GALAXY CLUSTERING

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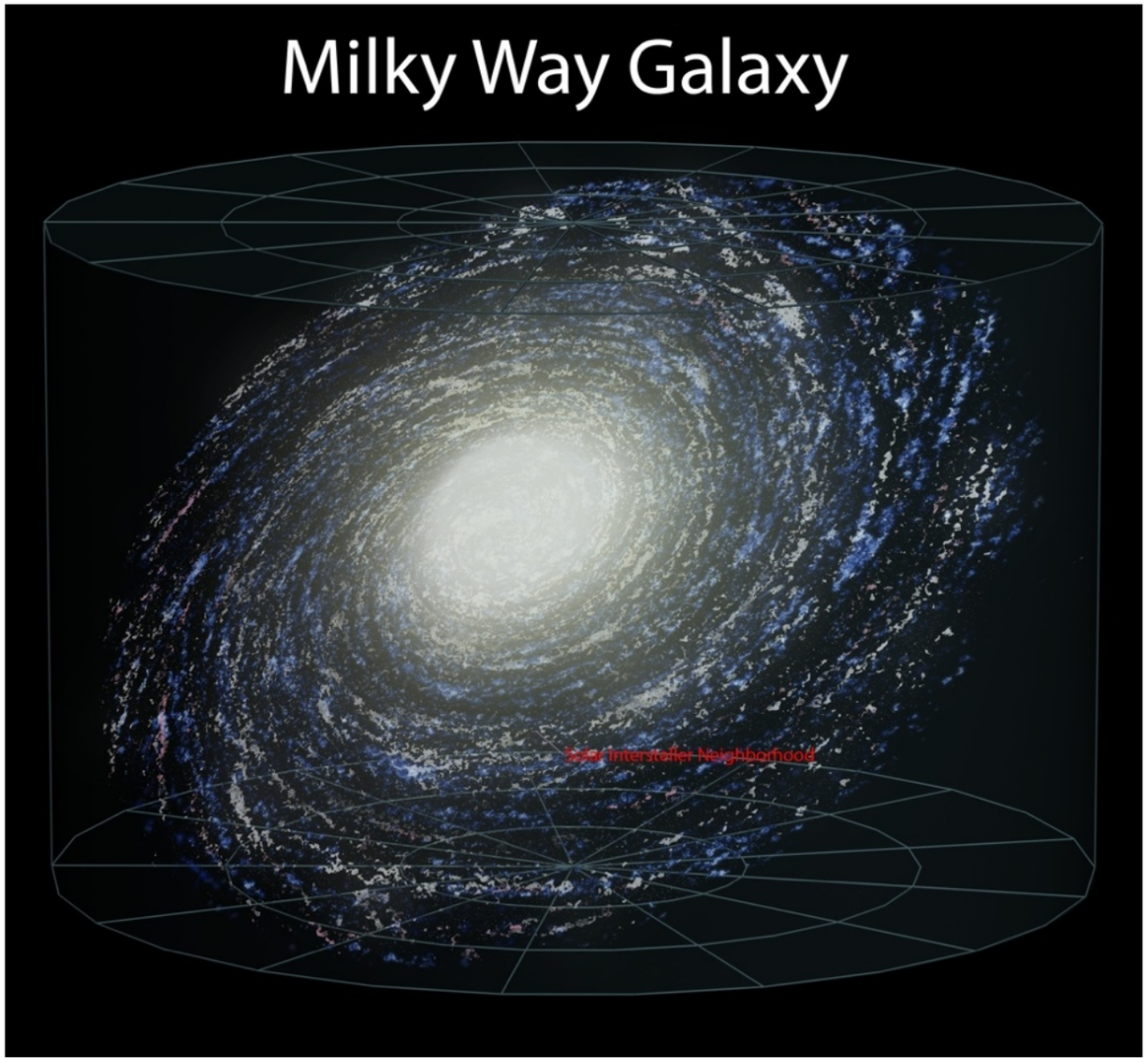
AST 542

April 10th 2013

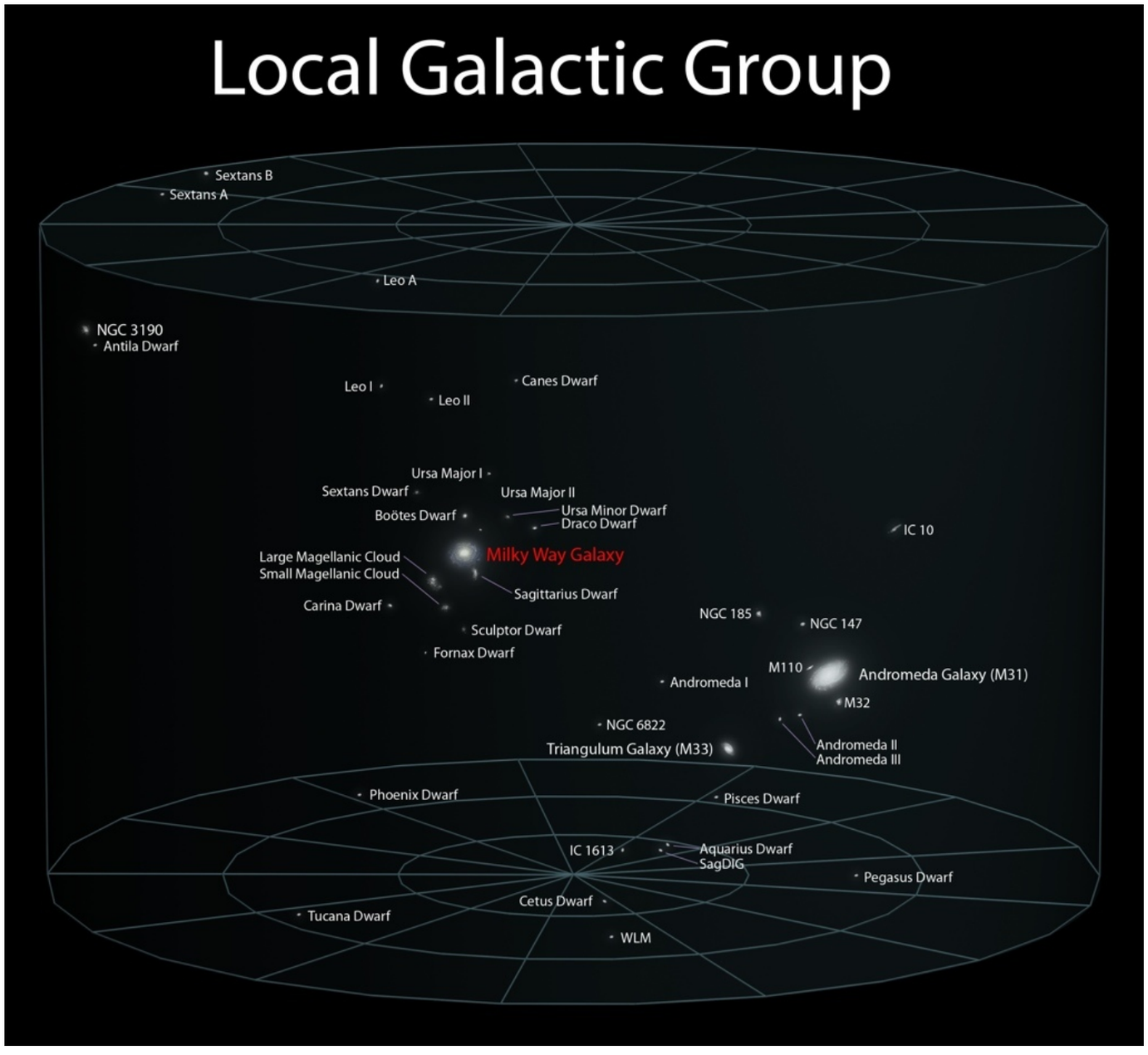
INTRODUCTION: SCALES

GALAXIES: 10kpc



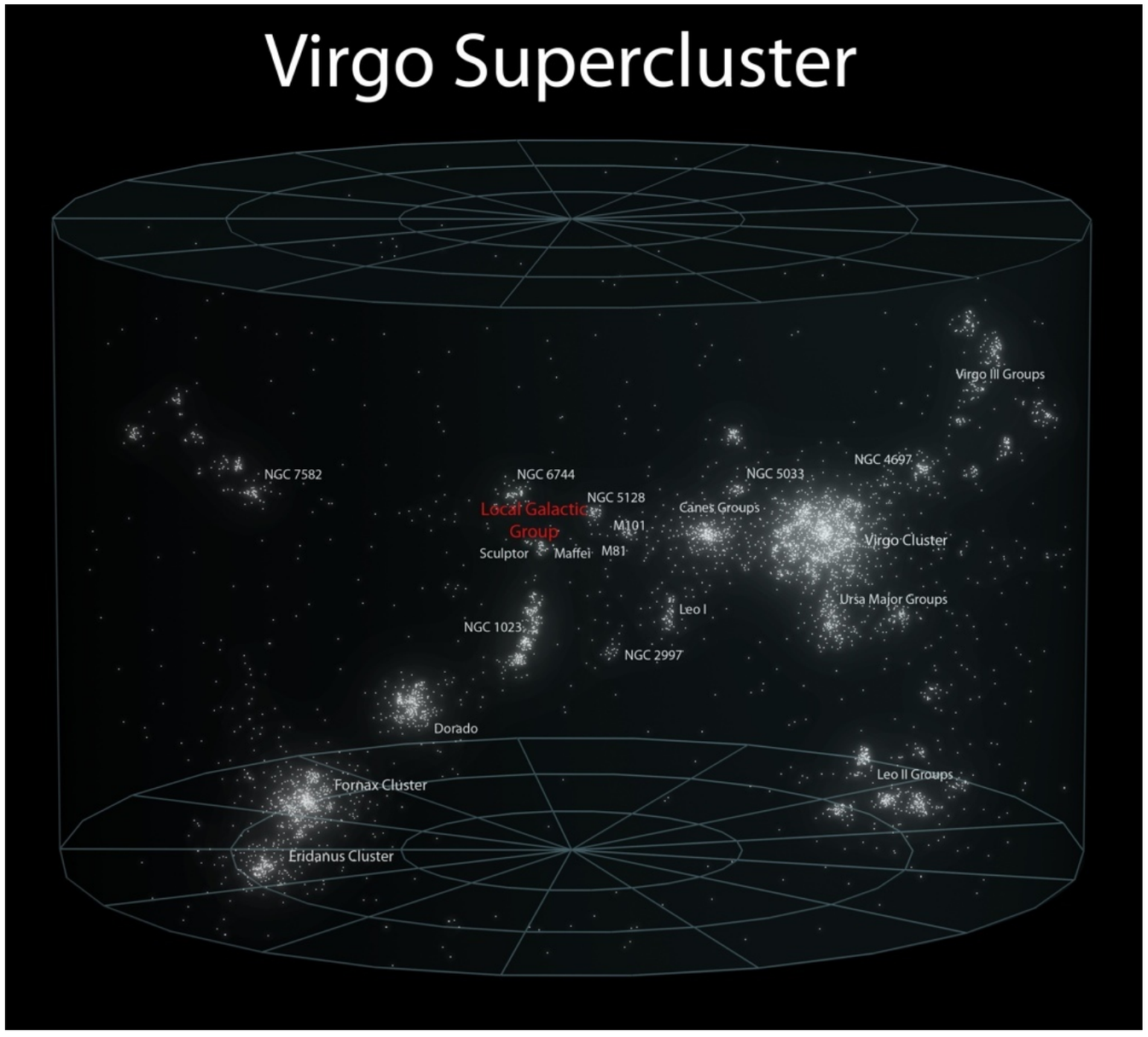
- Milky Way: 10kpc, $10^{12} M_\odot$

GALAXY GROUPS: 100kpc



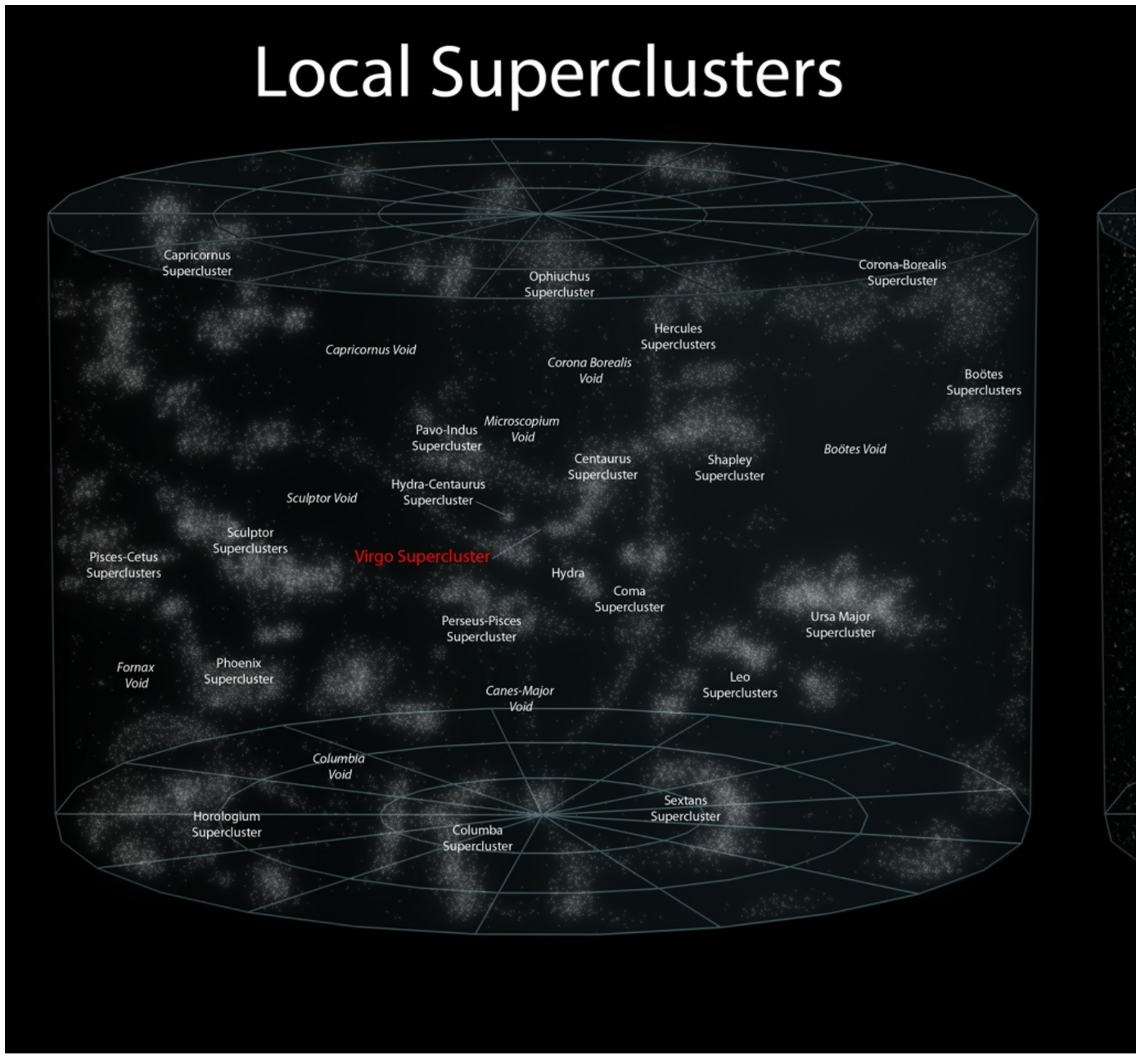
- or «poor clusters»
- Local Group: ~50gal, 3Mpc, $10^{13} M_\odot$

GALAXY CLUSTERS: 1Mpc



- or «rich clusters»
- Virgo Cluster: ~1000 gal, 2.2Mpc, $10^{15} M_\odot$

GALAXY SUPERCLUSTERS: 10Mpc



- Superclusters: 10-100clusters, 10Mpc
- sheets, filaments, tracing the cosmic web of dark matter

GALAXY CLUSTERING

What?

- Statistical properties of the distribution of galaxies on various scales

Why?

- Tracers of DM$\longleftrightarrow$cosmology!
- Clues on galaxy evolution

OUTLINE

- Methods to study galaxy clustering
- Cosmological contribution to the correlation function
- Clues on galaxy evolution

TOOLS AND METHODS

AVAILABLE SURVEYS

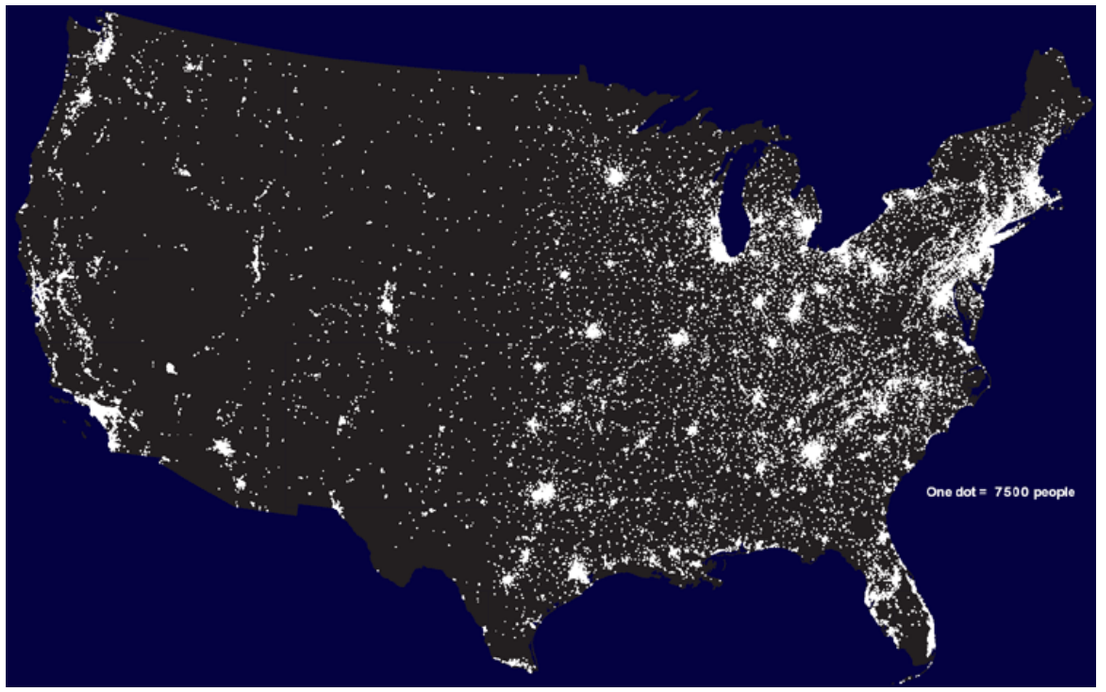
- 2DFGRS: 2°, 220kgal, z<0.22
- 6DFGRS: 6°, 130kgal, not as deep
- SDSS: 1/4 sky, ~1Mgal, z<0.15, high resolution local survey
- DEEP2: 4 fields of 120‘x30’, 0.75<z<1.4, resolution comparable to SDSS
- COSMOS: 2sq deg, up to z~5, (photo-z)
- NMBS: up to z~3, (photo-z)

CORRELATION FUNCTION

- Usual tool to study noise
- Continuum definition:

$$\delta_{(\vec{x})} := \left(n(\vec{x}) - \overline{n}\right)/\overline{n}$$

$$\xi_{(\vec{r})} := \langle \delta_{(\vec{x})} \delta_{(\vec{x}+\vec{r})} \rangle$$



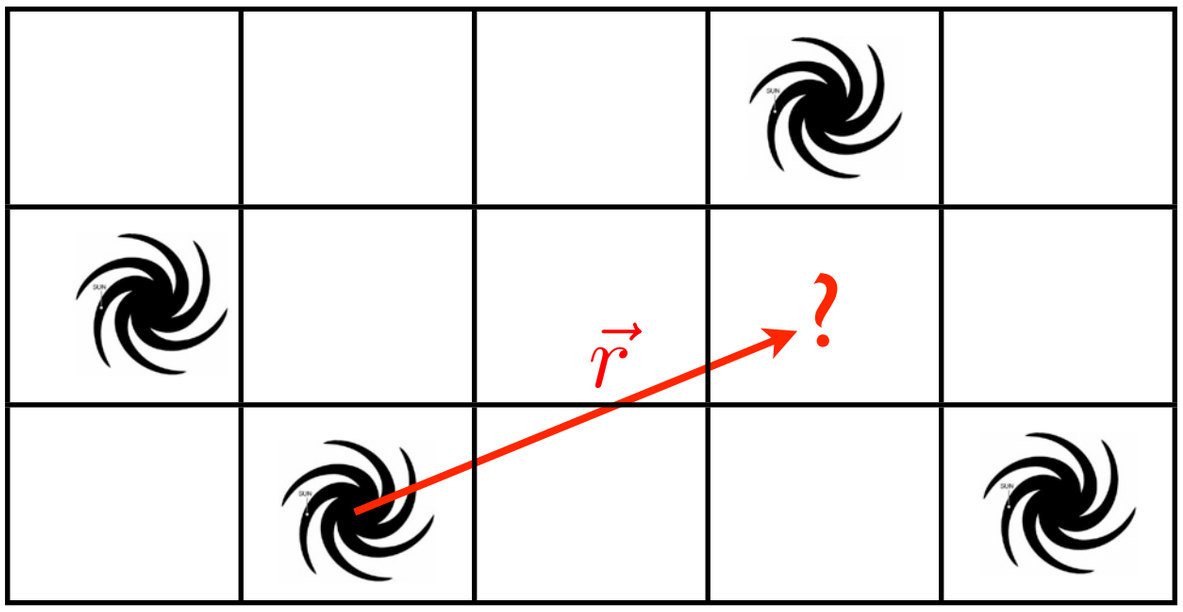
$$\langle n_{(\vec{x})} n_{(\vec{x}+\vec{r})} \rangle = \overline{n}^2 \left[1 + \langle \delta_{(\vec{x})} \delta_{(\vec{x}+\vec{r})} \rangle\right]$$

CORRELATION FUNCTION

- Interpretation as extra probability on top of uniform Poisson sampling.

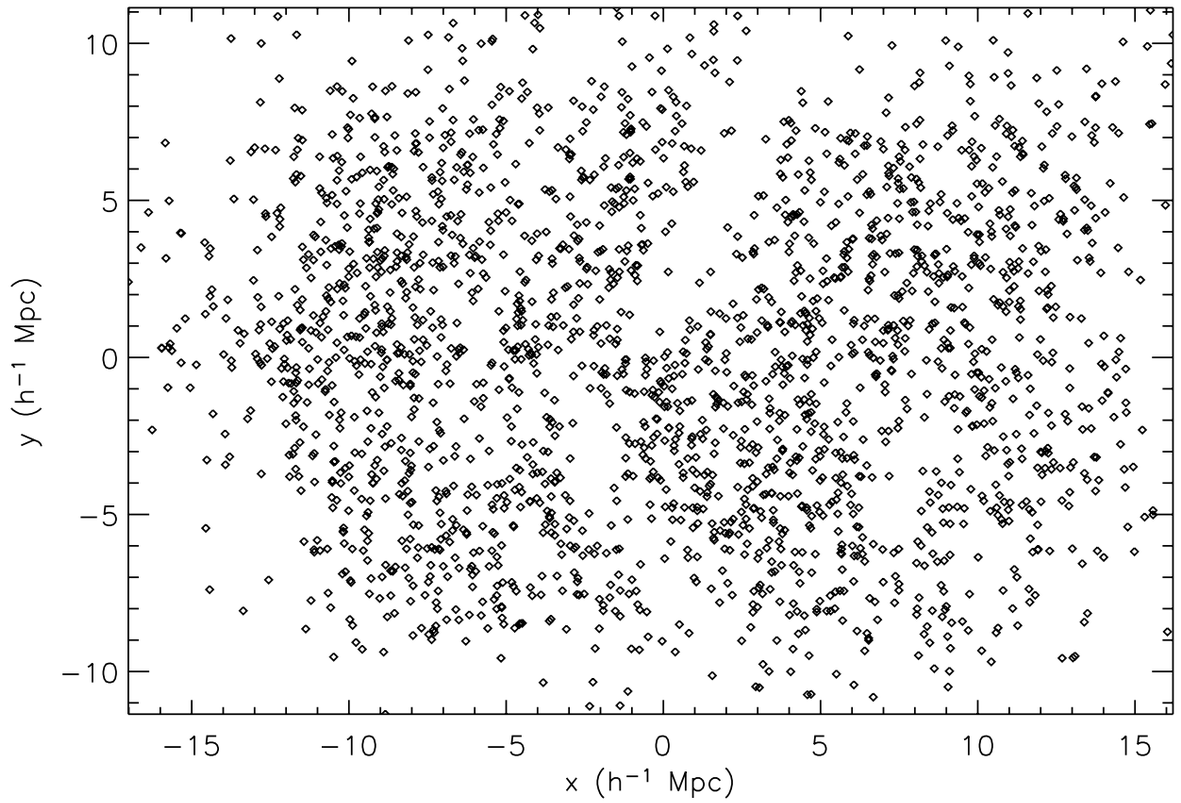
$$\langle n_{(\vec{x})} n_{(\vec{x}+\vec{r})} \rangle = \overline{n}^2 \left[1 + \langle \delta_{(\vec{x})} \delta_{(\vec{x}+\vec{r})} \rangle \right]$$

$$P_{(\vec{x}+\vec{r}|\vec{x})} = (\overline{n} V) \left[1 + \xi_{(\vec{r})} \right]$$



ESTIMATOR FOR CORRELATION FUNCTION

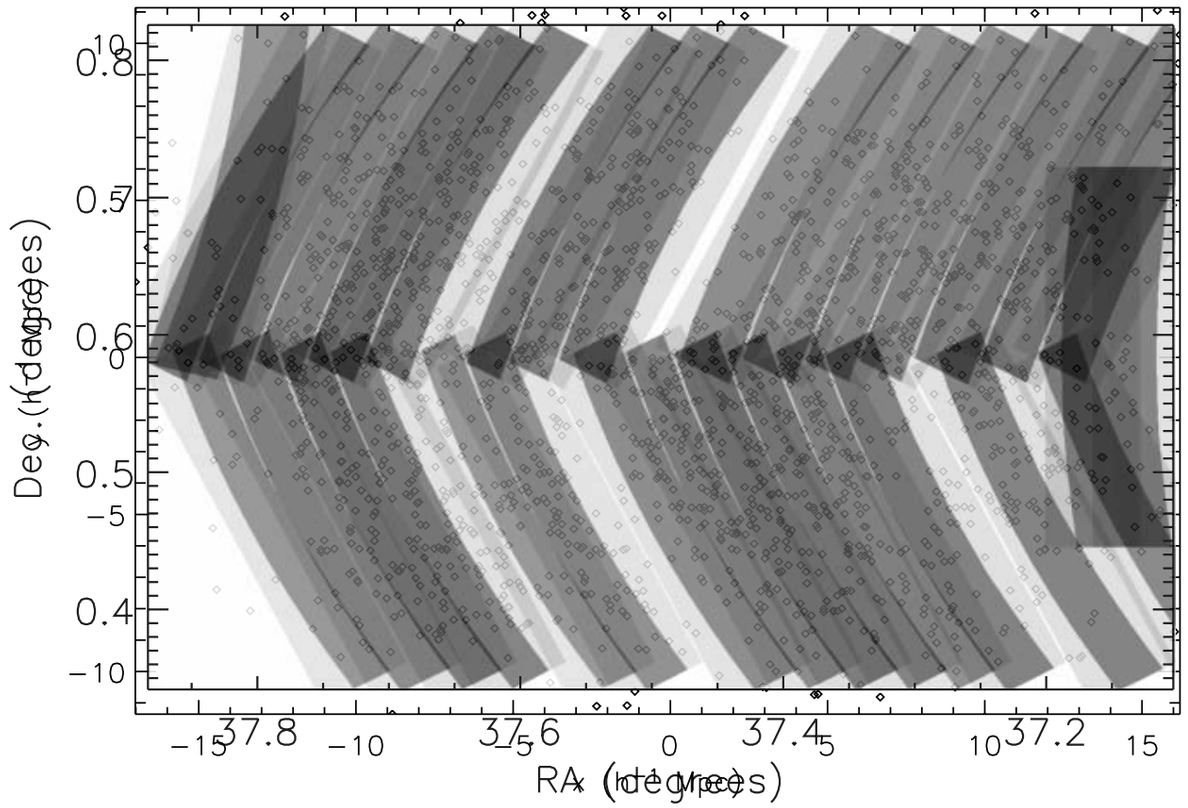
- Galaxy survey
- Mock map: Poisson sampling of a uniform galaxy number density



from Coil et al. 2004

ESTIMATOR FOR CORRELATION FUNCTION

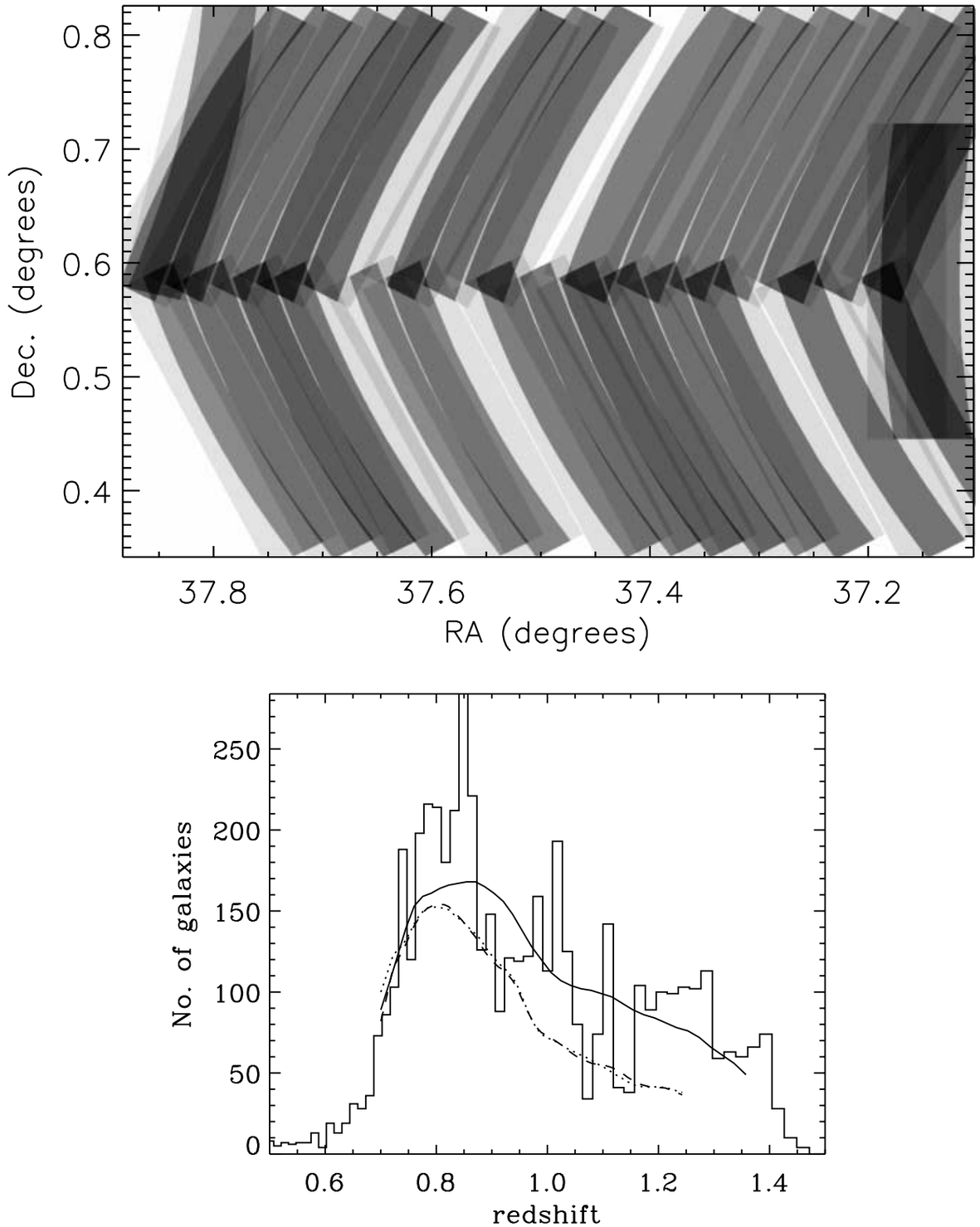
- Galaxy survey
- Mock map: Poisson sampling of a uniform galaxy number density
- Window function



from Coil et al. 2004

ESTIMATOR FOR CORRELATION FUNCTION

- Galaxy survey
- Mock map: Poisson sampling of a uniform galaxy number density
- Window function
- Redshift selection function

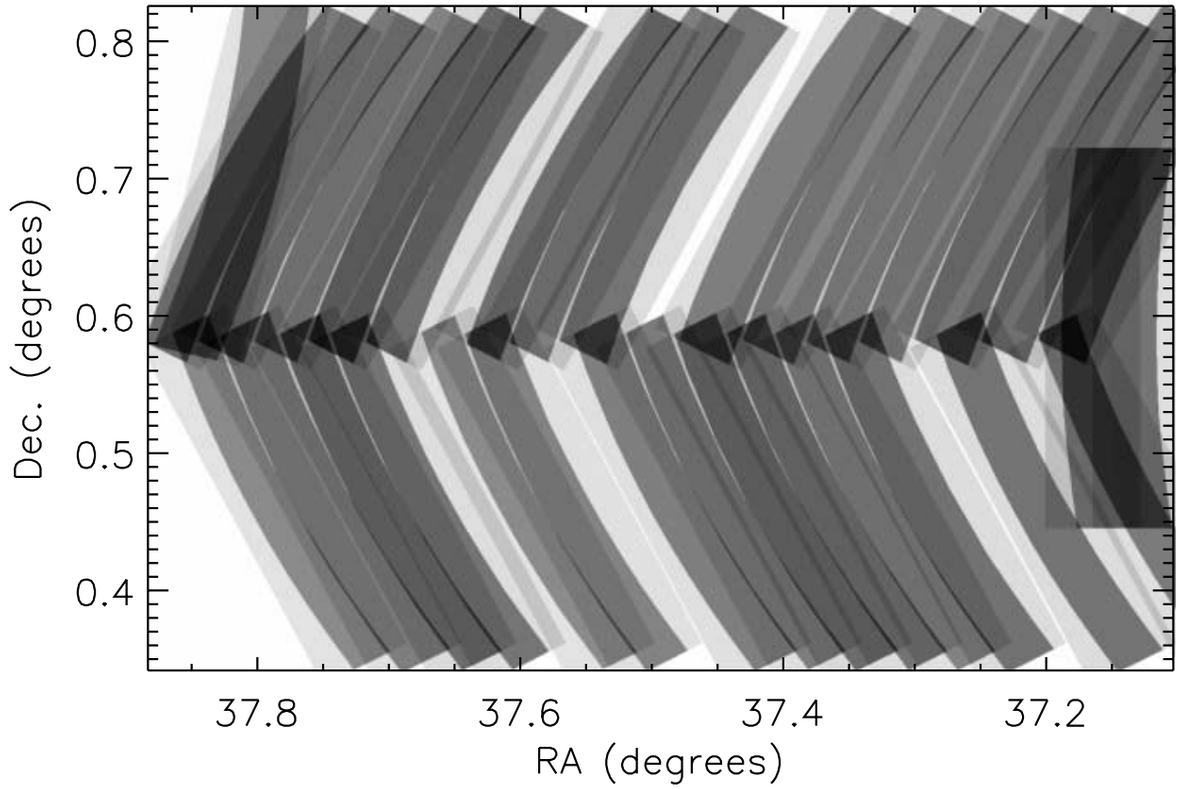


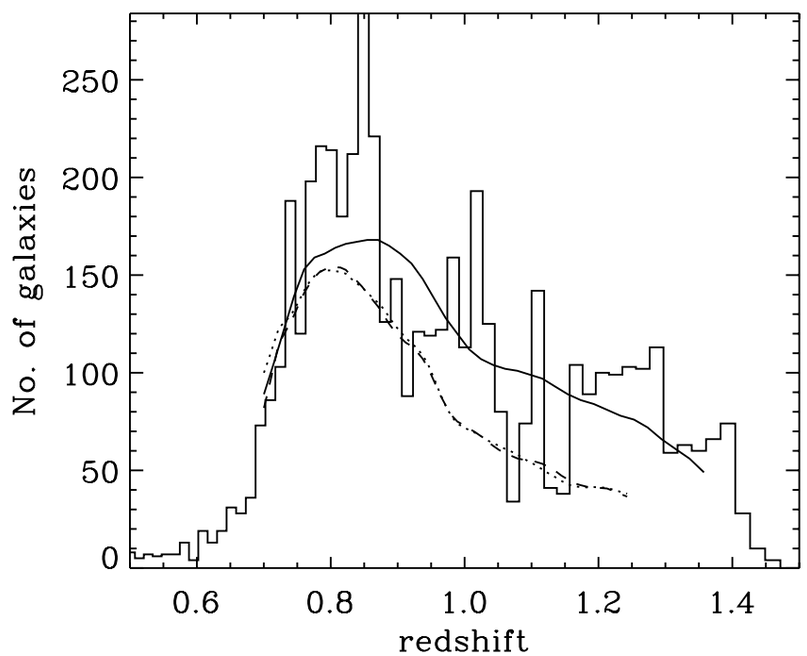
from Coil et al. 2004

ESTIMATOR FOR CORRELATION FUNCTION

- Galaxy survey
- Mock map: Poisson sampling of a uniform galaxy number density
- Window function
- Redshift selection function
- Discrete estimator (Landy & Szalay estimator 1993):

$$\xi = \frac{DD}{SS}\left(\frac{n_S}{n_D}\right)^2 - 2\frac{DS}{SS}\left(\frac{n_S}{n_D}\right) + 1$$

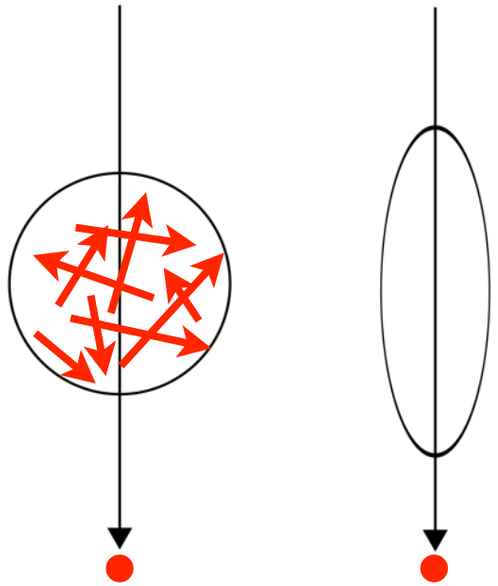




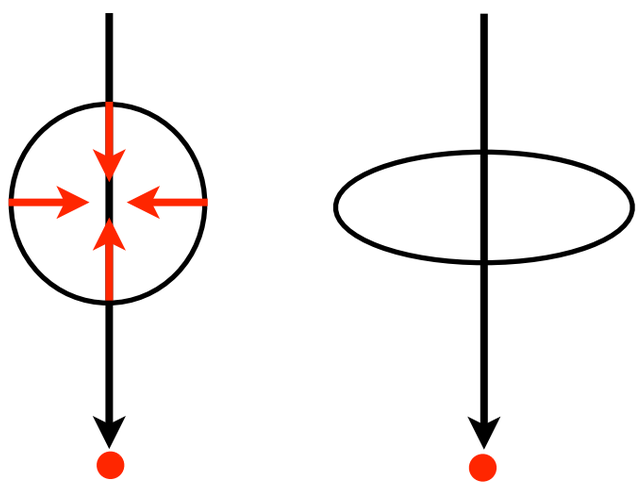
from Coil et al. 2004

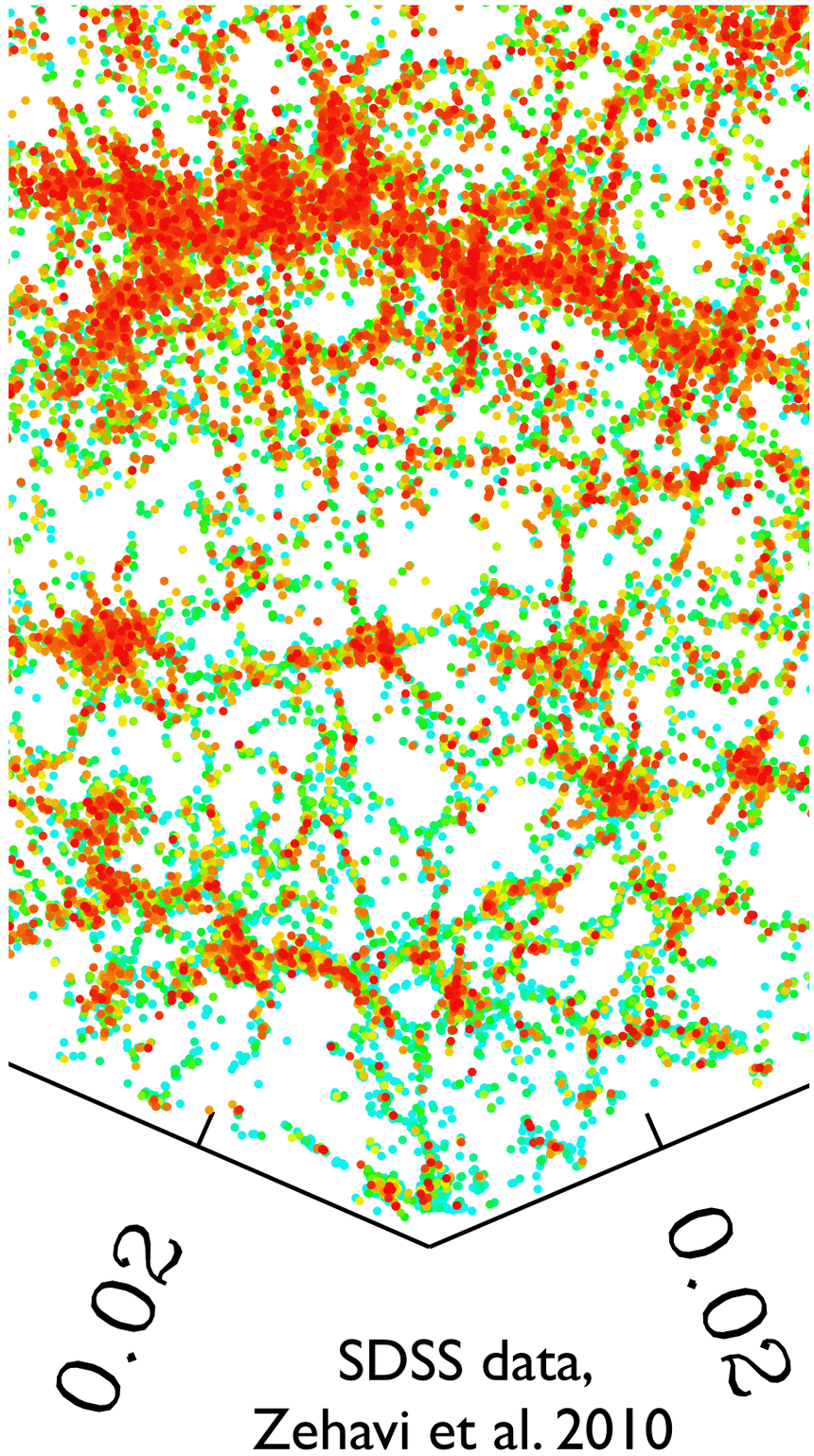
REDSHIFT-SPACE DISTORTIONS

- Small scales: finger of god



- Large scales: density-velocity correlation





SDSS data,
Zehavi et al. 2010

GALAXY BIAS

- Untangling cosmology and galaxy evolution:

$$\delta_g(m, \mathrm{color}, ...) = b_g(m, \mathrm{color}, ...)\delta_{\mathrm{matter}}$$

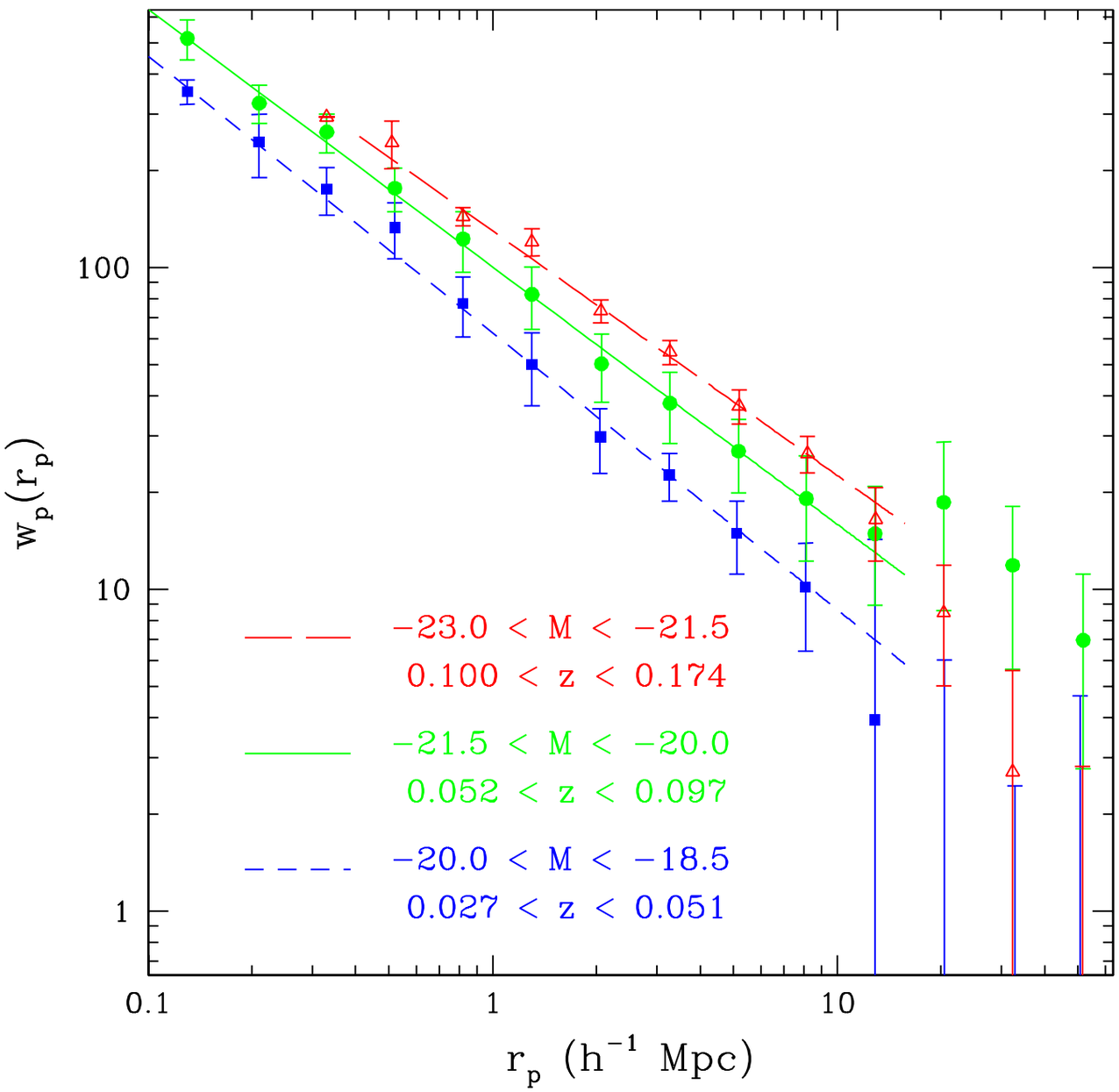
$$n_g = \overline{n}_g \left[1 + b_g \delta_{\mathrm{matter}}\right]$$

- In practice:

$$b_g = \frac{\sigma_g(\mathrm{color}, ...)}{\sigma_{\mathrm{matter}}}$$

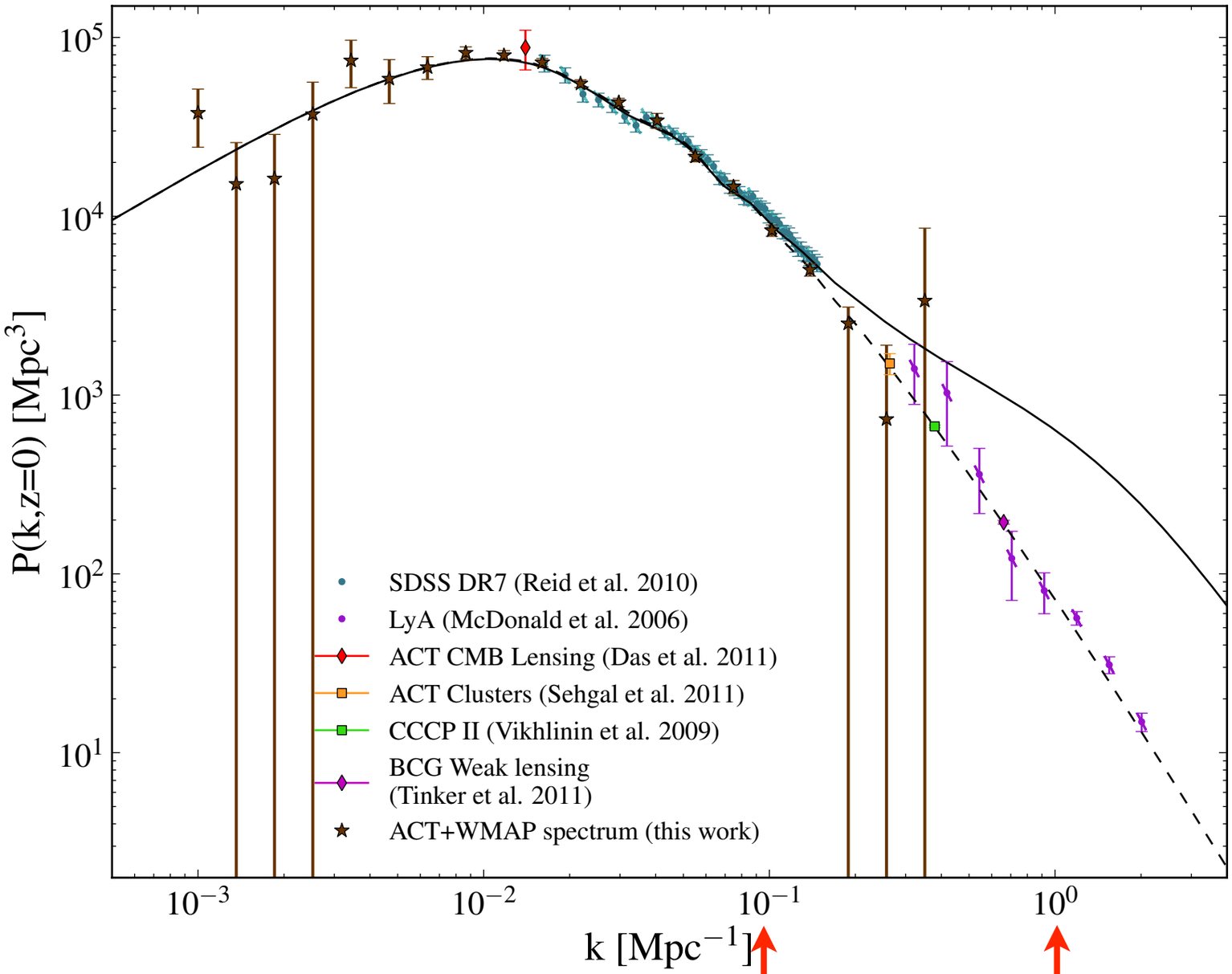
COSMOLOGICAL INSIGHTS ON/FROM THE GALAXY CORRELATION FUNCTION

GALAXY CORRELATION FUNCTION



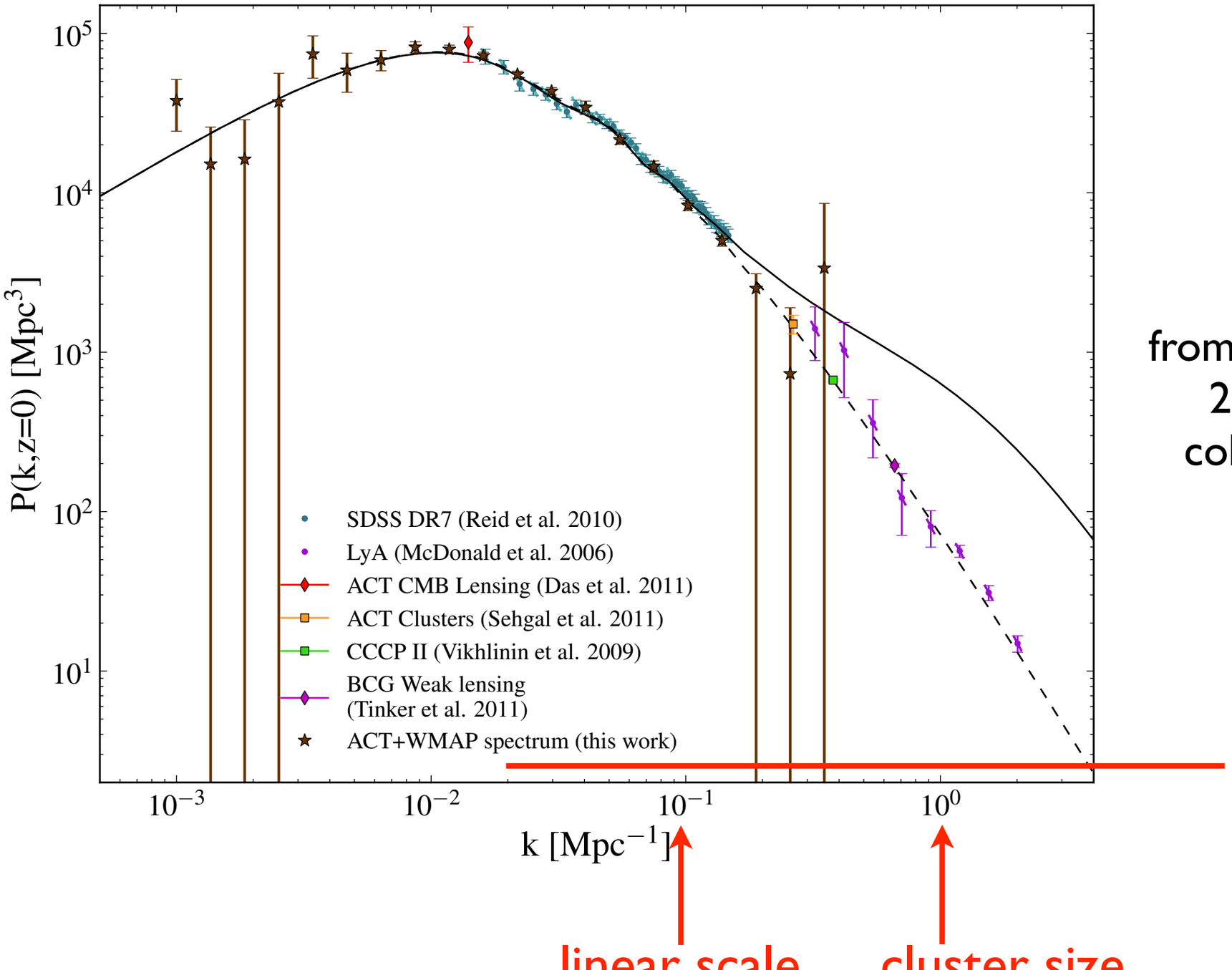
from Zehavi et al. 2002

LINK WITH MATTER



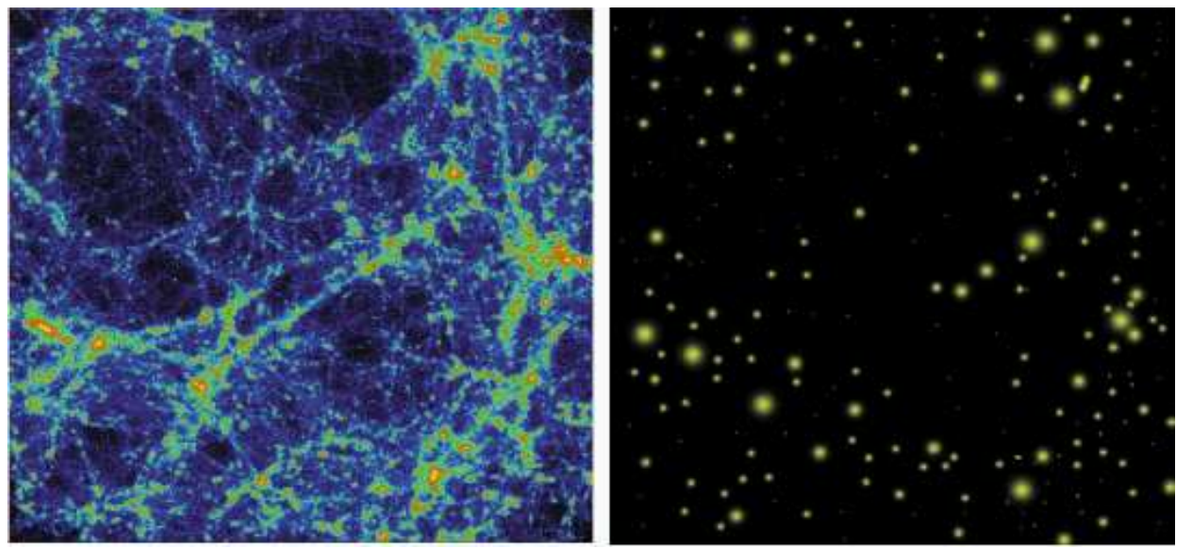
from Hlozek et al. 2011 (ACT collaboration)

LINK WITH MATTER



from Hlozek et al. 2011 (ACT collaboration)

HALO MODEL



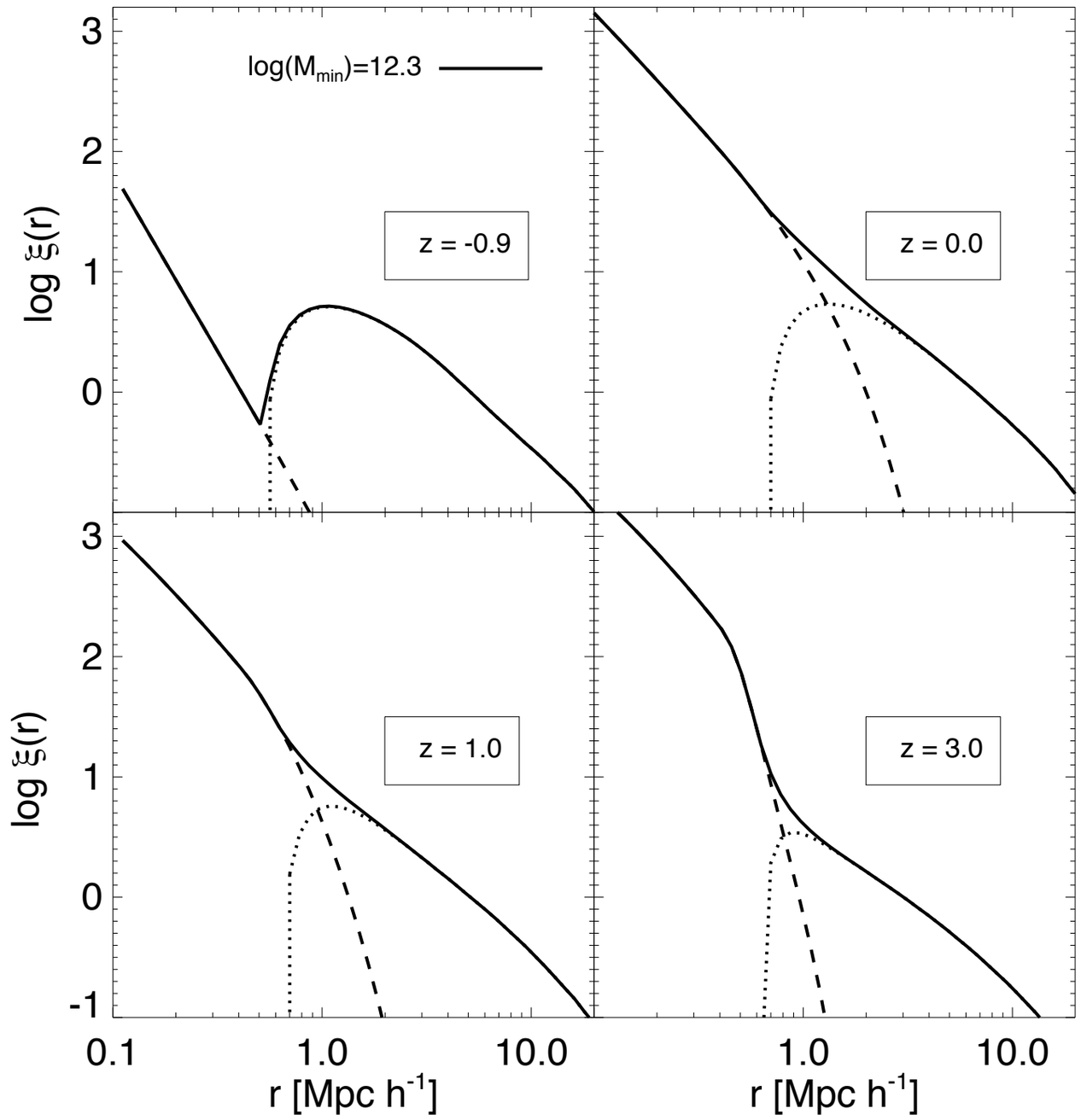
from Cooray & Sheth 2002

$$P_{\rm gal}(k) = P^{1h}_{\rm gal}(k) + P^{2h}_{\rm gal}(k)\,, \qquad \text{where}$$

$$P^{1h}_{\rm gal}(k) = \int dm\, n(m)\, \frac{\langle N_{\rm gal}(N_{\rm gal}-1)|m\rangle}{\bar{n}^2_{\rm gal}}\, |u_{\rm gal}(k|m)|^p\,, \quad \longleftarrow \text{distribution of galaxies inside halos (small scales)}$$

$$P^{2h}_{\rm gal}(k) \approx P^{\rm lin}(k) \left[\int dm\, n(m)\, b_1(m)\, \frac{\langle N_{\rm gal}|m\rangle}{\bar{n}_{\rm gal}}\, u_{\rm gal}(k|m)\right]^2 \quad \longleftarrow \text{distribution of halos (large scales)}$$

«COSMIC COINCIDENCE»

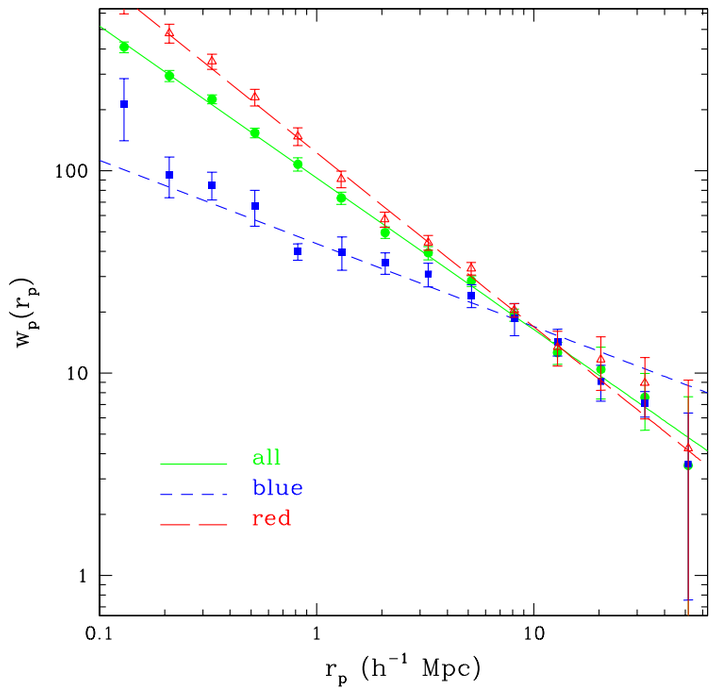


from Watson et al. 2011

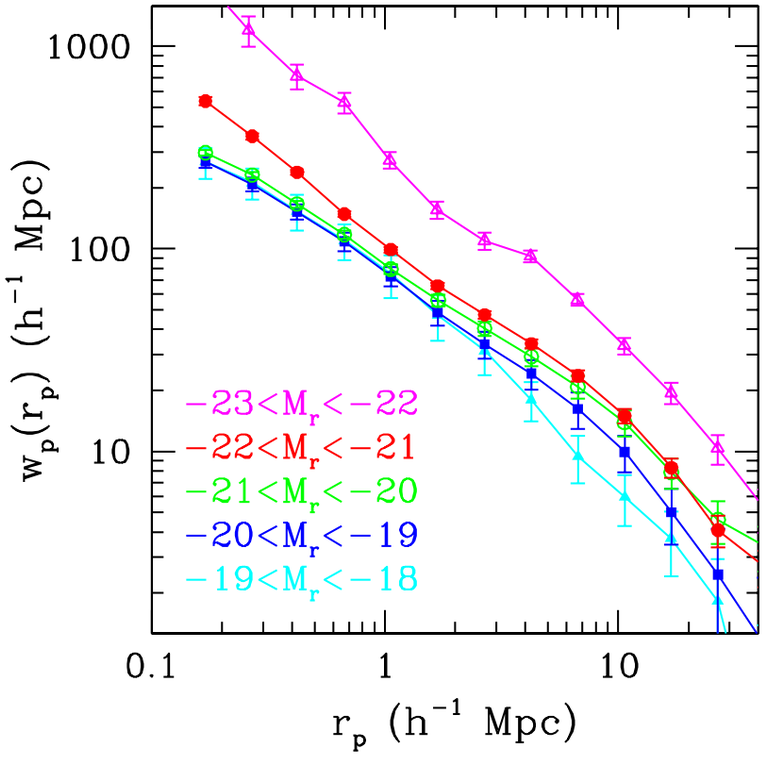
CLUES ON GALAXY EVOLUTION

z < 0.15

- Red galaxies more clustered



- Bright galaxies more clustered

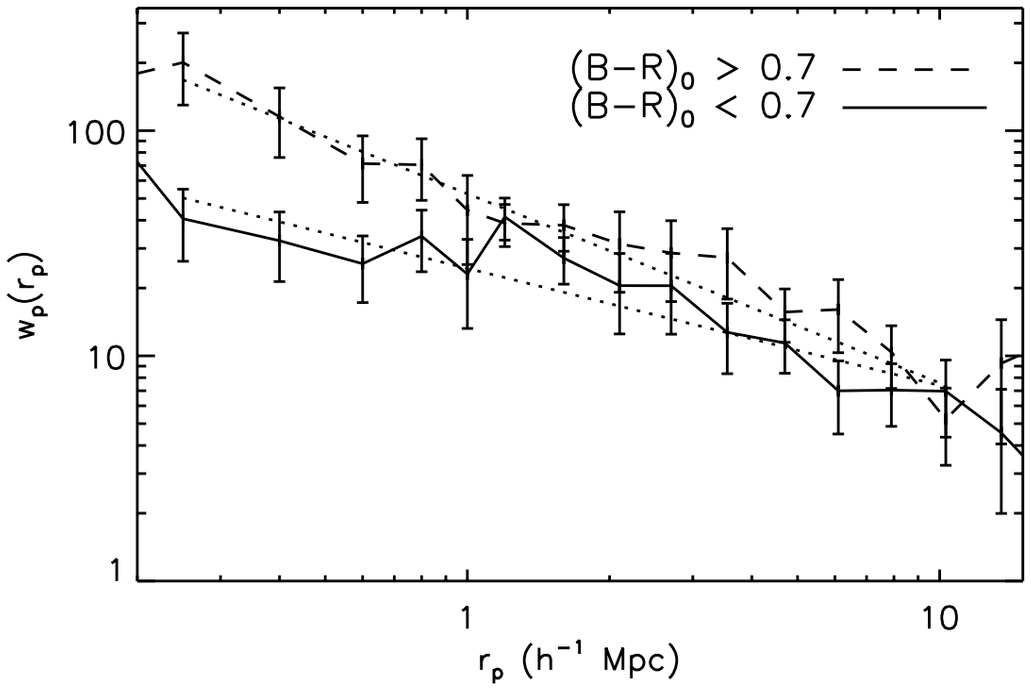


from Zehavi et al. 2002, 2011

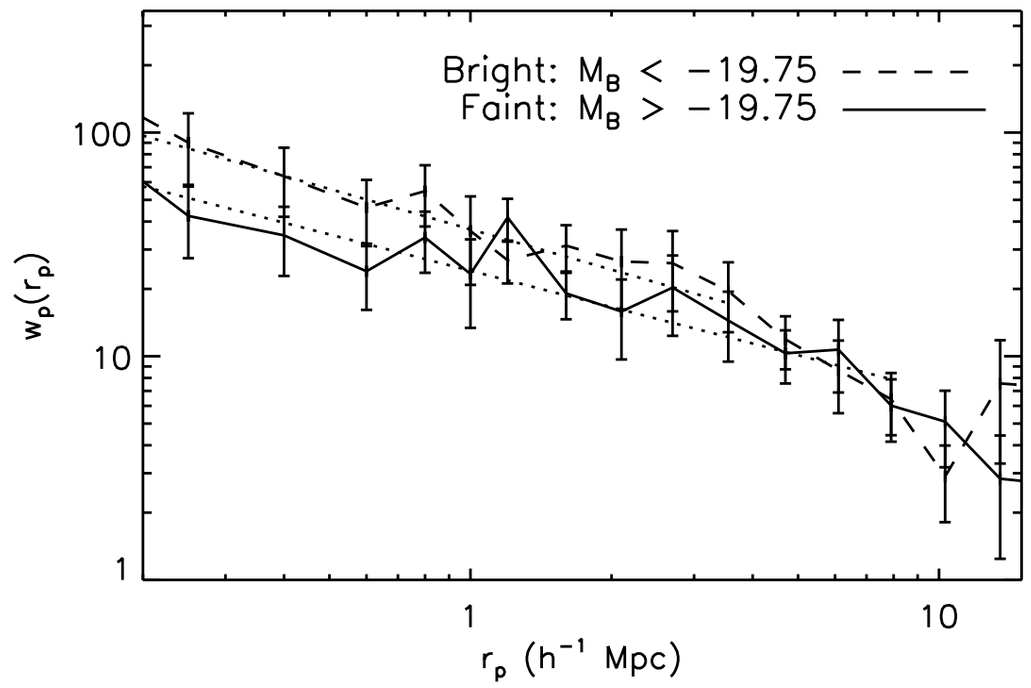
0.7 < z < 1.35

- Red more clustered,

  b/b = 1.4



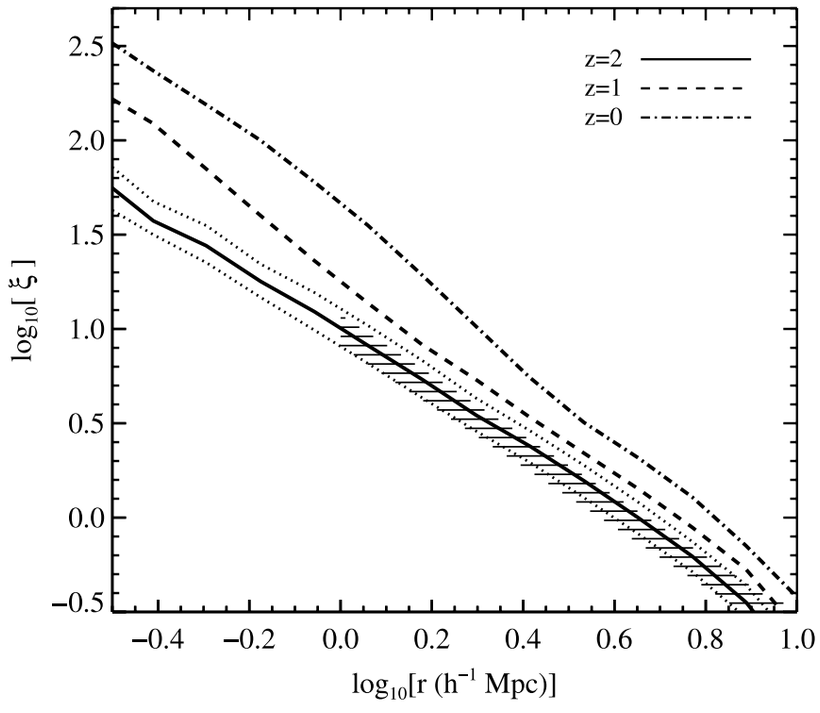
- Brighter galaxies more clustered

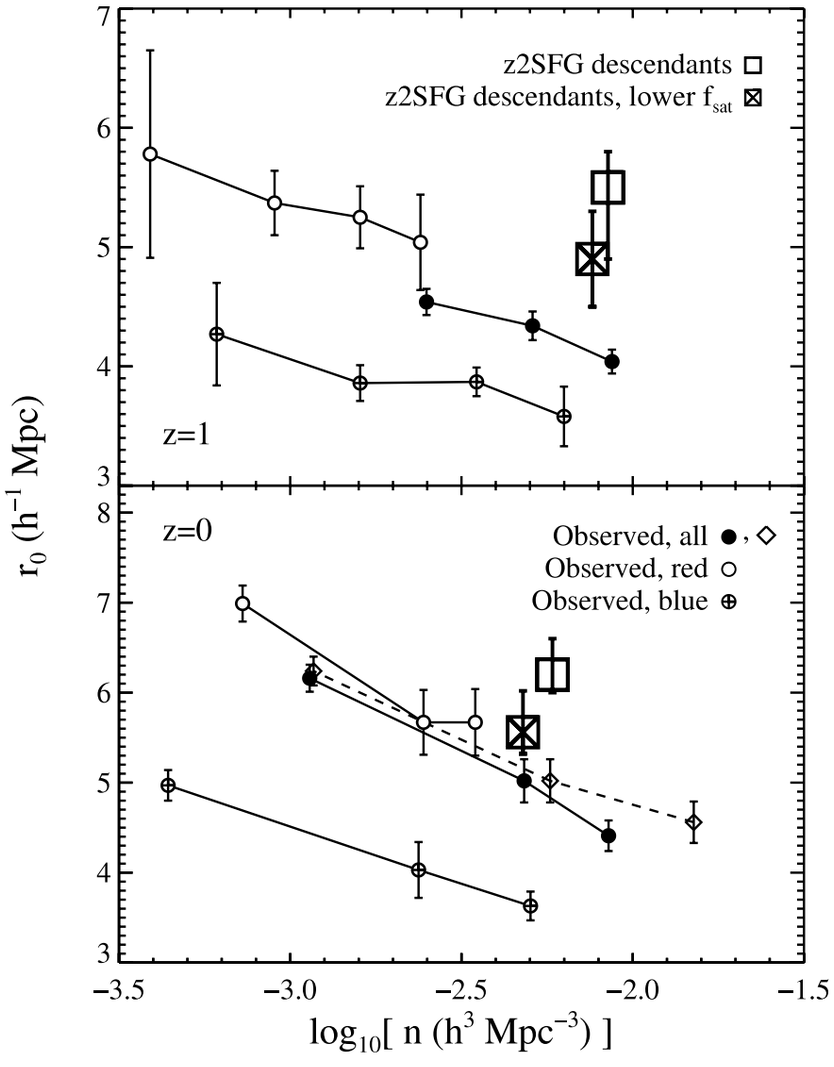


from Coil et al. 2004

Star forming galaxies at z~2

- identify mass of halo hosts

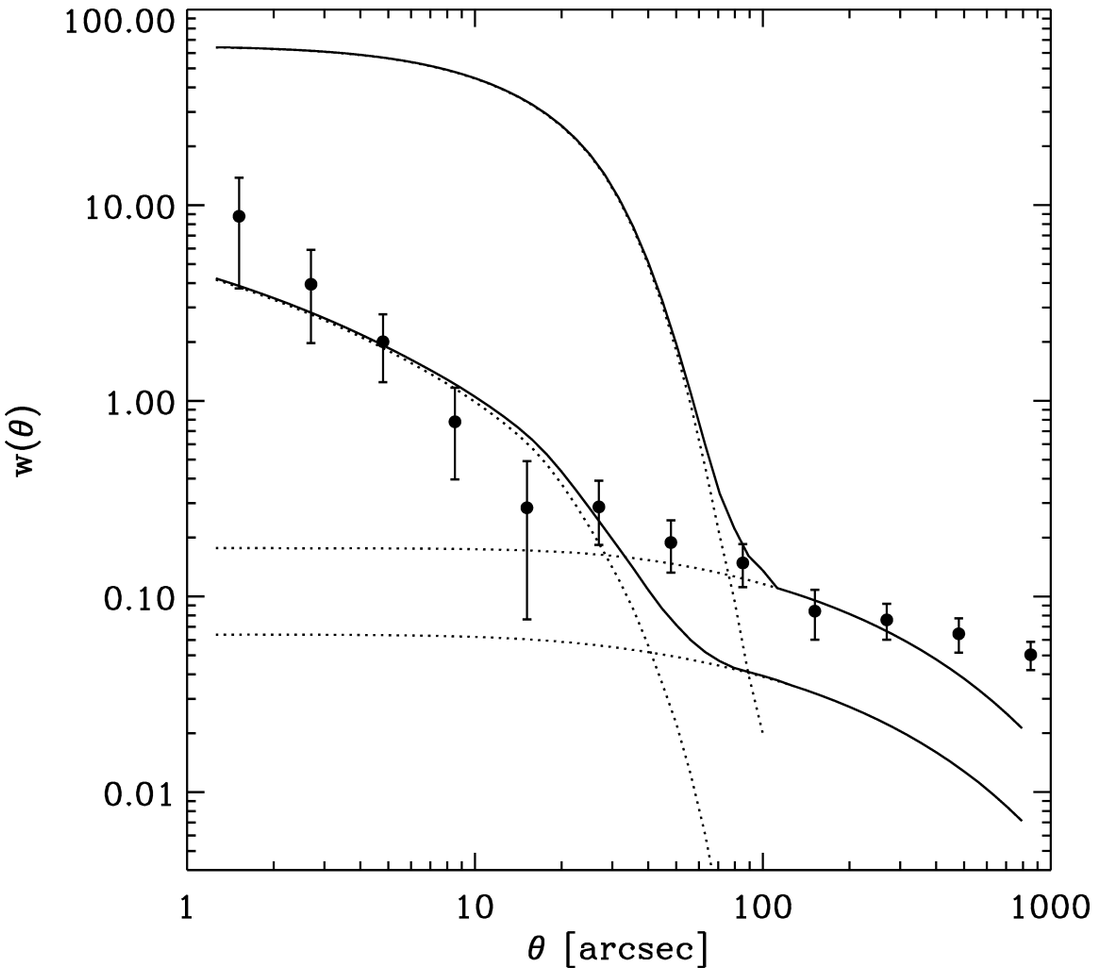




from Conroy et al. 2008

- simulate halos
- Conclusion: 50% survive, of which 30% become satellite galaxies

DISTANT RED GALAXIES AT 2< z <3



from Quadri et al. 2008

- Incompatibility between number density and clustering
- Conclusion: incorrect biasing for DRGs?

CONCLUSION

- Galaxy clustering $\longleftrightarrow$ cosmology
- Clues on galaxy evolution

REFERENCES

- Coil et al. 2004
- Conroy et al. 2008
- Quadri et al. 2008
- Zehavi et al. 2002, 2010, 2011
- Hlozek et al. 2011
- Cooray Sheth 2002
- Watson et al. 2011

LYMAN ALPHA EMITTERS

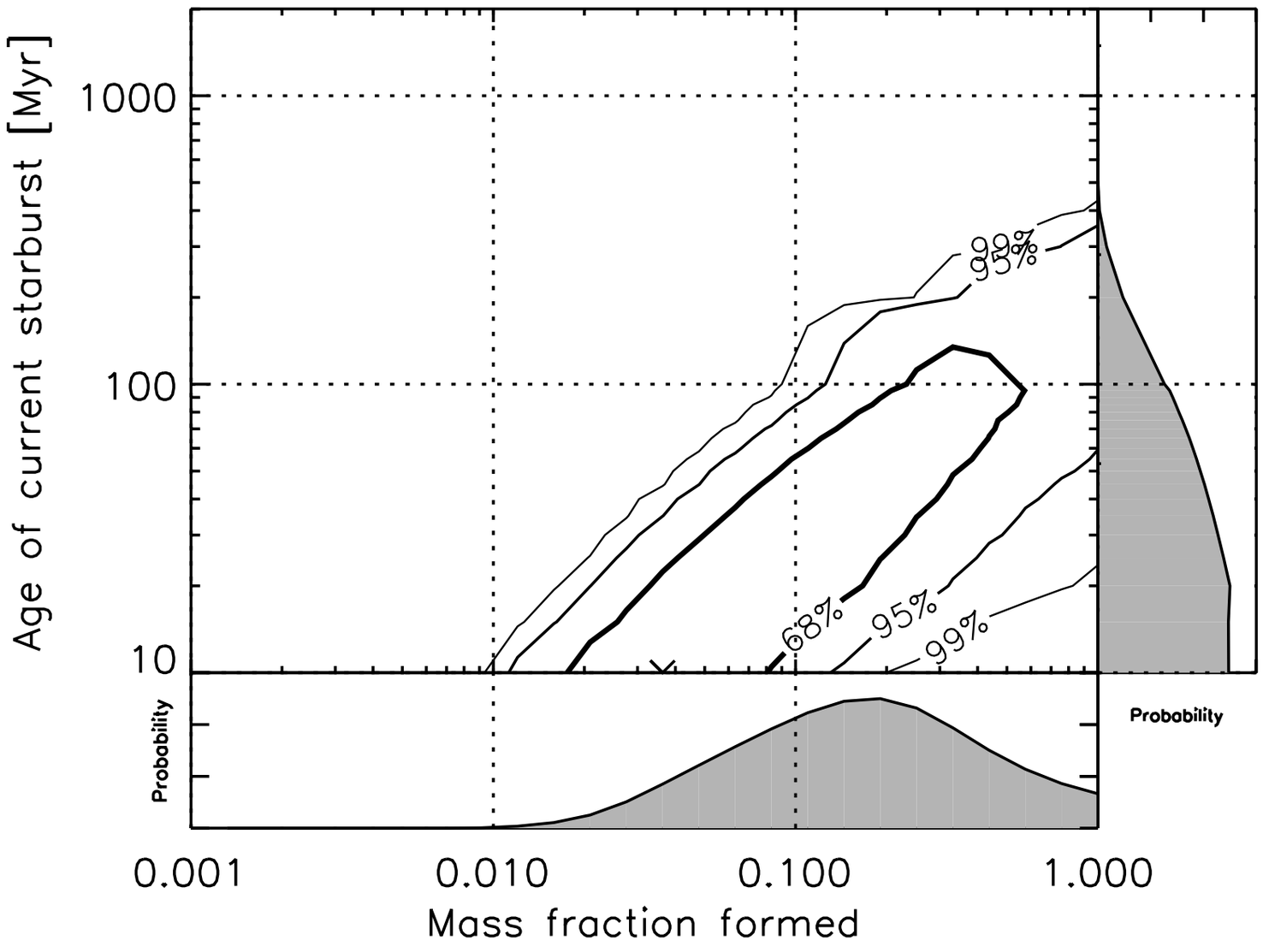


FIG. 5.—Constraints on age of the young stellar population vs. its mass fraction.