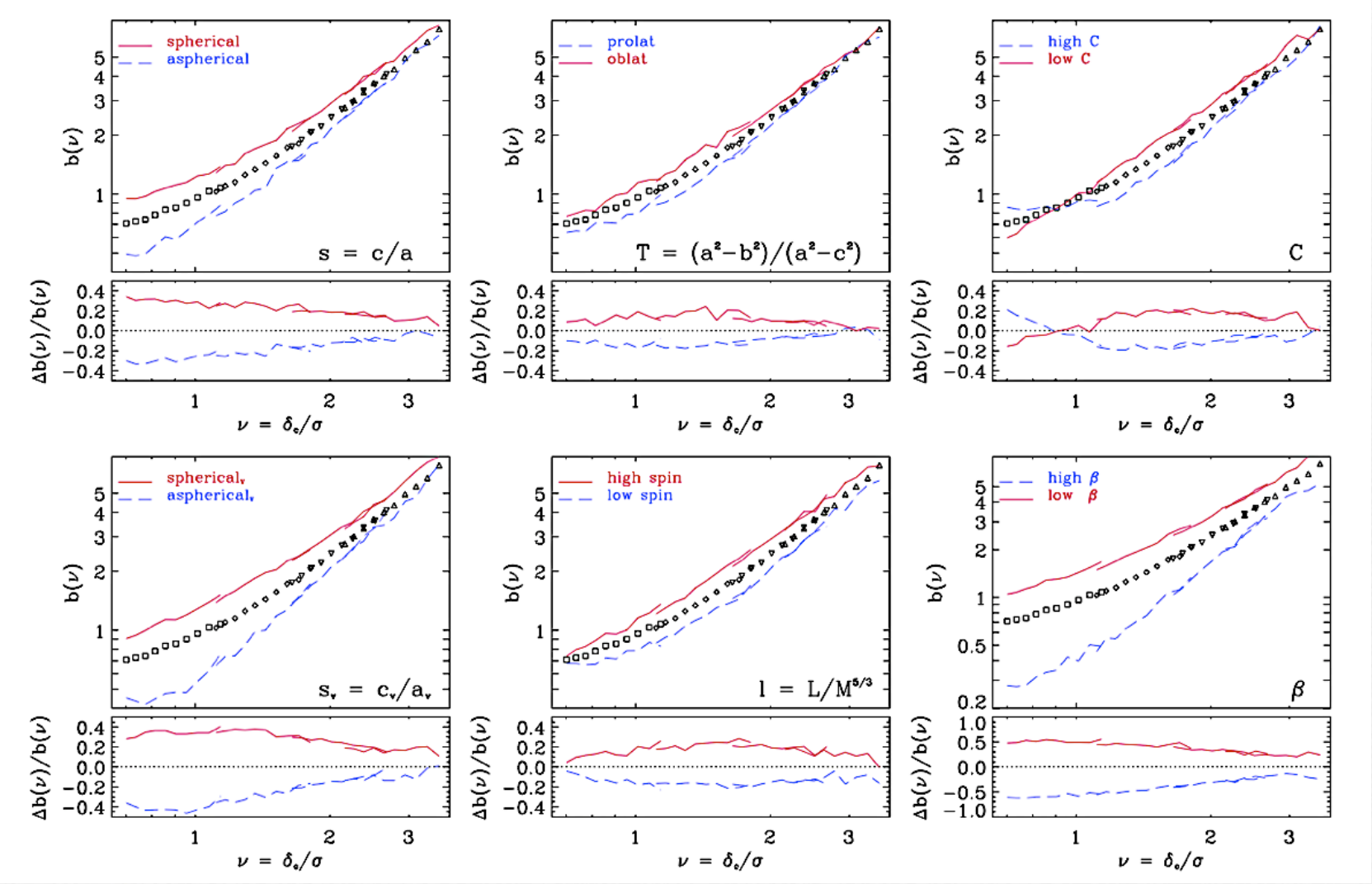
Measuring halo assembly bias is relevant to both astrophysics and cosmology





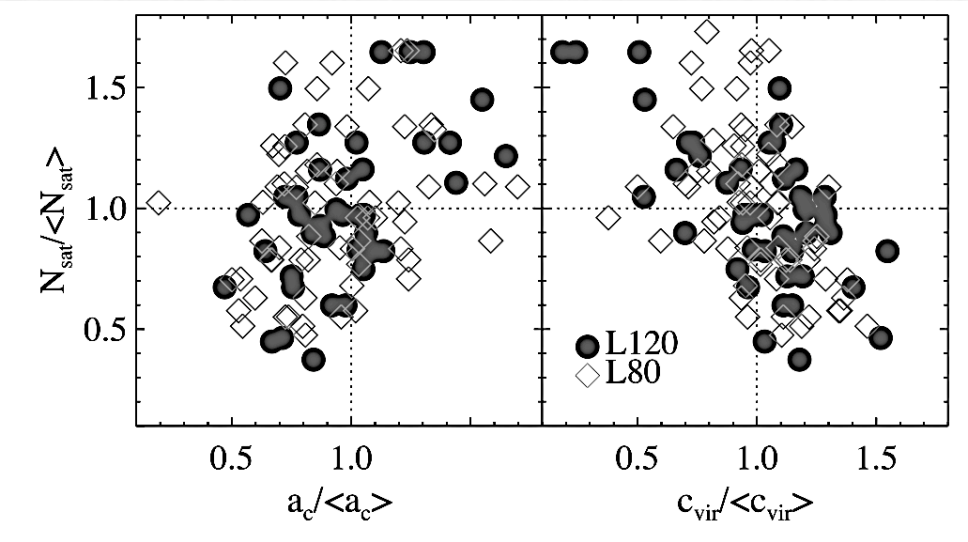
Wechsler et al. '06; Wu, Rozo, and Wechsler '08

Halo bias also depends on various structural and dynamical properties



Faltenbacher & White '10

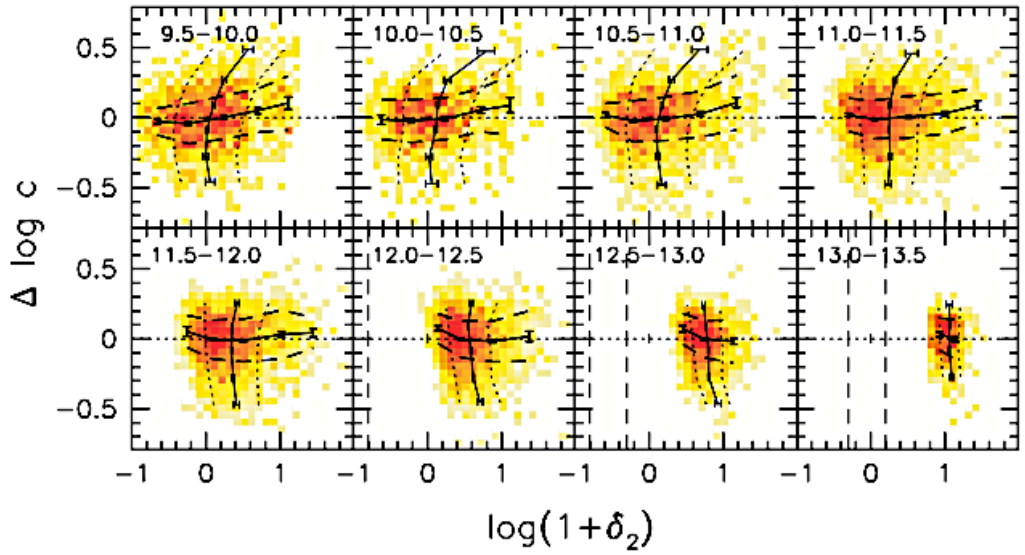
Why do we want to measure assembly bias?



Measuring assembly bias can constrain the correlation between various halo properties

$$b(M_{obs}, C) \propto \int dM P(M, M_{obs}, C) \times b(M, C) n(M)$$

Wechsler et al. '06;
Maccio et al. '07



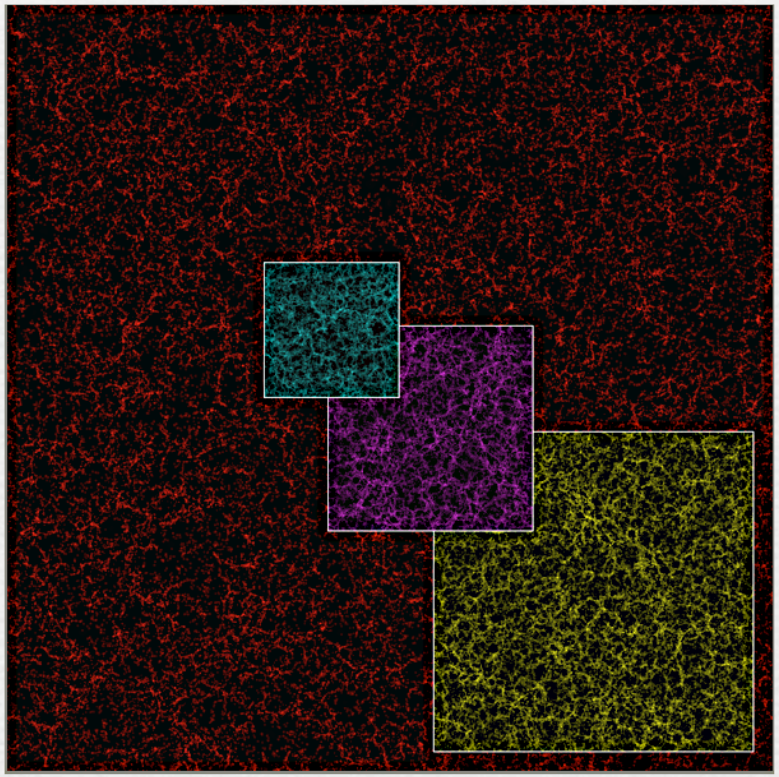
What are we going to observe?

- 2011; DECam on the 4-meter Blanco telescope at CTIO (525 nights)
- g, r, i, z, y; 24.3 mag in i + overlapping with SPT and VISTA (J, H, K)
- Survey area = 5000 deg^2; volume = 17 Gpc^3/h^3
- Galaxy clusters selected from optical imaging
  - Cluster sample: $M_{th} = 10^{13.7}\ M_\odot/h$ and $z_{max} = 1.5$ (~10^5 clusters)

DES Website: http://www.darkenergysurvey.org/

Large Suite Dark Matter Simulations (LasDamas)

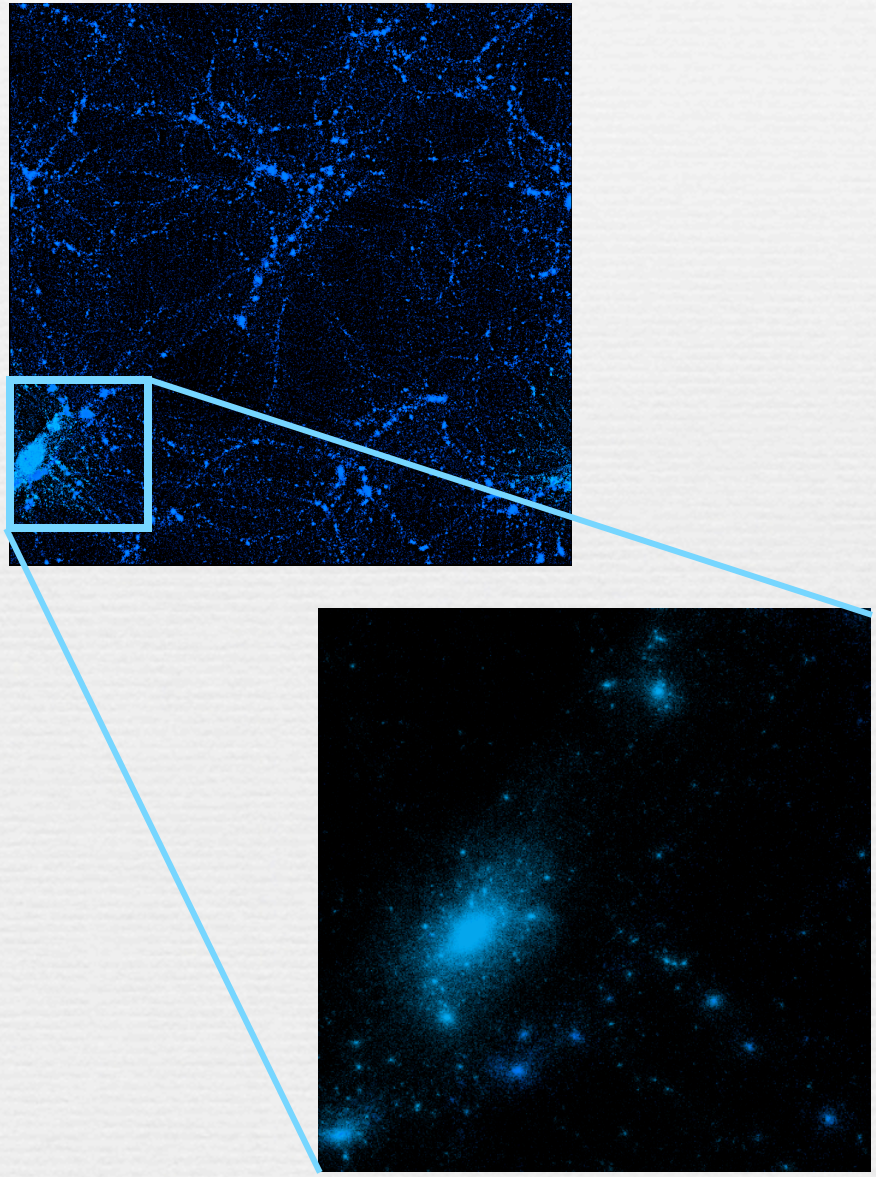
McBride, Berlind, Busha, Manera, Scoccimarro, van den Bosch, Wechsler



Name	Box Size (Mpc/h)	Particle Mass ($M_\odot/h$)	Total Volume (Gpc^3/h^3)
Oriana	2400	4.5E+11	550
Carmen	1000	4.9E+10	40
Esmeralda	640	9.0E+09	10
Consuelo	420	1.8E+09	3.0

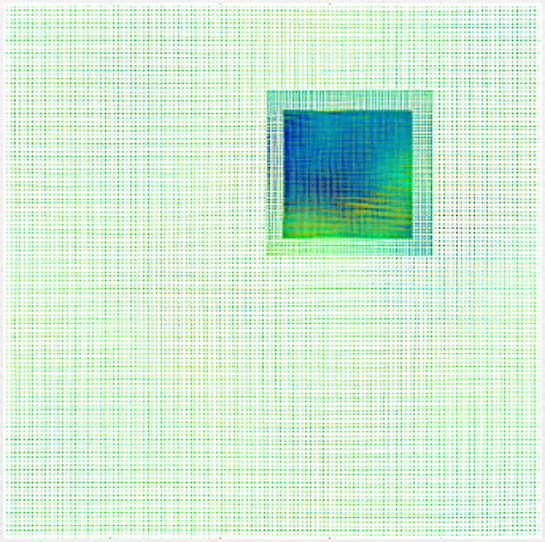
LasDamas website:
http://lss.phy.vanderbilt.edu/lasdamas
McBride et al.

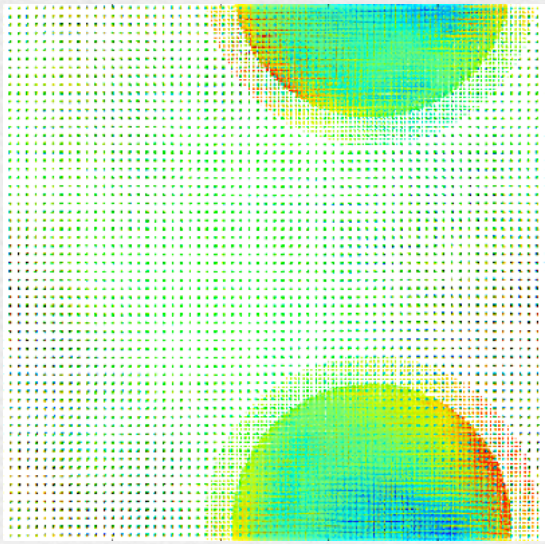
Ongoing project I: re-simulations of massive halos in a Gpc box



- Zooming in the region where a massive halo forms and re-simulating it with high-resolution particles
- Aiming for calibrating large-scale halo bias and small-scale subhalo properties simultaneously
- Representative of the statistical properties of clusters observable in DES and massive cluster surveys
- Resolving subhalos down to $10^9 M_\odot/h$; also relevant to the study of galaxy formation in massive halos

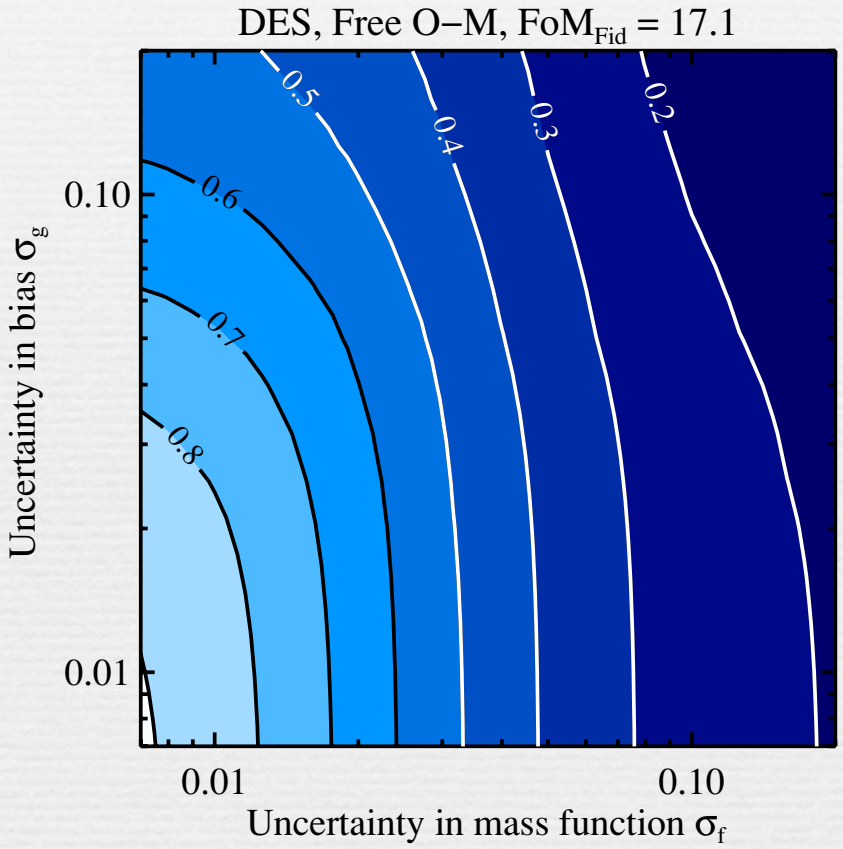
Generating initial conditions





- Multi-scale Initial Conditions (MUSIC, Hahn '10)
  - Allowing multiple levels of refinement
  - Transfer function calculated in the intermediate refinement level
- 2LPT (Crocce et al. '06)
  - Generating full-volume initial conditions with the same modes
  - Cutting and pasting
- Re-simulation targets:
  - Selecting most massive halos and identifying the Lagrangian volumes in the initial condition
  - Highest mass resolution ~10^8 $M_\odot/h$; softening ~ 5 kpc/h
  - Gadget-2 N-body simulations (dark matter only)

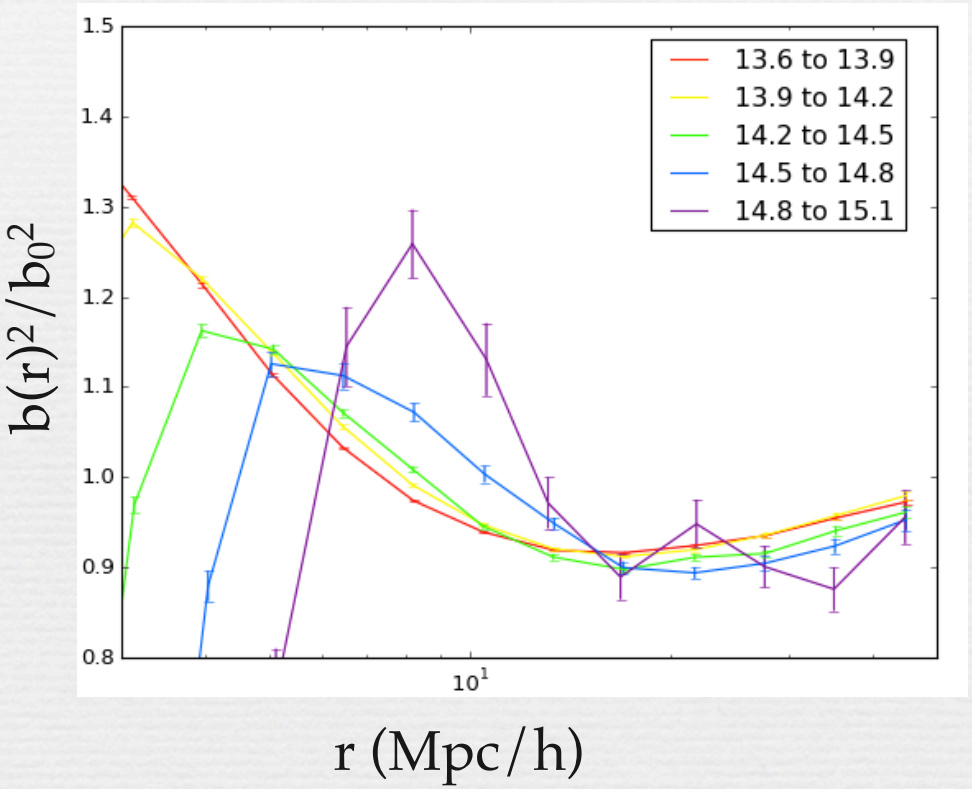
Ongoing project II: scale-dependent bias and mass calibration



Wu, Zentner, and Wechsler '10, ApJ

- Halo bias can help cluster mass self-calibration and thus improve the dark energy constraints; accurate calibration of halo bias is essential when no external mass information is present.
- Current clustering measurements are limited to large-scale bias. How does the small-scale bias help mass self-calibration in surveys?

Small-scale bias calibration



- Calibrating halo bias b(M,r) down to Mpc scale; using the statistics in LasDamas
- Oriana: 41 simulations of box size 2.4 Gpc/h
- The shape of small-scale bias will provide information for cluster mass calibration in surveys.

Summary / Outlook

- Measuring halo bias in upcoming surveys (e.g. DES) will help the understanding of assembly history of dark matter halos. It will also help the cluster mass self-calibration in surveys and improve the constraints on dark energy.
- Ongoing projects:

  - We are performing re-simulations of massive halos in a Gpc box to study halo bias and halo substructures simultaneously. This will allow us to resolve the substructures hosting all observed galaxies in the most massive systems.

  - We are calibrating scale-dependent bias using LasDamas and applying it to cluster mass self-calibration.