Calibration of Cluster Masses with Weak Lensing in the SDSS

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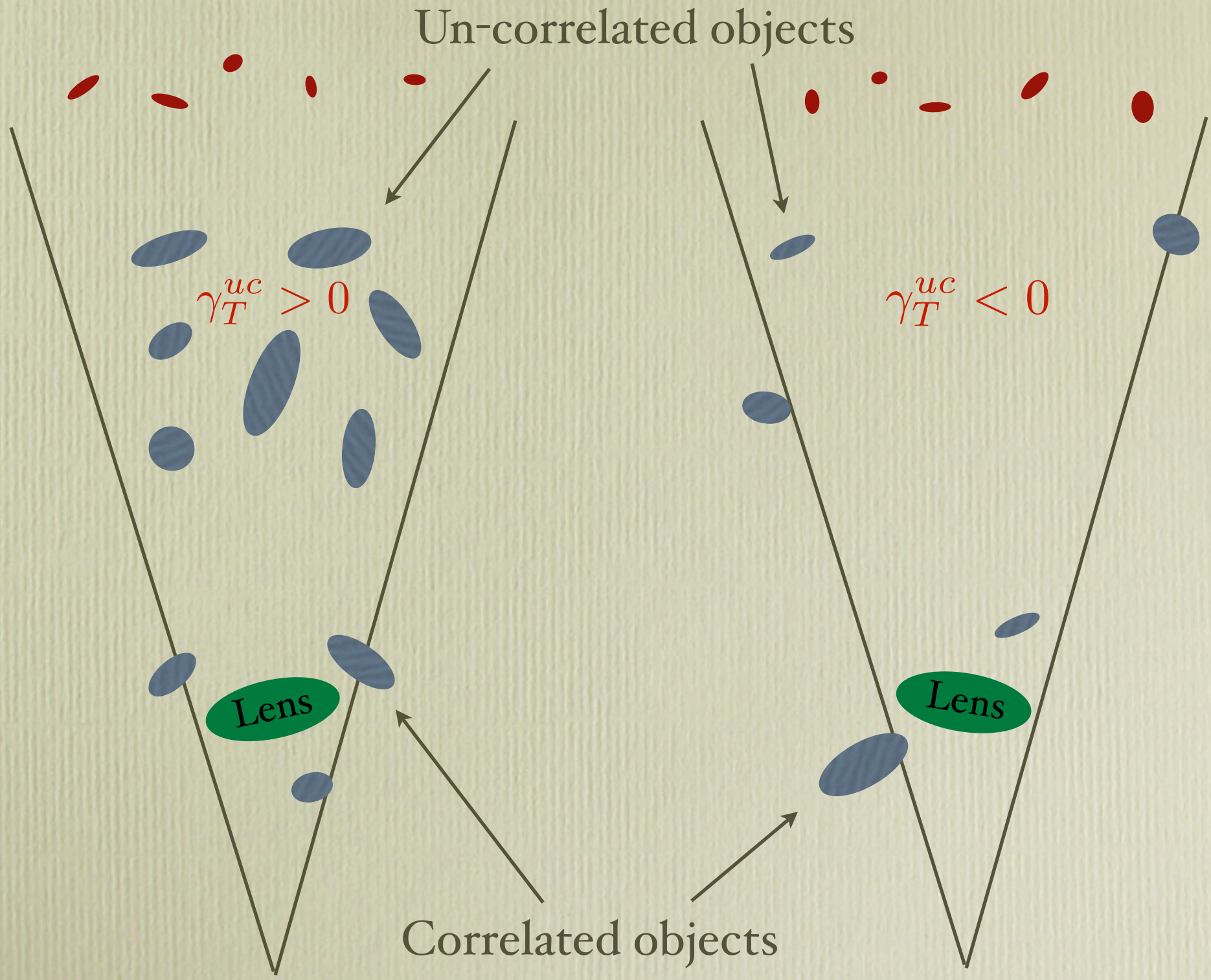
Statistical Lensing

- Average lensing signal over many lenses to improve S/N

$$\begin{aligned}\Sigma_{crit} \times \gamma_T &= \overline{\Sigma}(< R) - \overline{\Sigma}(R) \\ &\equiv \Delta\Sigma(R)\end{aligned}$$

- Projection effects cancel to zero over many lines of sight: no net shear
- Simplifies interpretation


Un-correlated objects
$\gamma_T^{uc} > 0$
$\gamma_T^{uc} < 0$
Lens
Lens
Correlated objects

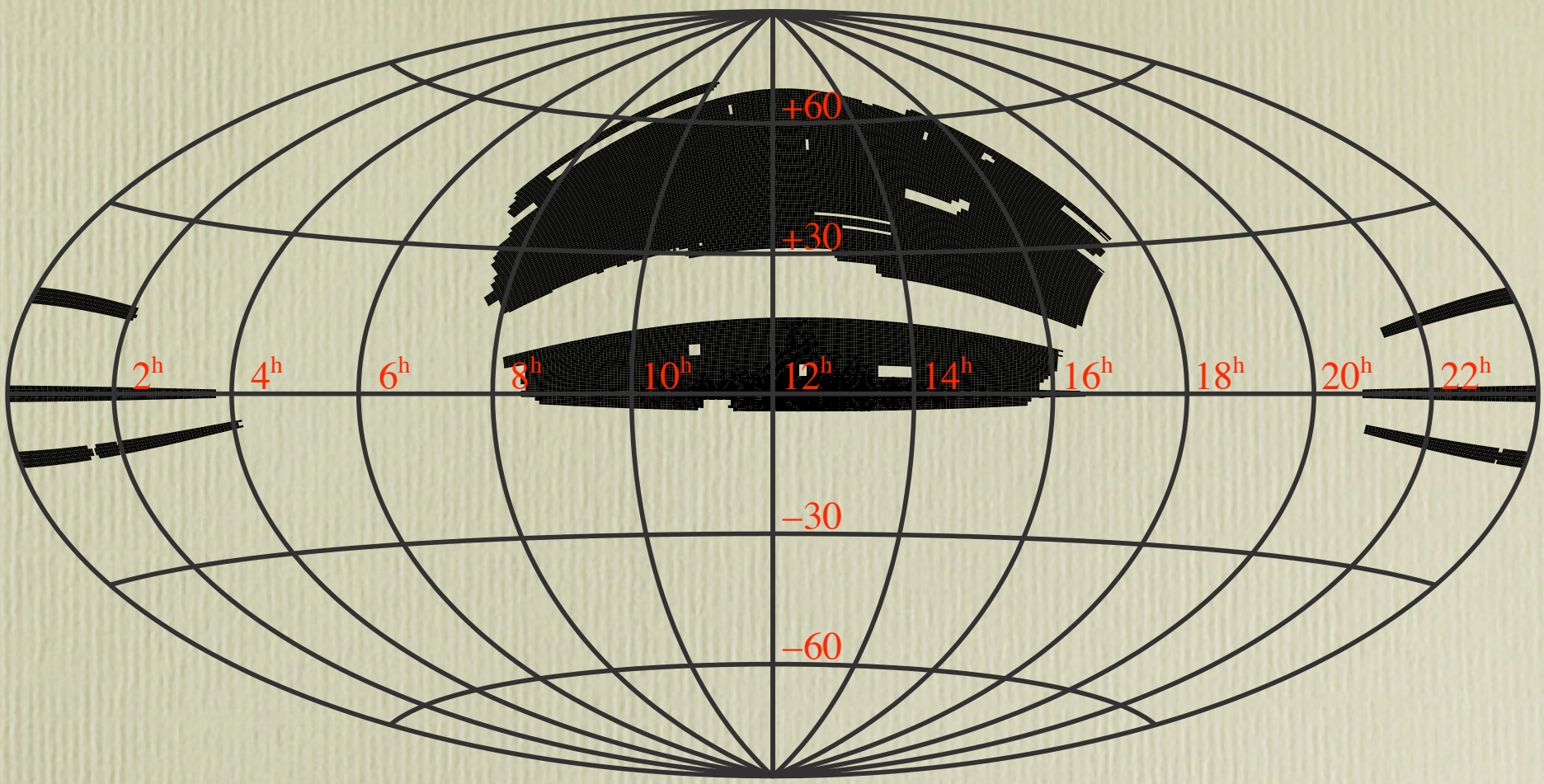
Inversion

$$\Sigma_{crit} \times \gamma_T = \overline{\Sigma}(< R) - \overline{\Sigma}(R)$$
$$\equiv \Delta\Sigma(R)$$

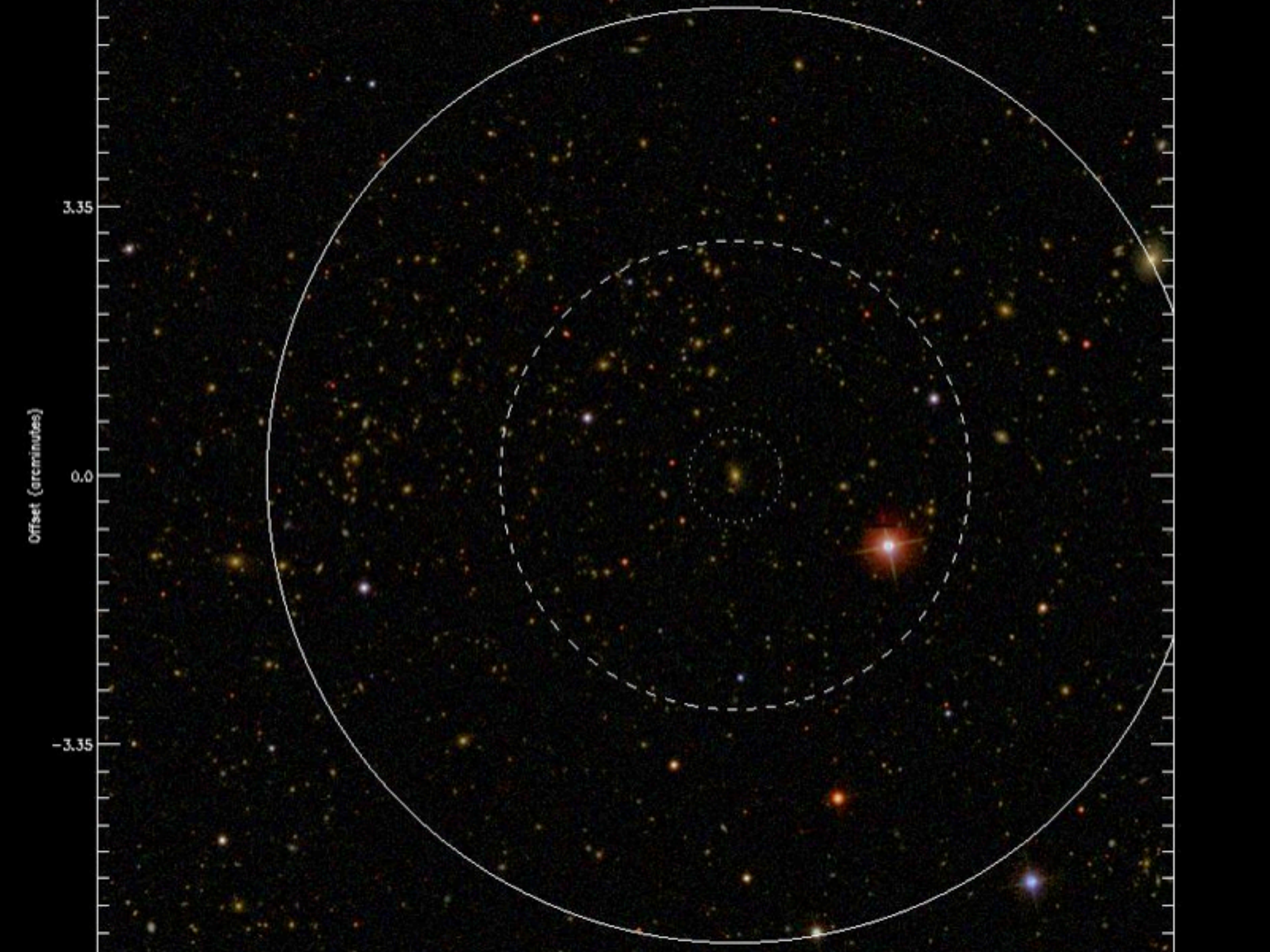
$$\frac{d\Sigma}{dR} = -2\frac{\Delta\Sigma}{R} - \frac{d\Delta\Sigma}{dR}$$

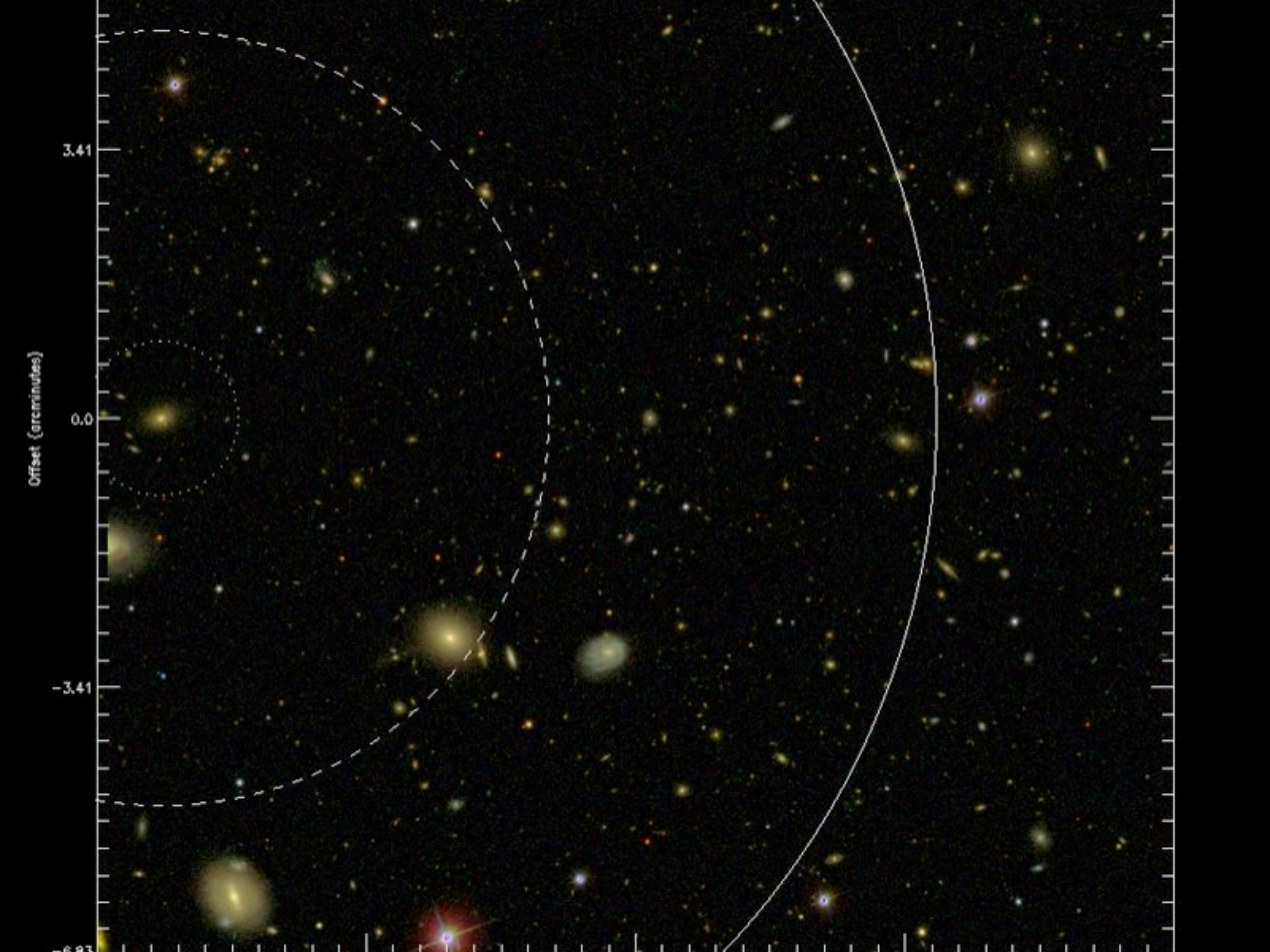
Assuming spherical symmetry: isotropy

$$\rho(r) - \overline{\rho} = -\frac{1}{\pi}\int_r^\infty \frac{d\Sigma/dR}{\sqrt{R^2 - r^2}} dR$$



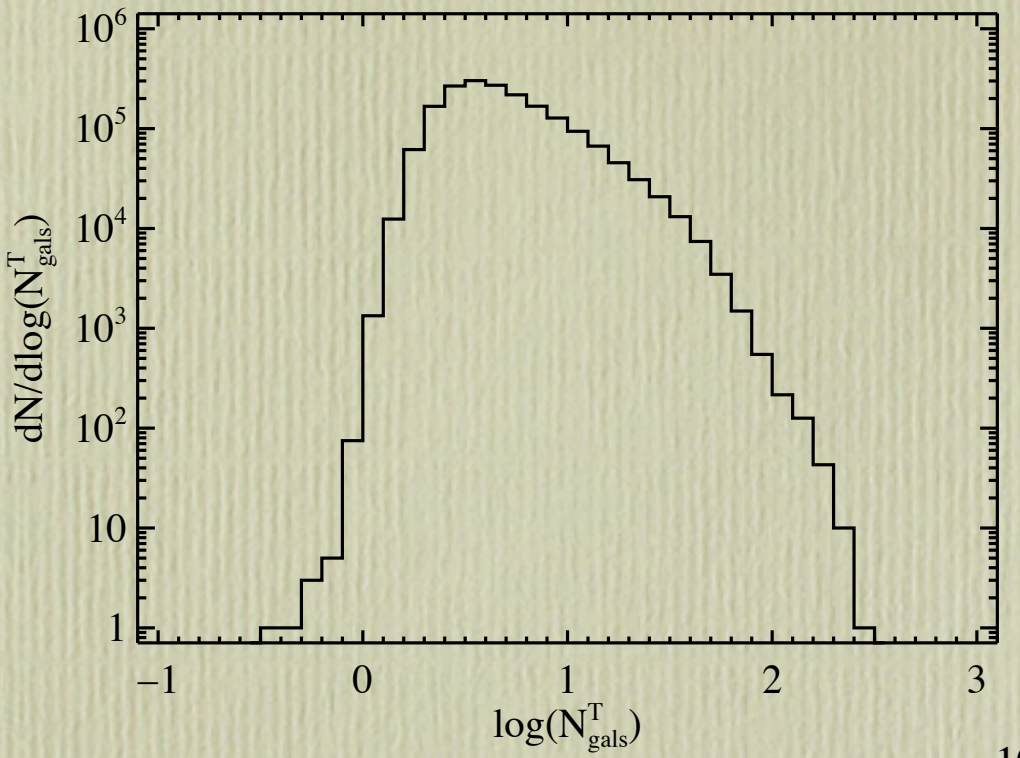
- 6325 Square Degrees
- 1,399,461 Groups and Clusters
- 30,194,004 Source galaxies


3.35
0.0
−3.35
Offset (arcminutes)

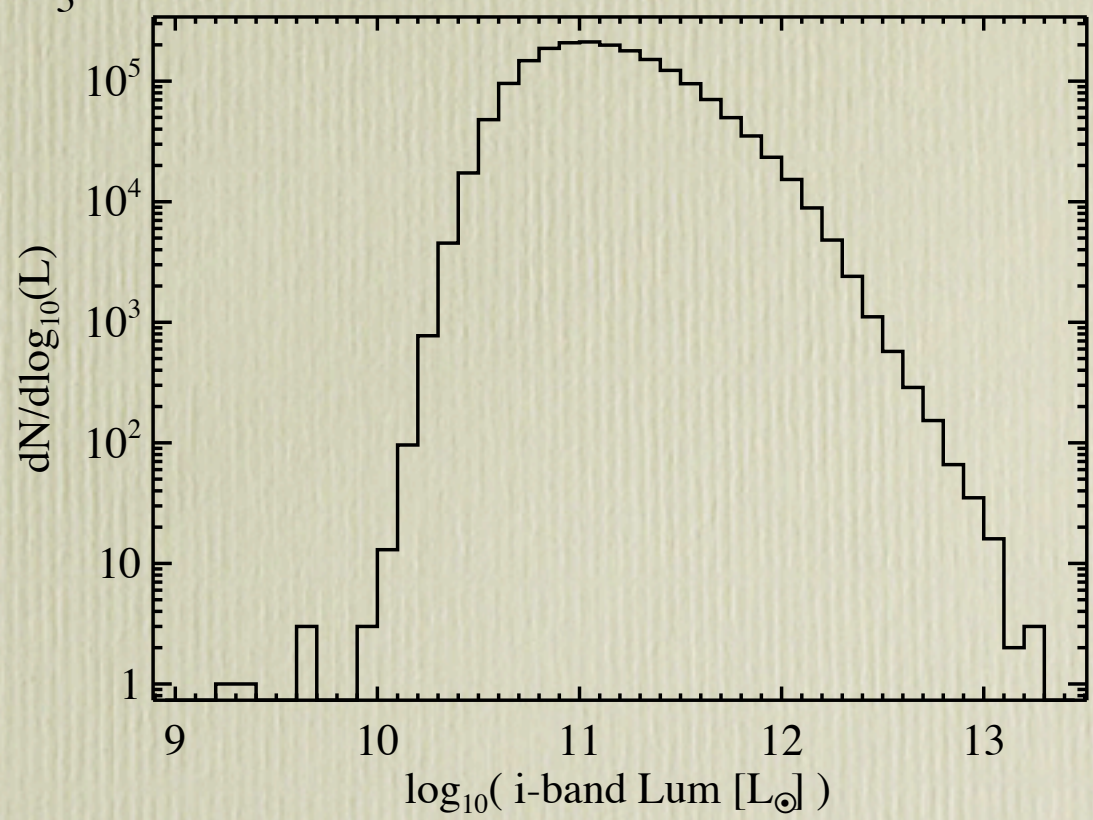

3.41
0.0
-3.41
-6.83
Offset (arcminutes)

Clusters

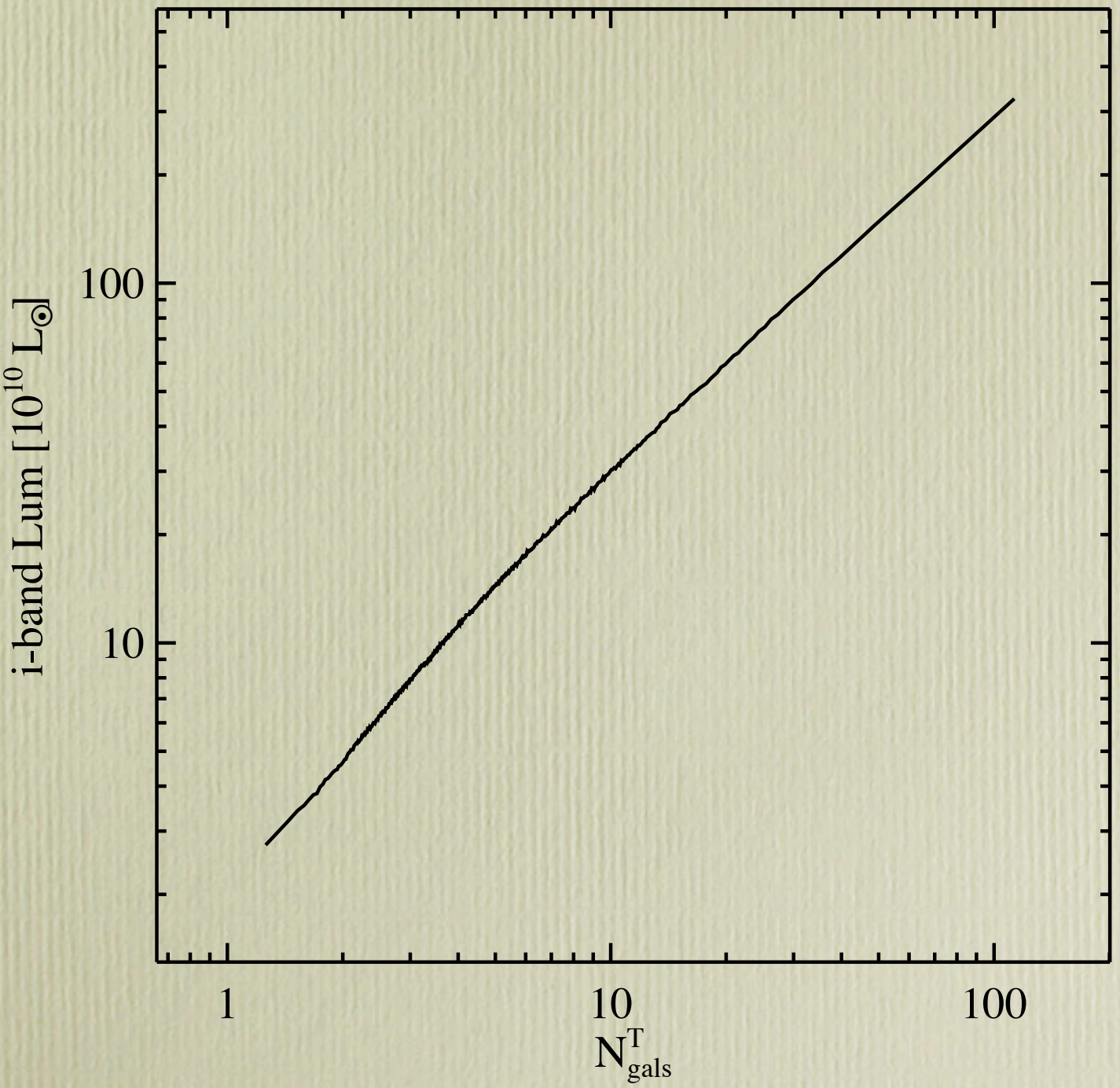
- Basic measurement: Ngals, the number of galaxies brighter than 0.4 L* within 1 Mpc
- tNgals: background subtracted Ngals on 2 Mpc scales.
- tLum: background subtracted i-band luminosity on 2Mpc scales.

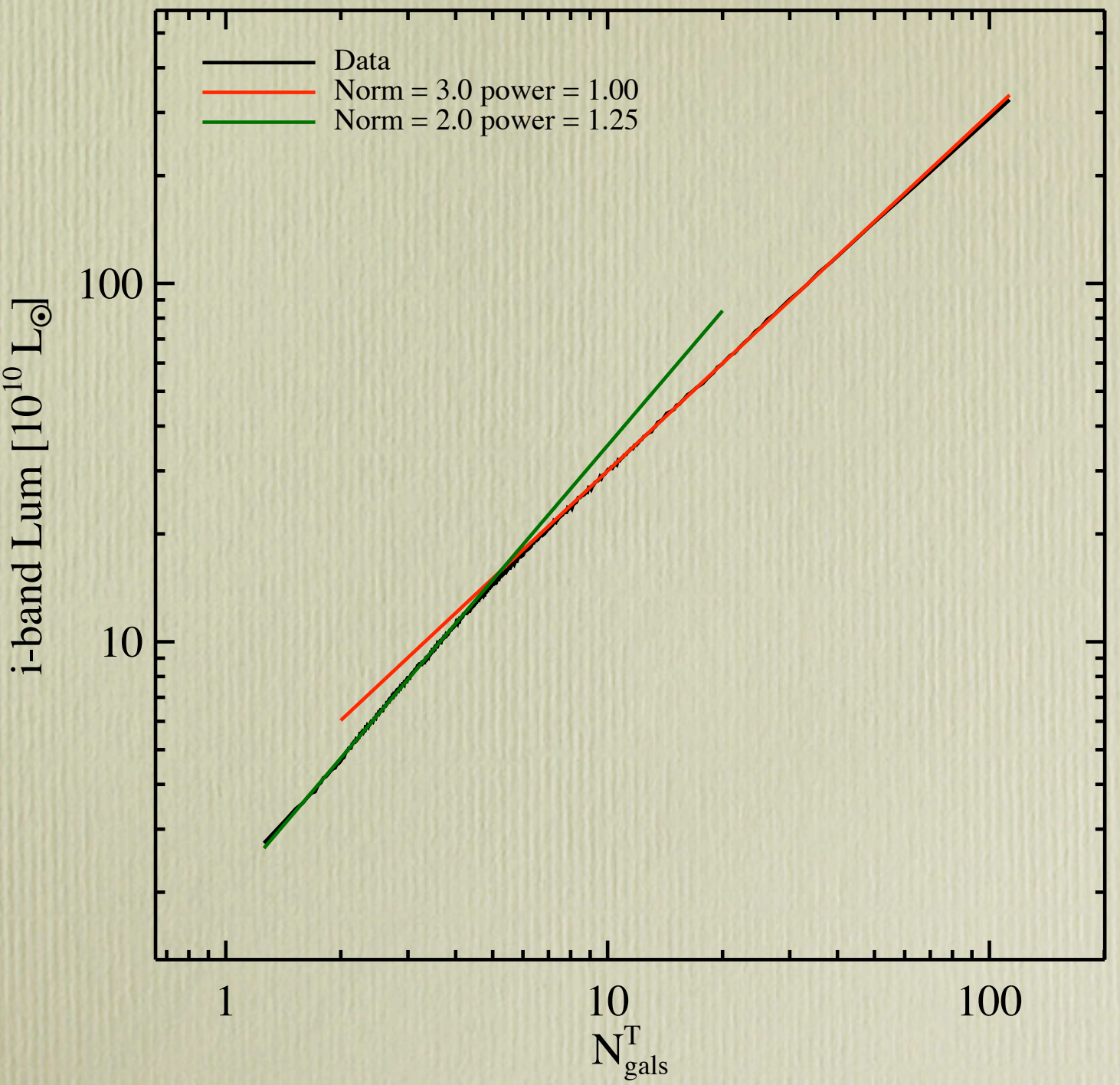


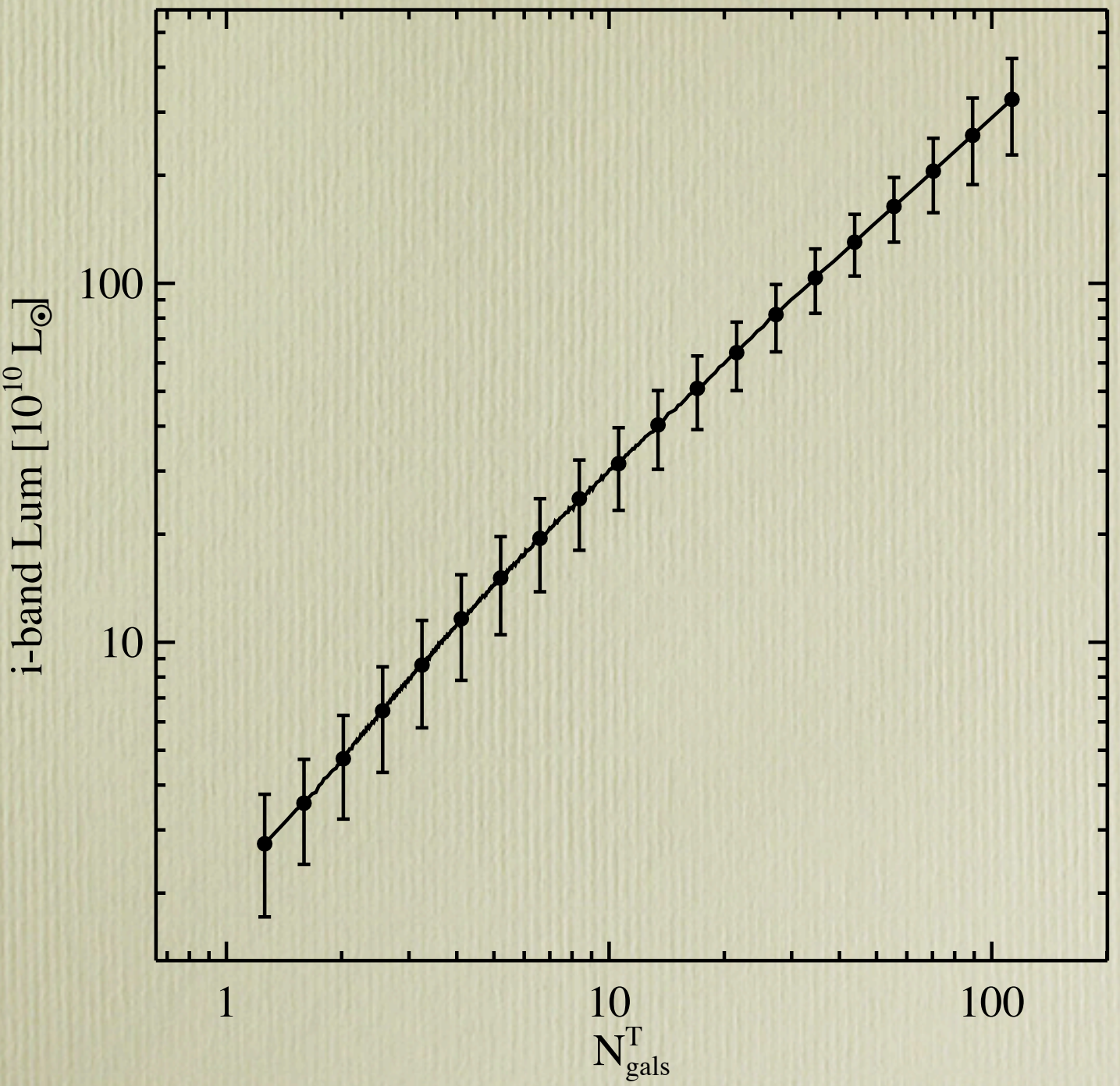
Ngals Function



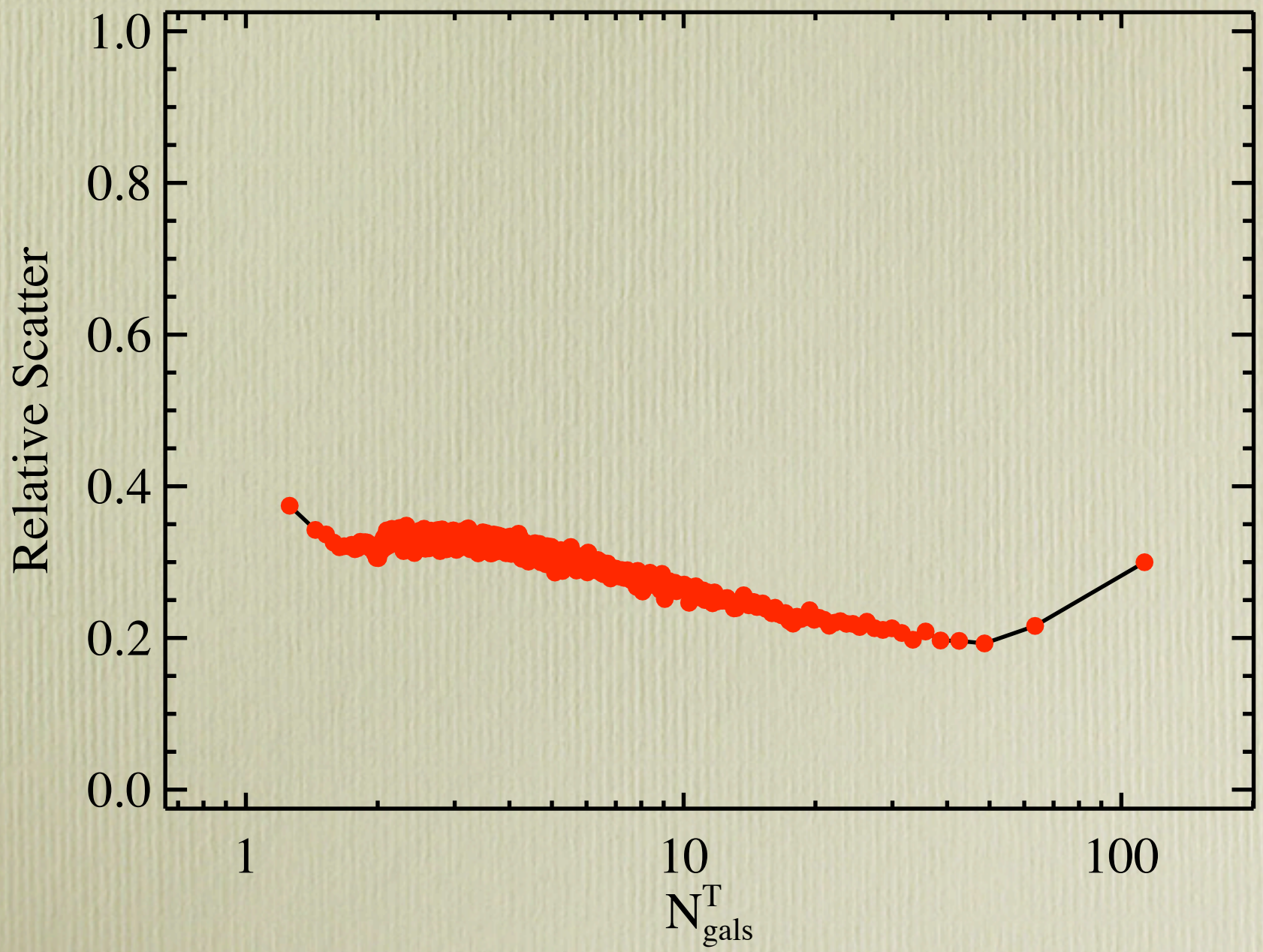
i-band Luminosity Function


100
10
i-band Lum [10^{10} $L_\odot$]
1
10
100
N^T_{gals}

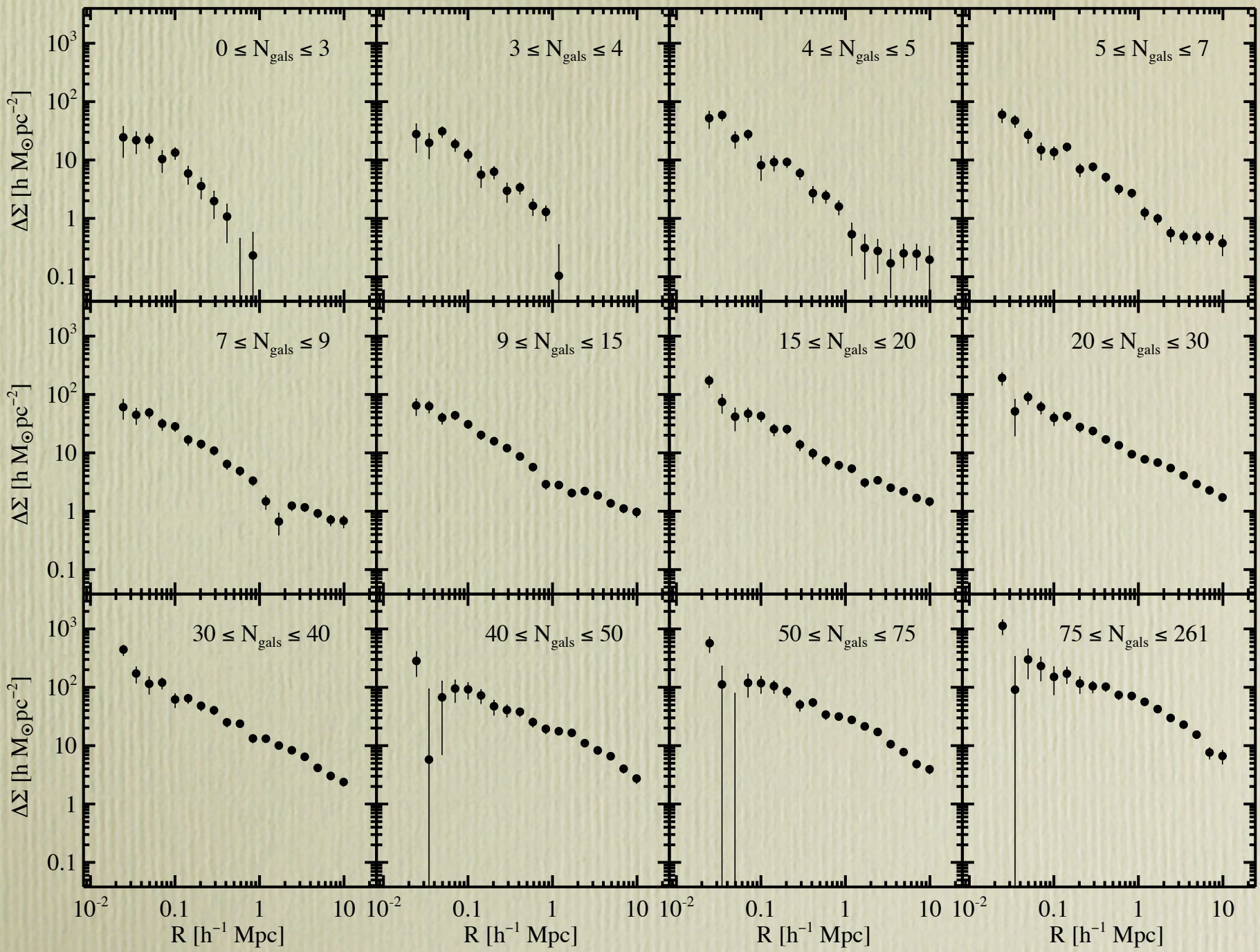

Data
Norm = 3.0 power = 1.00
Norm = 2.0 power = 1.25
100
10
1
10
100
i-band Lum [10^{10} $L_\odot$]
N^T_{gals}


100
10
i-band Lum [10^{10} $L_\odot$]
1
10
100
N^T_{gals}

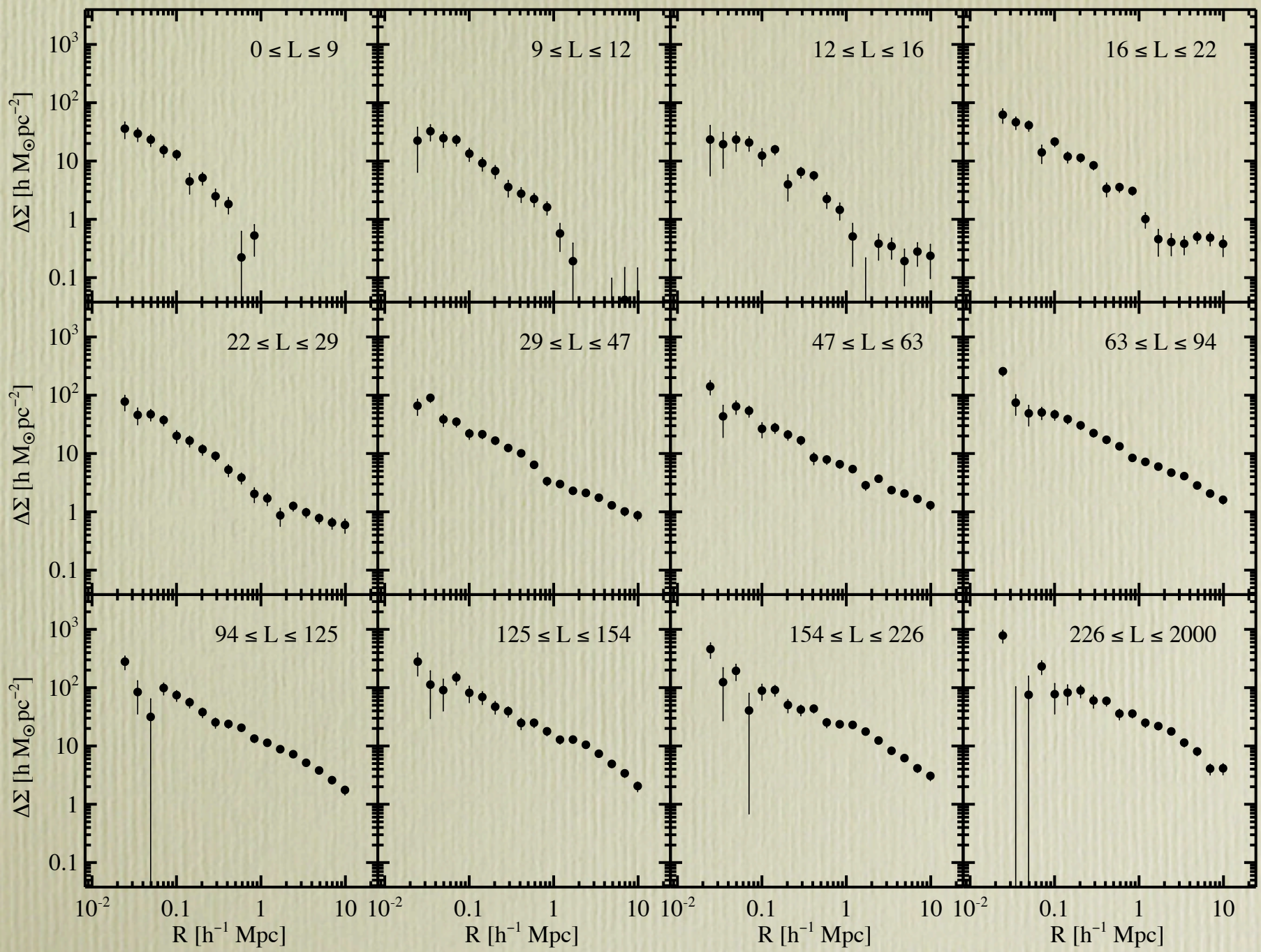
Scatter in Lum-Ngals

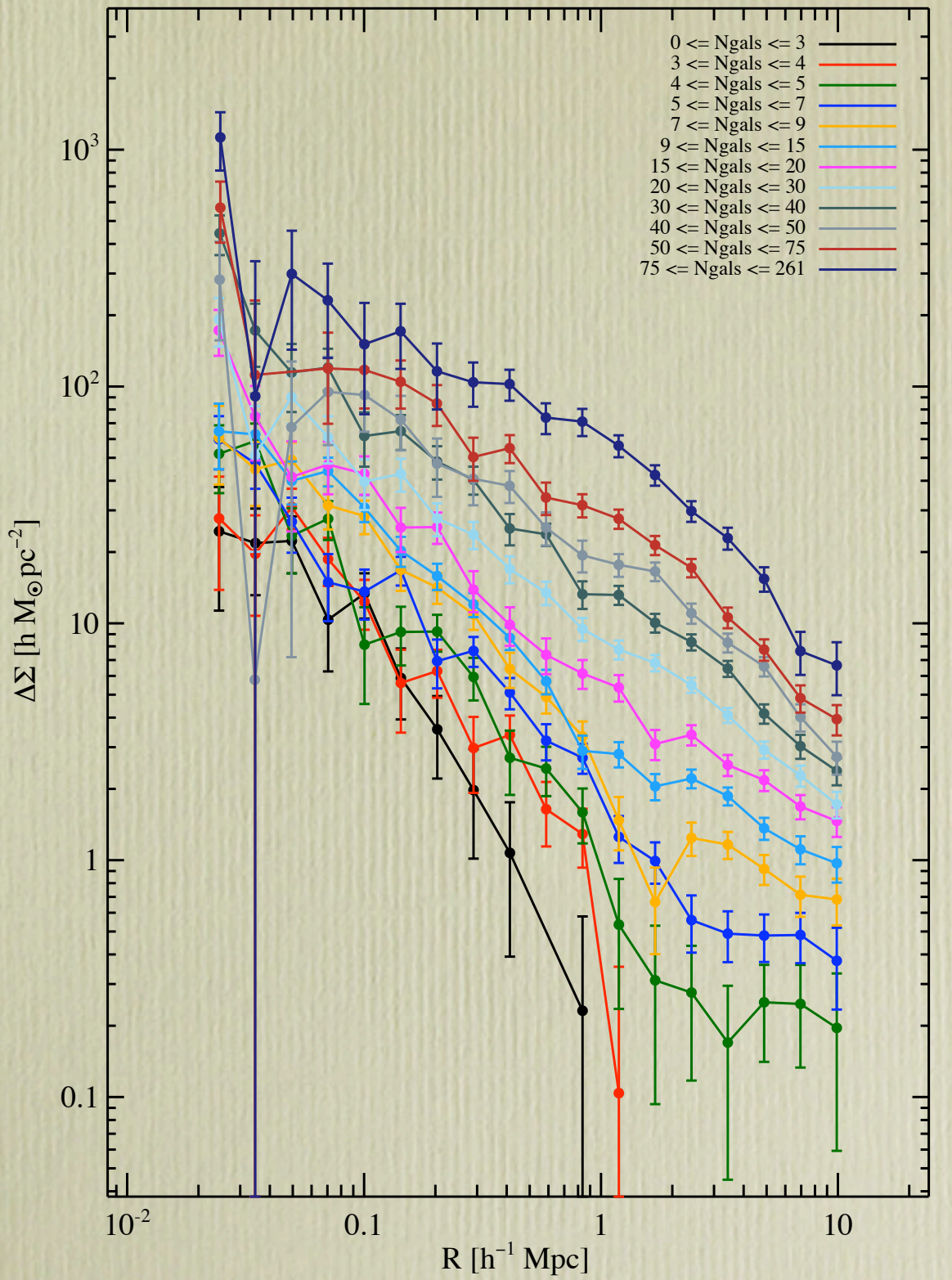


Lensing Measurements to 10 Mpc

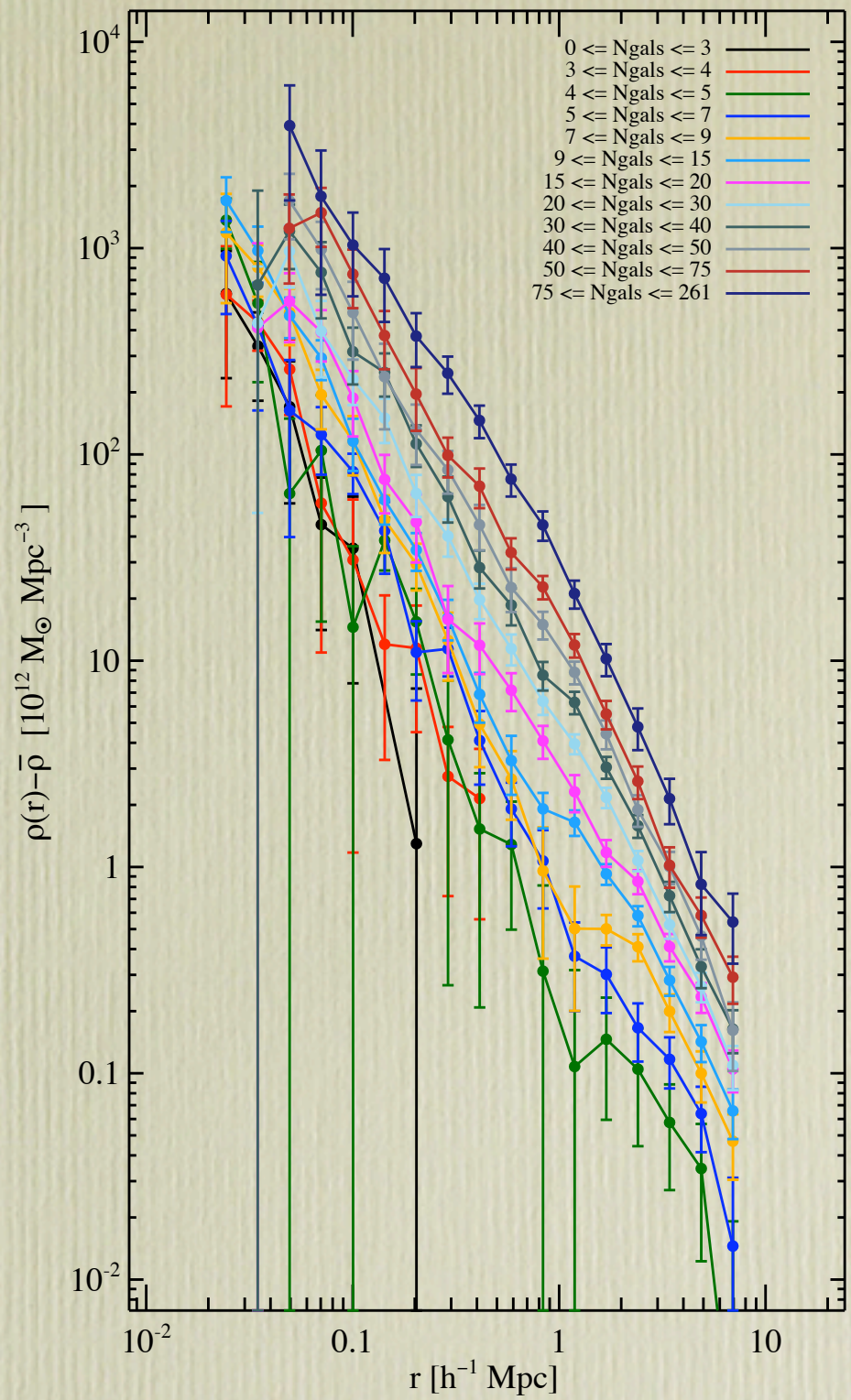


Luminosity Bins



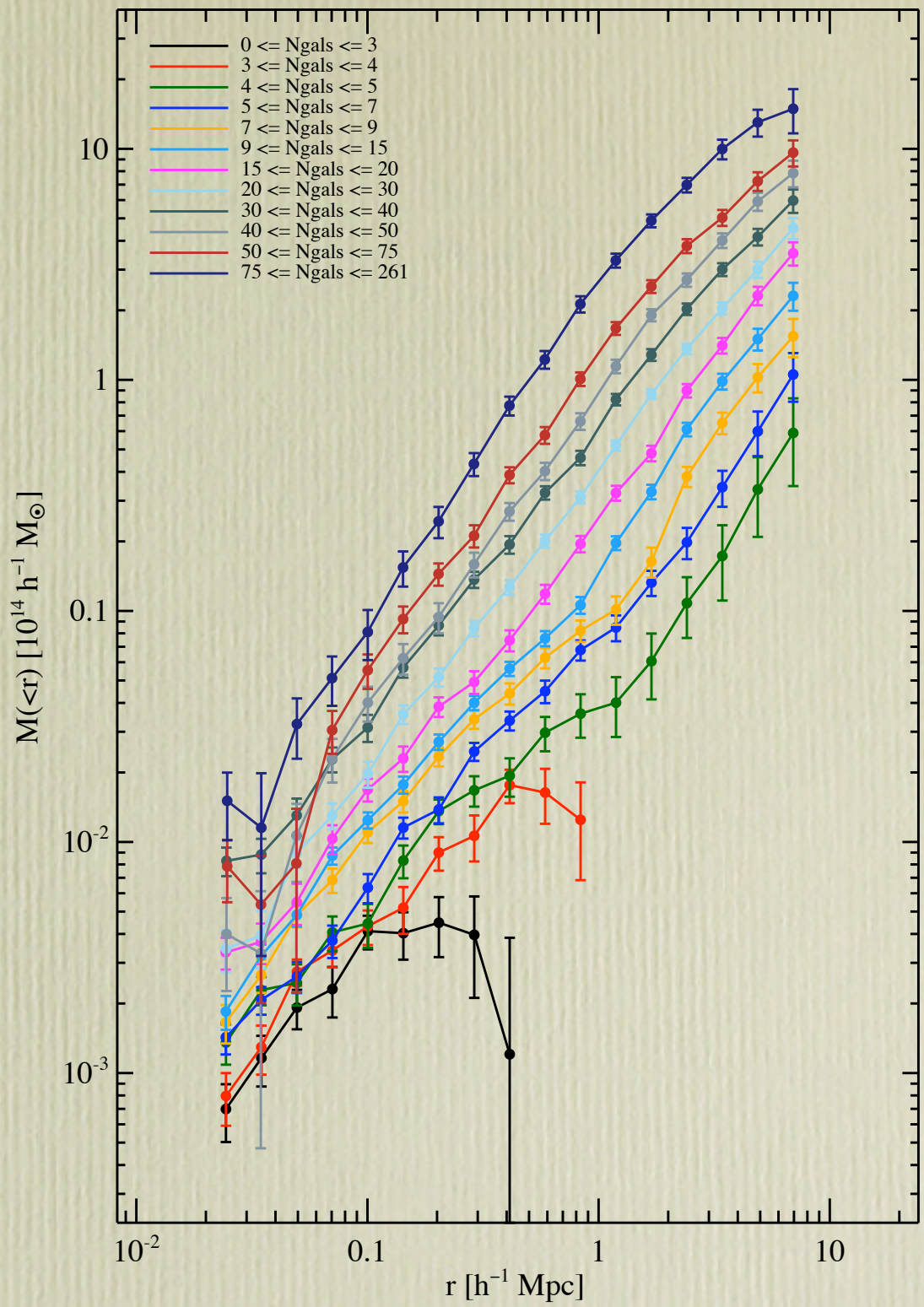

0 <= Ngals <= 3
3 <= Ngals <= 4
4 <= Ngals <= 5
5 <= Ngals <= 7
7 <= Ngals <= 9
9 <= Ngals <= 15
15 <= Ngals <= 20
20 <= Ngals <= 30
30 <= Ngals <= 40
40 <= Ngals <= 50
50 <= Ngals <= 75
75 <= Ngals <= 261
10^3
10^2
10
1
0.1
$\Delta\Sigma$ [h $M_\odot$ pc^{-2}]
10^{-2}
0.1
1
10
R [h^{-1} Mpc]

- Equal scaling on x-y axes
- Non-power law shape
- Large scale halo bias shows dependence on Ngals

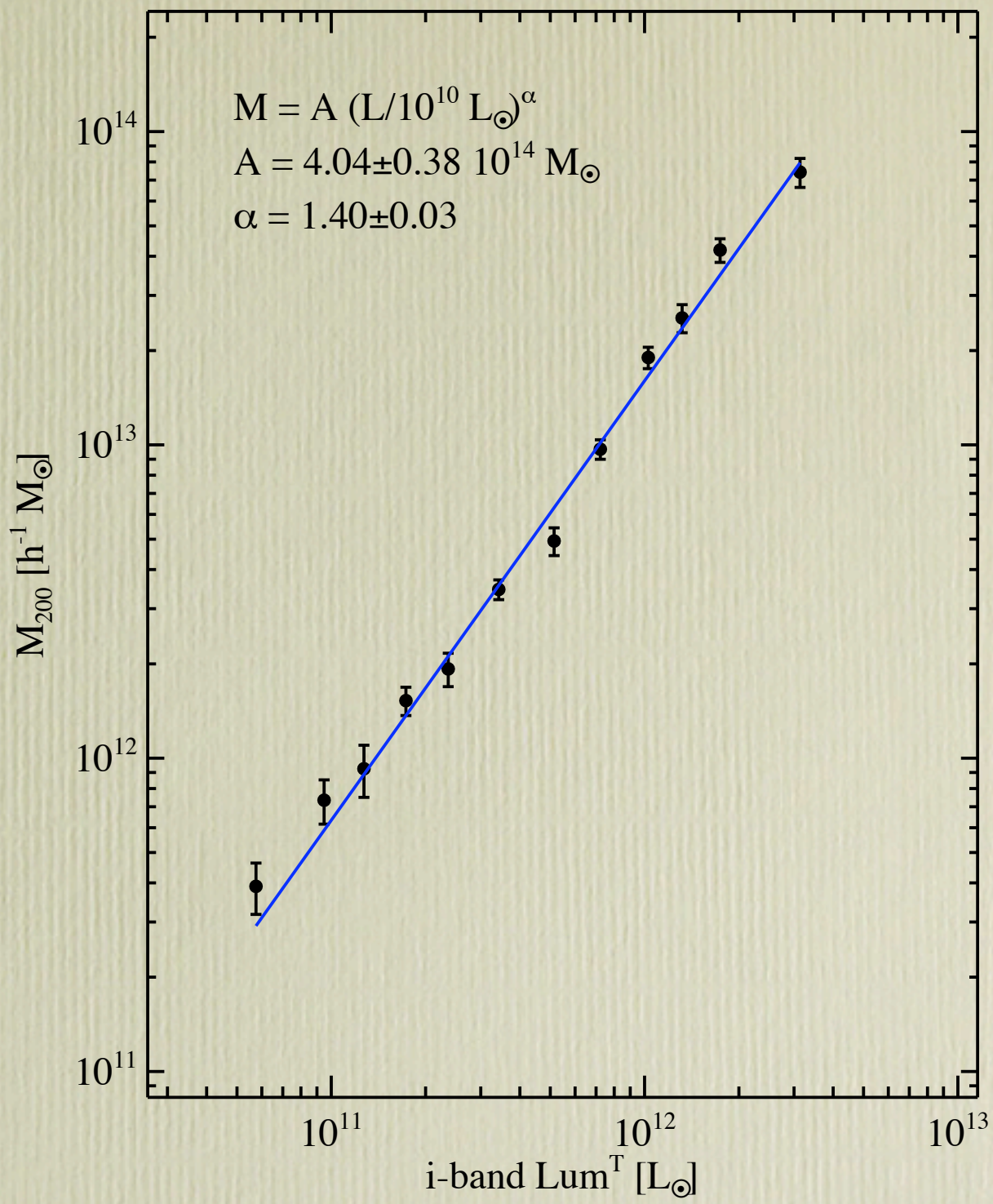


- Integrated mass scales with Ngals at all radii

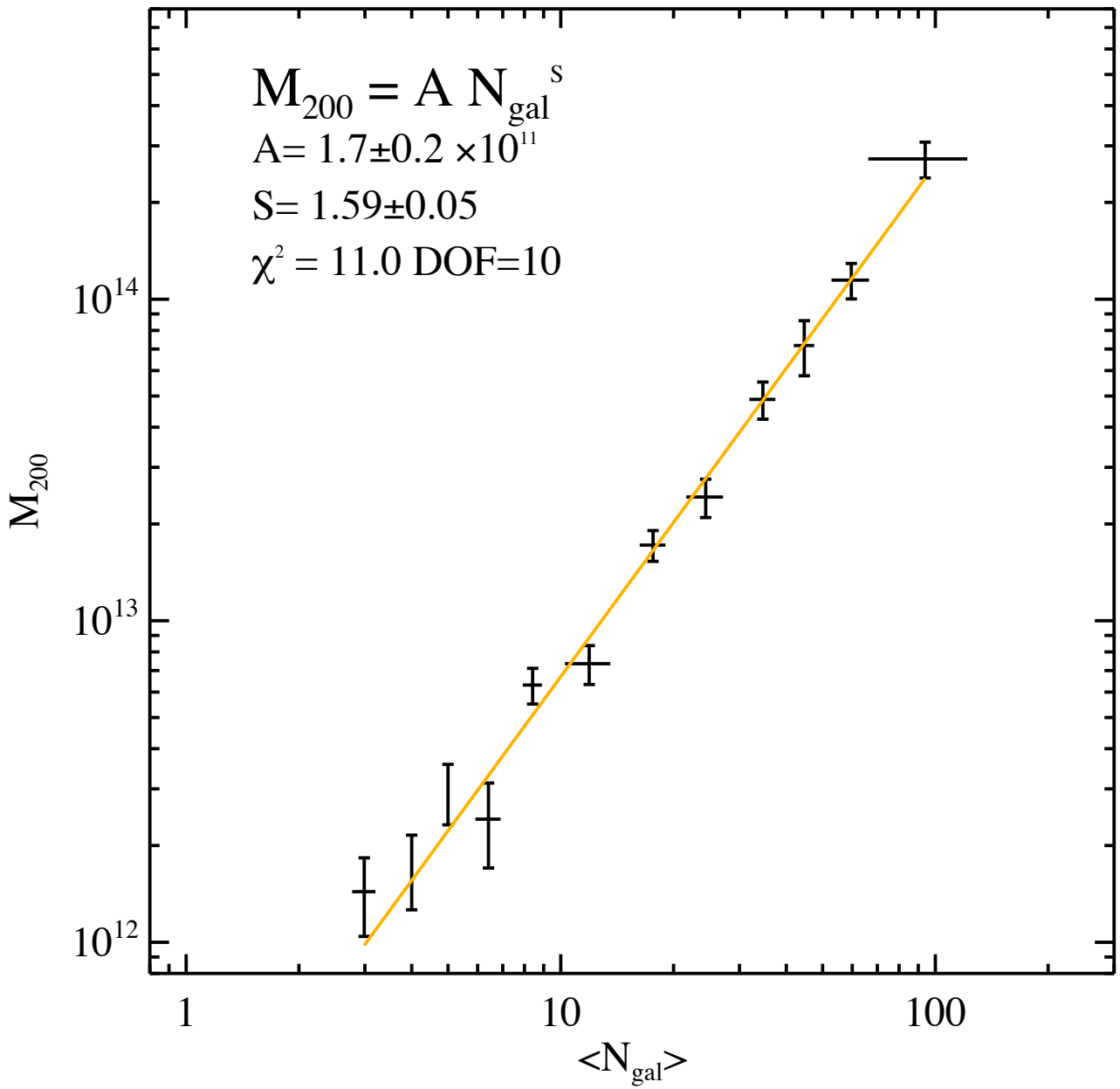
- Mass is non-parametric



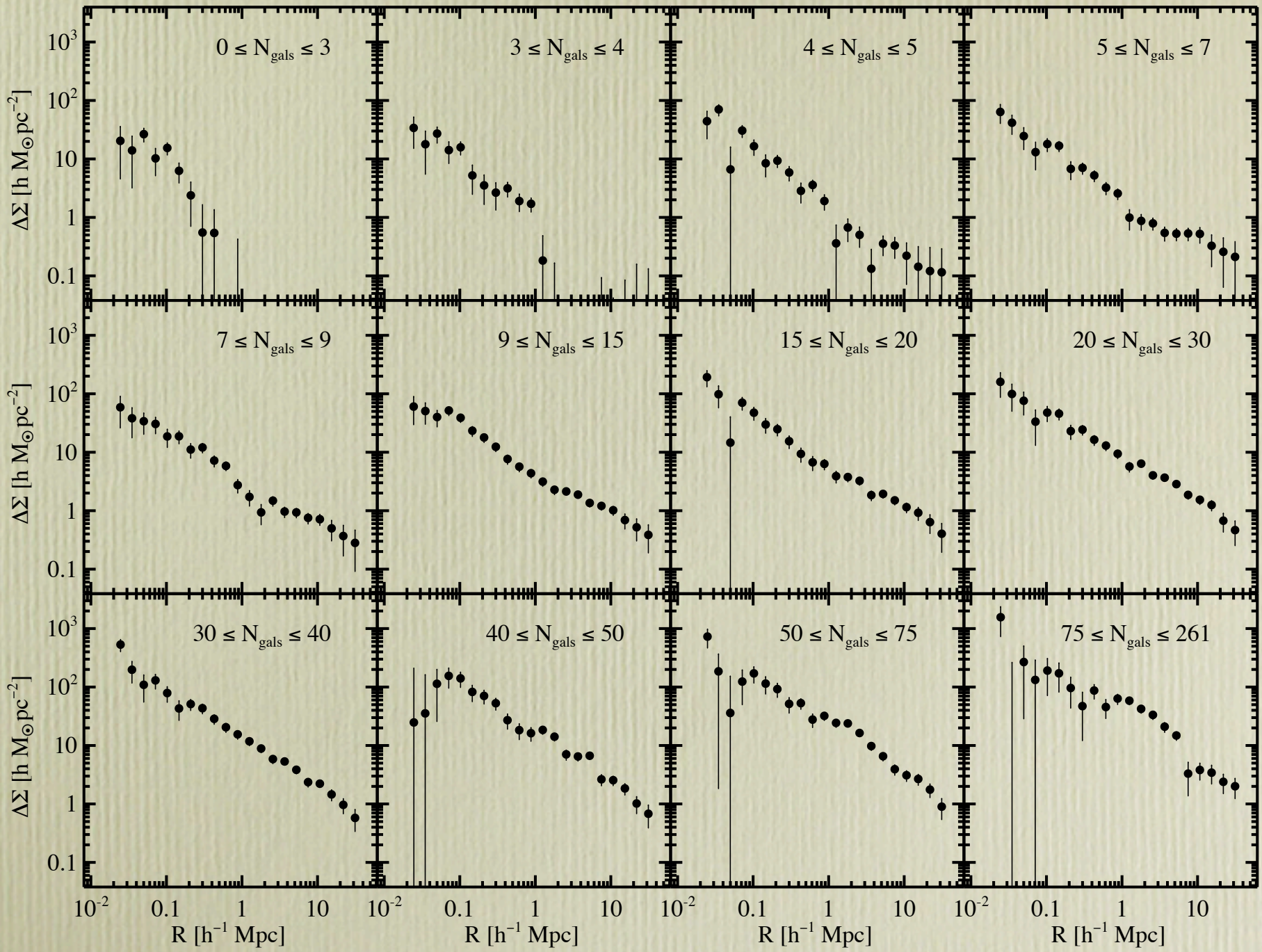
- M200 vs. Luminosity measured on 2Mpc scales.
- M/L normalization is low due to large aperture for luminosity measurement.
- Next step is to estimate L200

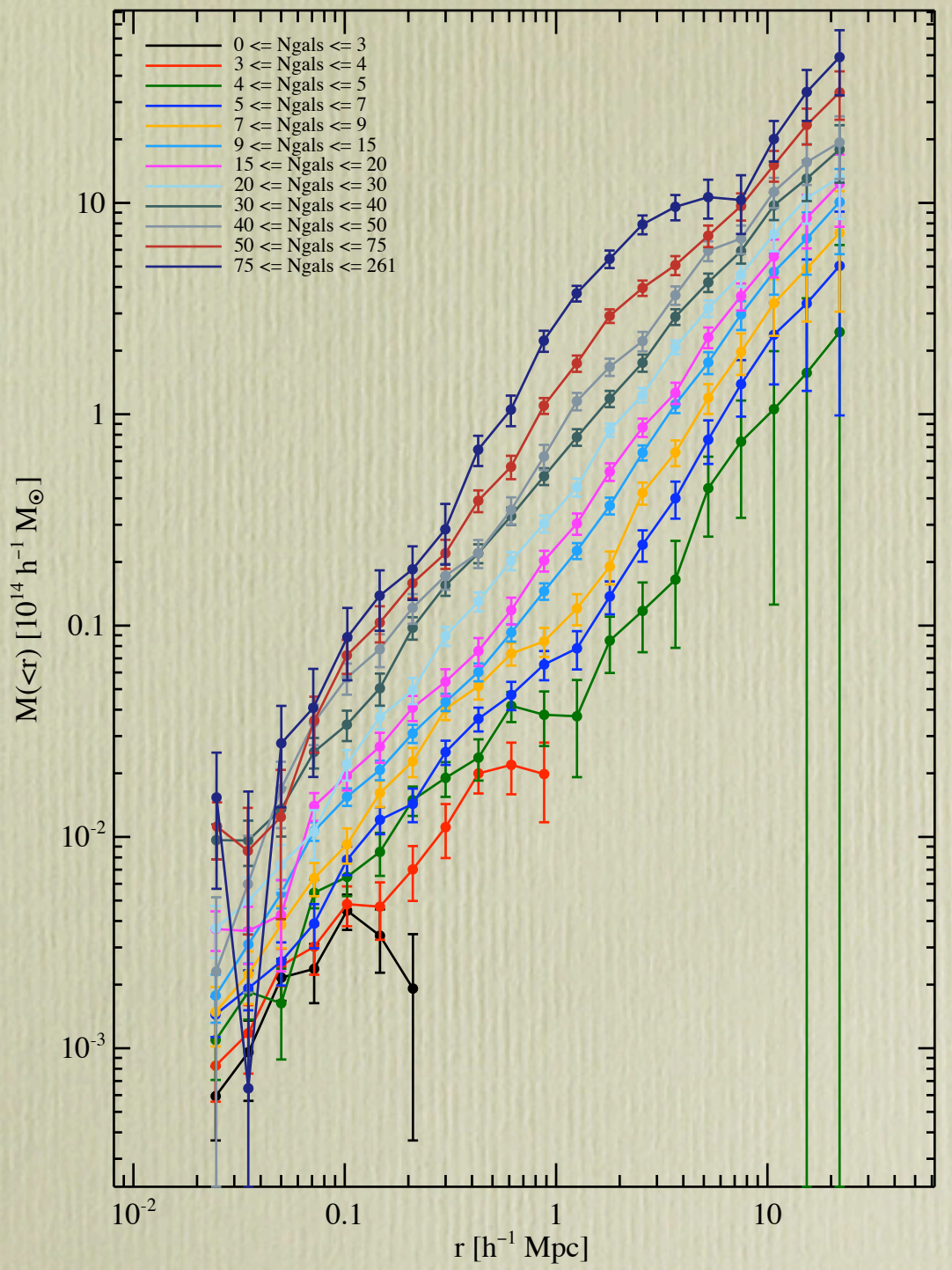


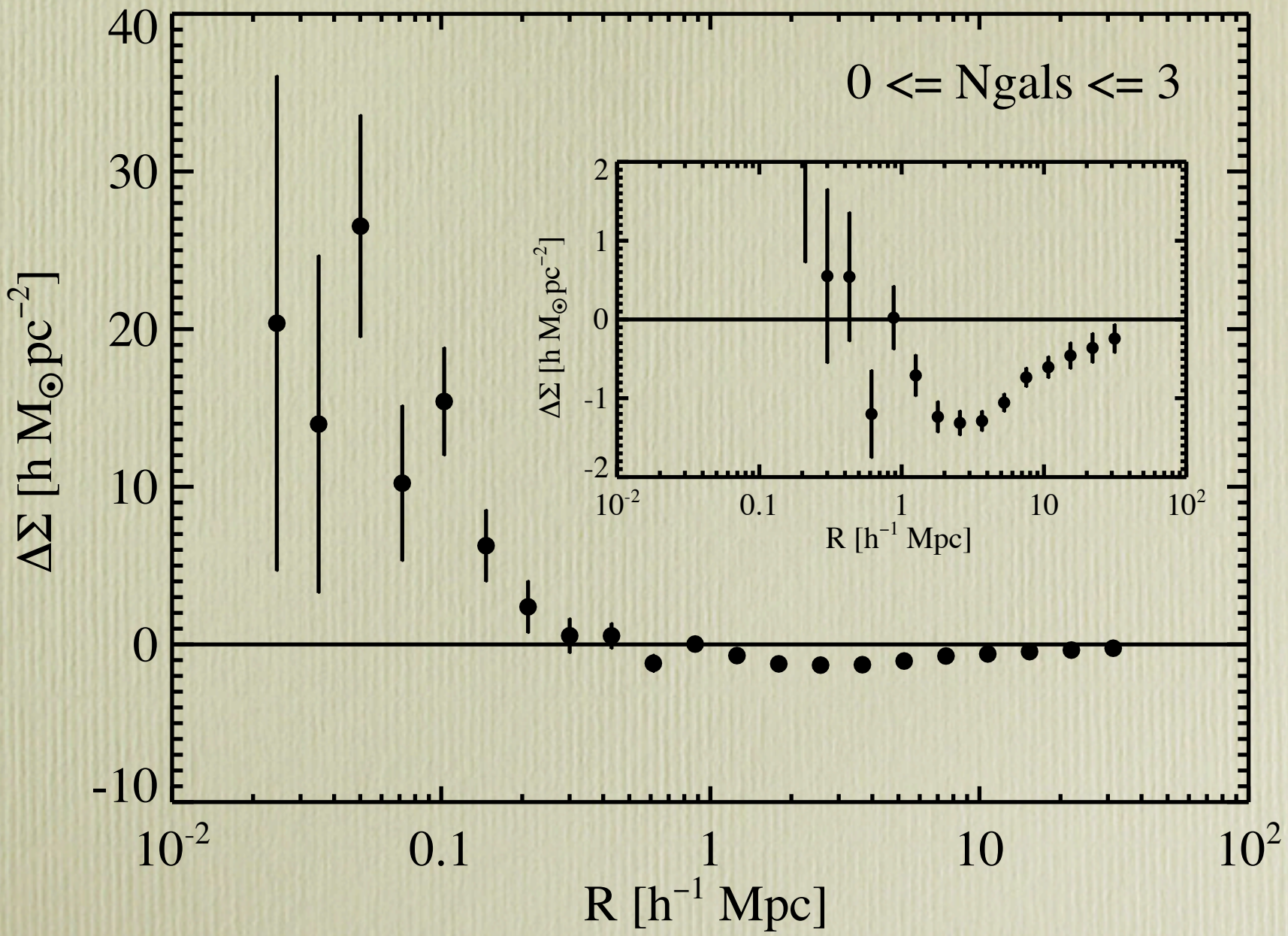
M200 vs. Ngal

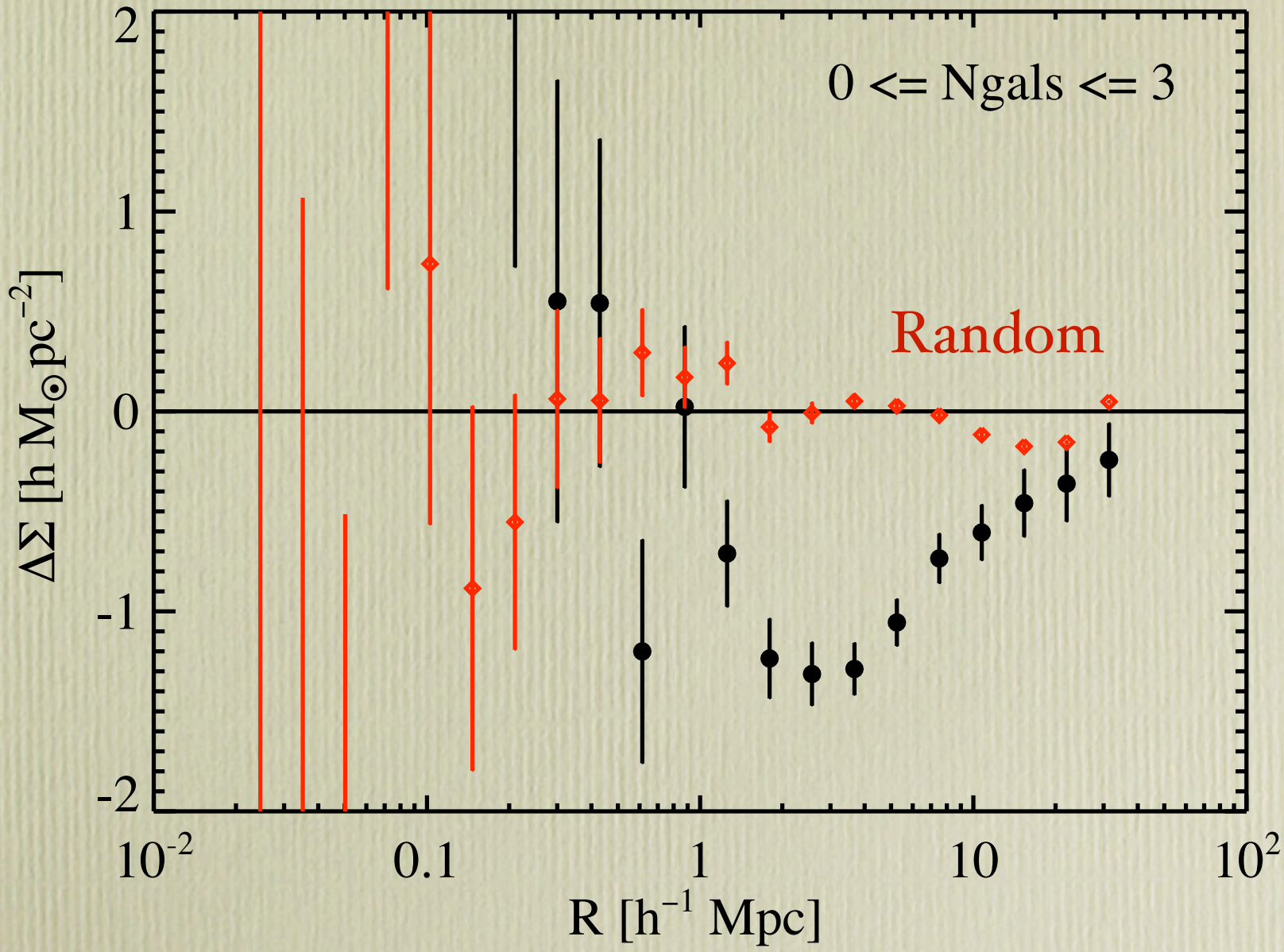

$M_{200} = A\ N_{gal}^{S}$
A= 1.7±0.2 ×10^11
S= 1.59±0.05
χ^2 = 11.0 DOF=10
10^{14}
10^{13}
10^{12}
M_{200}
1
10
100
$\langle N_{gal} \rangle$

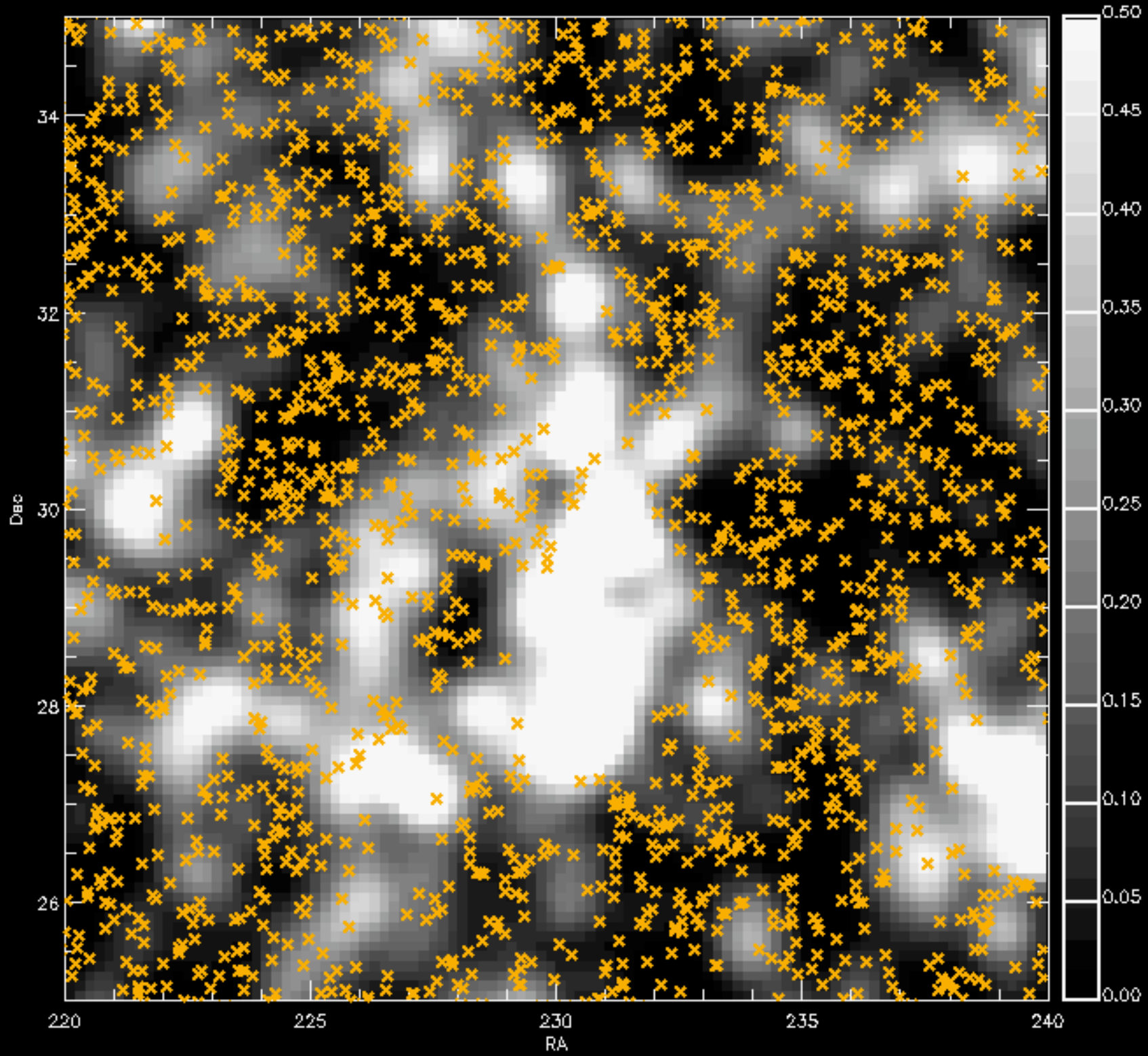
Pushing to 30 Mpc

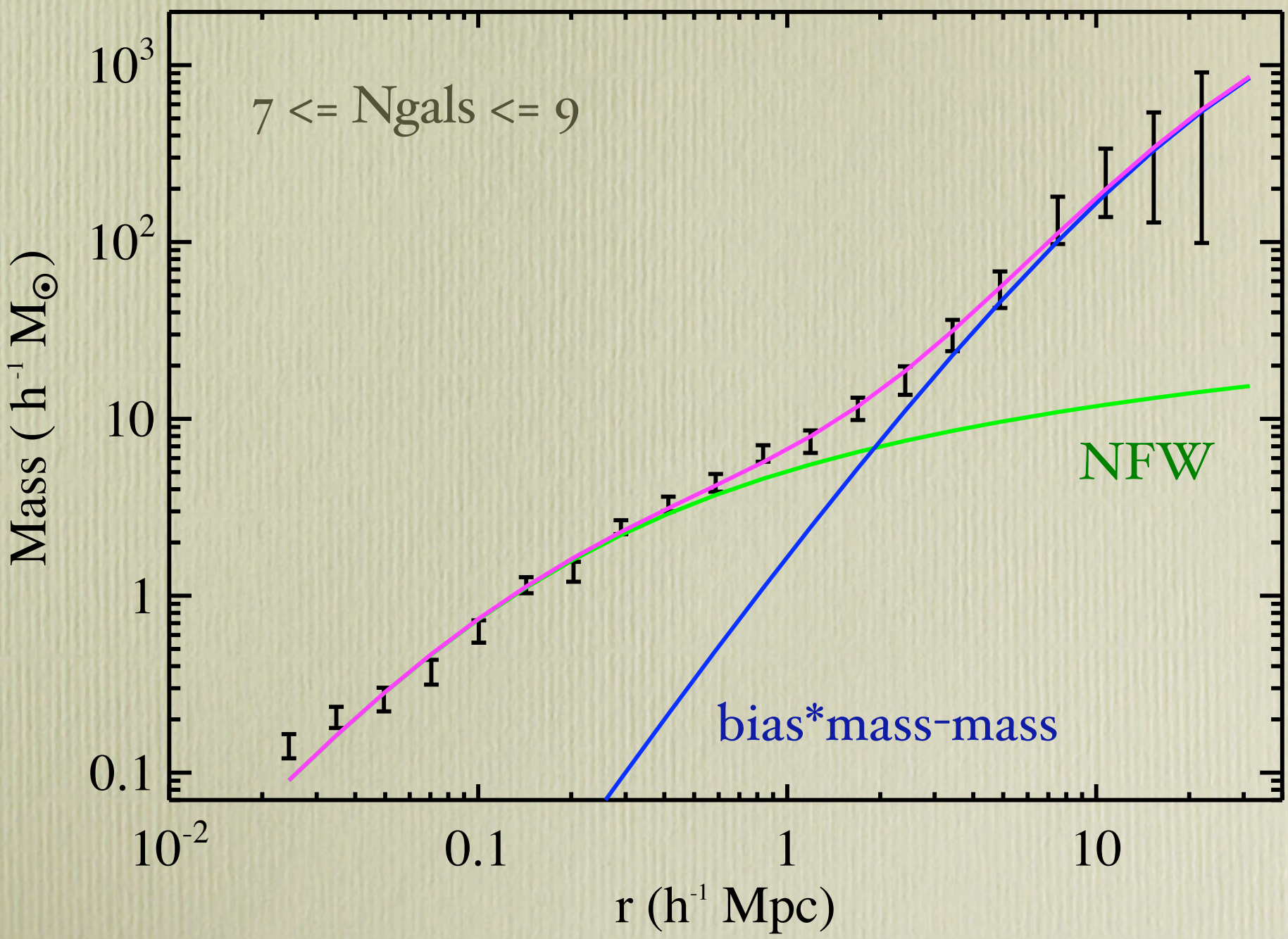


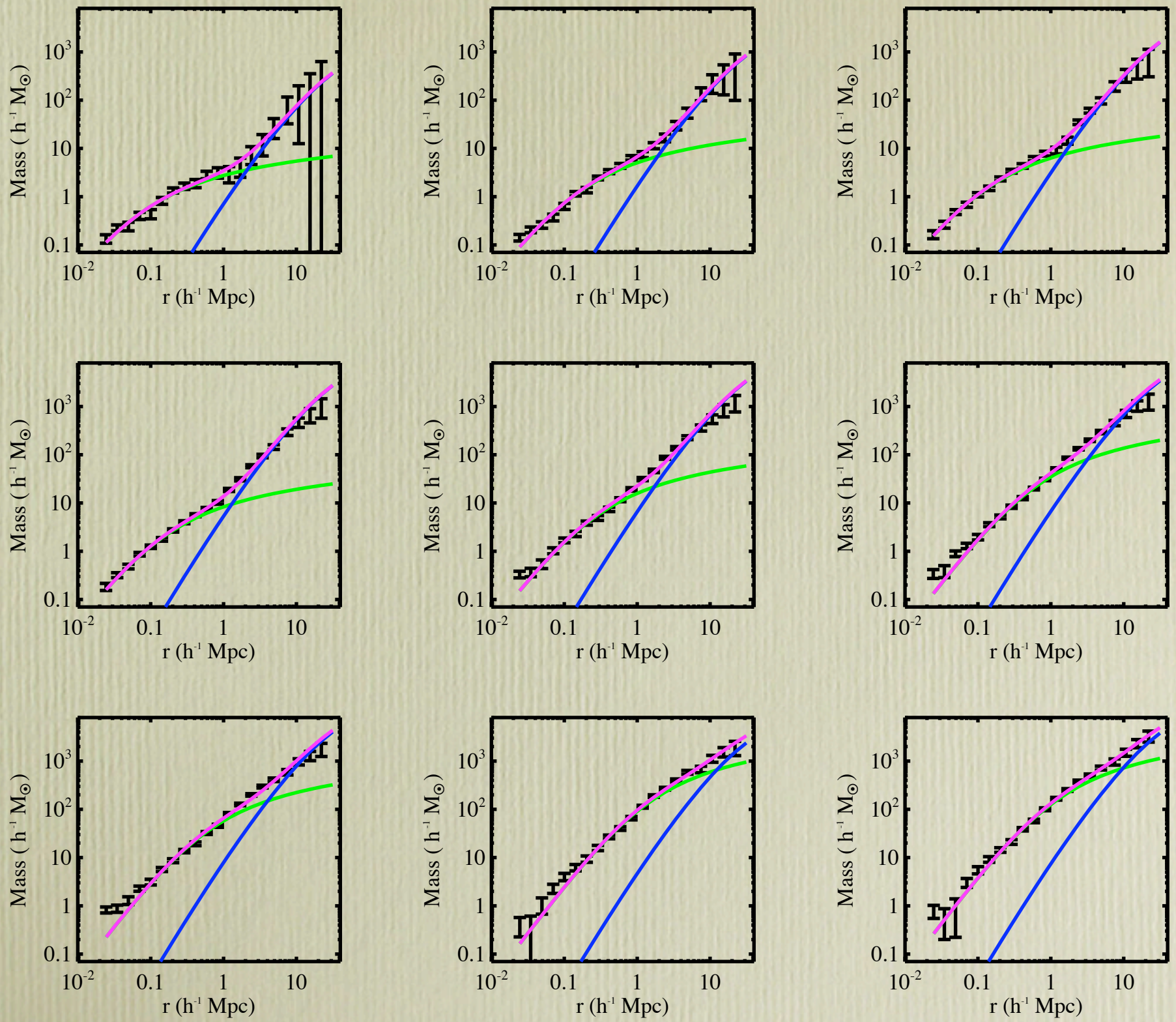

0 <= Ngals <= 3
3 <= Ngals <= 4
4 <= Ngals <= 5
5 <= Ngals <= 7
7 <= Ngals <= 9
9 <= Ngals <= 15
15 <= Ngals <= 20
20 <= Ngals <= 30
30 <= Ngals <= 40
40 <= Ngals <= 50
50 <= Ngals <= 75
75 <= Ngals <= 261
M(<r) [10^14 h^-1 M⊙]
r [h^-1 Mpc]
10
1
0.1
10^-2
10^-3
10^-2
0.1
1
10


0 <= Ngals <= 3
ΔΣ [h M⊙pc⁻²]
R [h⁻¹ Mpc]
40
30
20
10
0
-10
10⁻²
0.1
1
10
10²
2
1
0
-1
-2


0 <= Ngals <= 3
Random
2
1
0
-1
-2
ΔΣ [h M⊙pc⁻²]
10⁻²
0.1
1
10
10²
R [h⁻¹ Mpc]

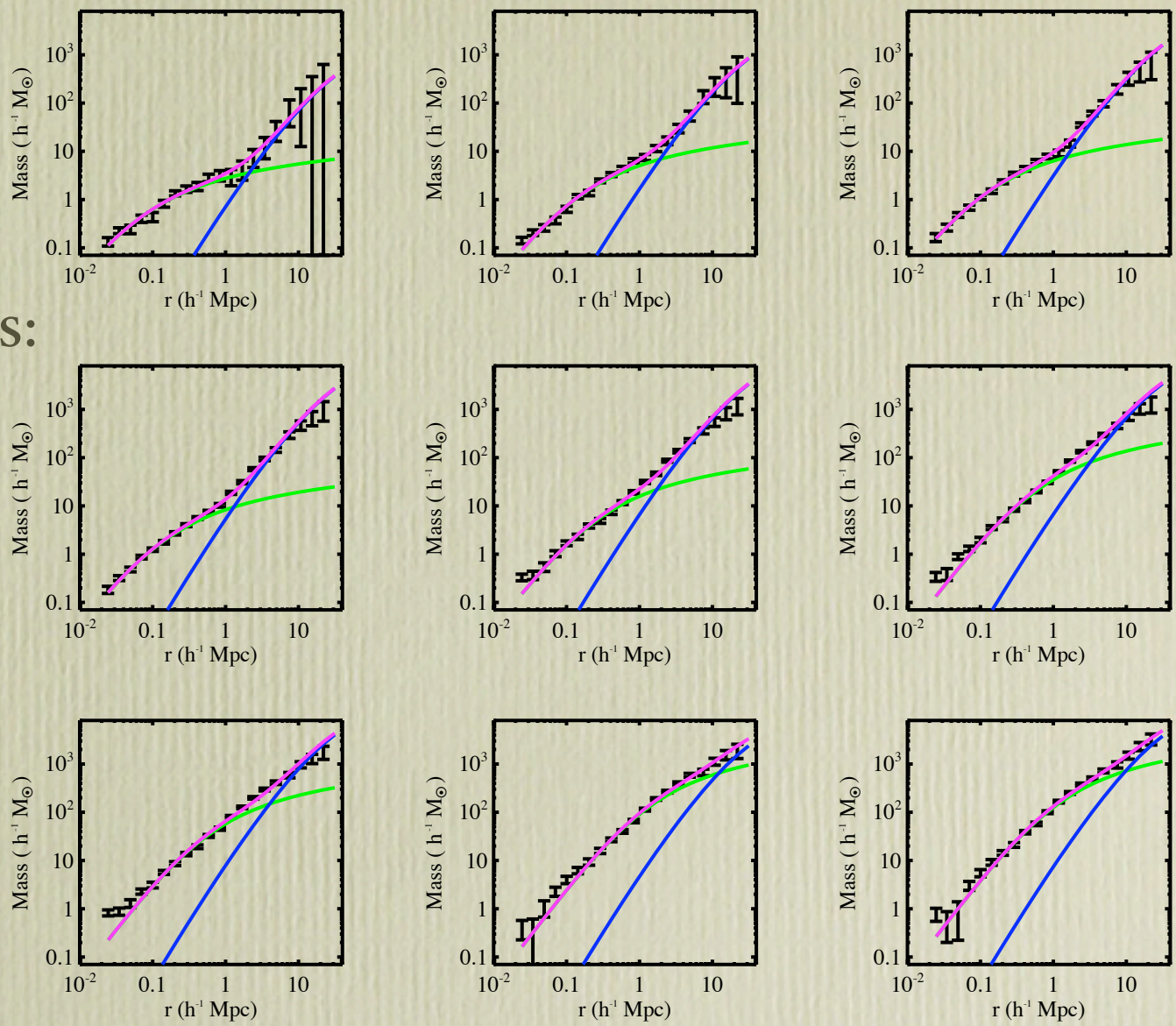

34
32
30
28
26
Dec
220
225
230
235
240
RA
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00


7 <= Ngals <= 9
NFW
bias*mass-mass
Mass (h^-1 M⊙)
r (h^-1 Mpc)
10^3
10^2
10
1
0.1
10^-2
0.1
1
10


Mass (h^{-1} M$_\odot$)
r (h^{-1} Mpc)
10^3
10^2
10
1
0.1
10^{-2}
0.1
1
10

Low Concentrations:

c < 4

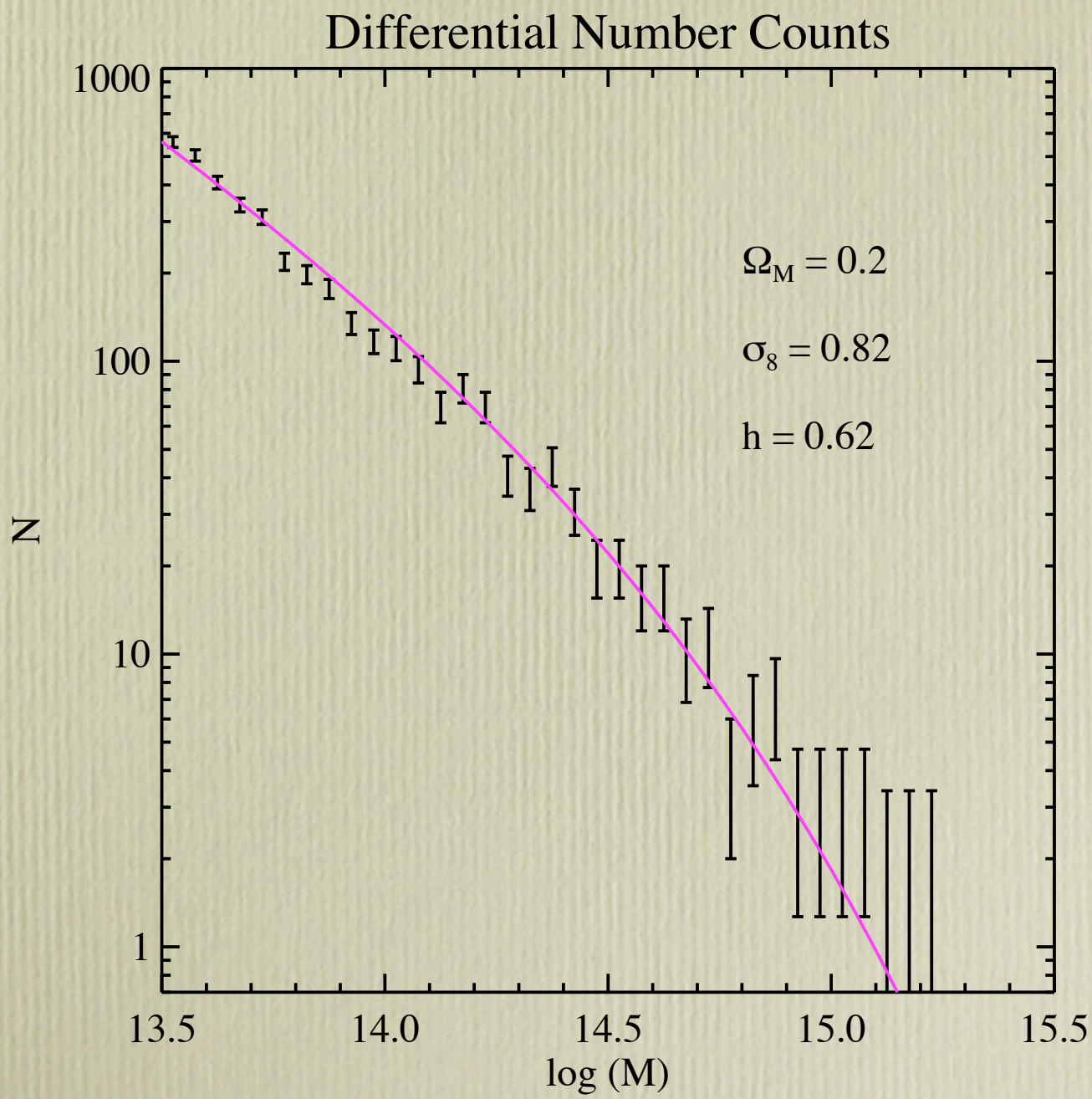


Summary

- High precision ensemble lensing measurements of clusters and groups.
- 10% calibration of Mass-Ngals Mass-Luminosity relations over factor of 100 in mass.
- At 30 Mpc, beginning to enter the regime of large scale structure measurements. See clear trend in the bias.
- Photoz bias is and will be dominant systematic

Future Work

- Push to larger scales to measure relative Halo bias
- Combining with auto-correlation function gives absolute bias and cosmology
- Measure scatter in Mass-Luminosity relation from velocities: Mass-function

Mass Function

Assuming small scatter