Cluster Observable-Mass Distribution and Halo Assembly History

Why do clusters of the same mass have such a diversity of galaxy content?

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Two halos of $5 \times 10^{14}\, M_\odot/h$

http://www.slac.stanford.edu/~kaehler/tmp/risa/heidi_halo_308.mov

Visualization: Ralf Kaehler

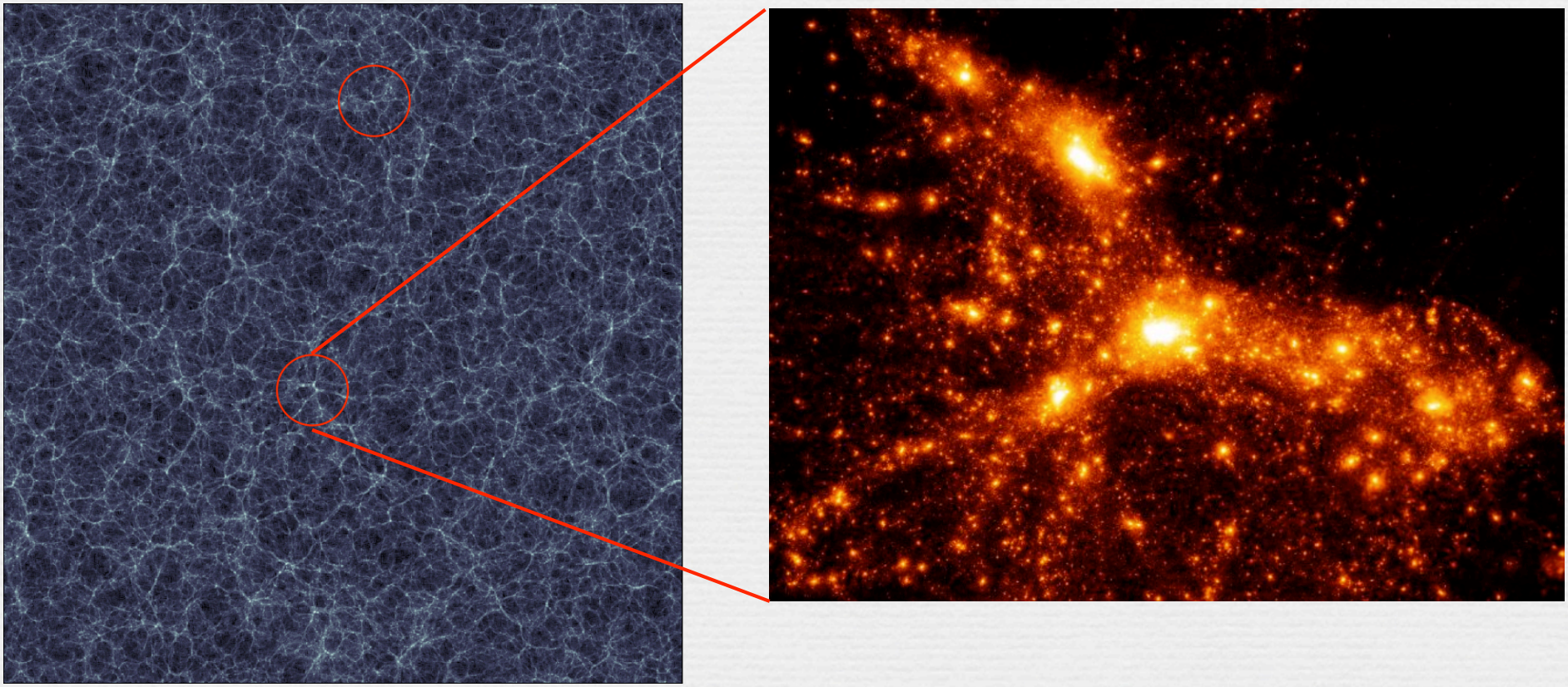
Two halos of $5 \times 10^{14}\, M_\odot/h$

http://www.slac.stanford.edu/~kaehler/tmp/risa/heidi_halo_390.mov

Visualization: Ralf Kaehler

RHAPSODY: Re-simulated Halo Sample for Statistical Observable-Mass Distribution Study

Zooming in on massive halos in a Gpc box; obtaining high resolution and good statistics
Current simulations: 93 halos of 5×10^{14} $M_\odot/h$ (mass resolution 10^9 $M_\odot/h$)



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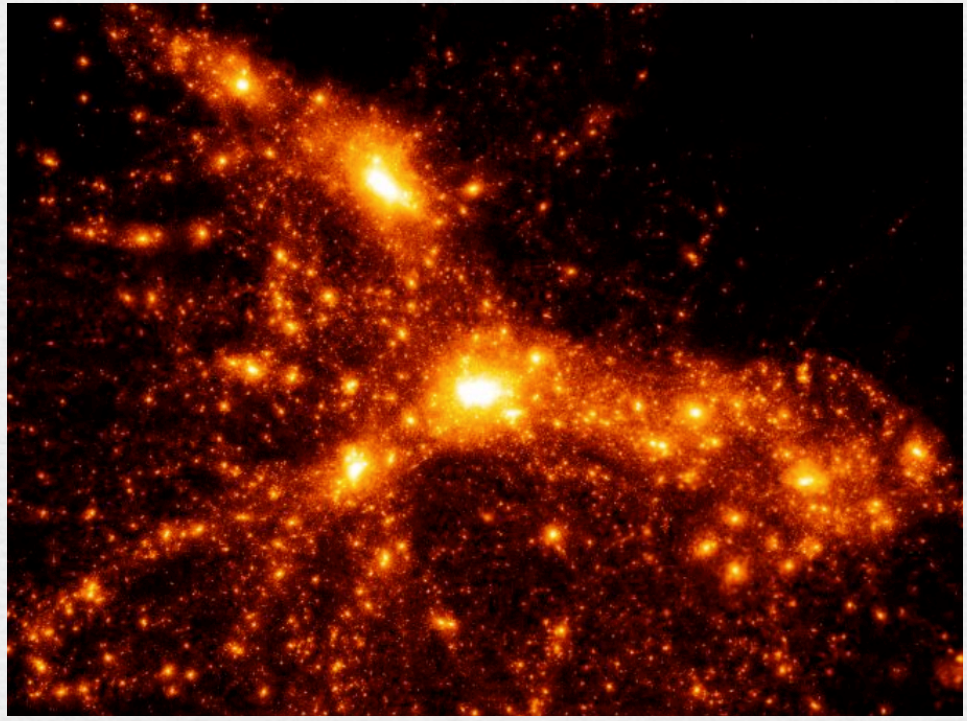
Simulation specs:

- Parent simulations: Large Suite Dark Matter Simulations (LasDamas; McBride et al.)
- Initial conditions: Multi-Scale Initial Conditions (MUSIC; Oliver Hahn)
- N-body simulations: Gadget-2
- 93 halos of M_{200}=$5x10^{14}$ (within 0.1 dex); subhalos are complete down to 70 km/s
- Mass resolution 10^9 Msun/h; force resolution 6.7 kpc/h (500,000 particles inside a halo)



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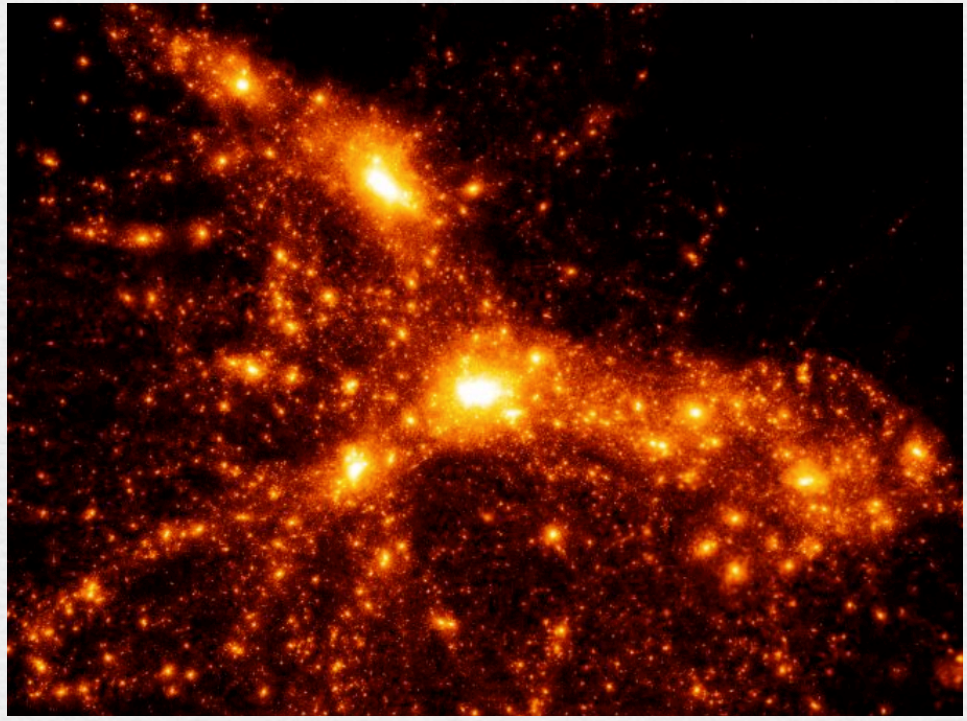
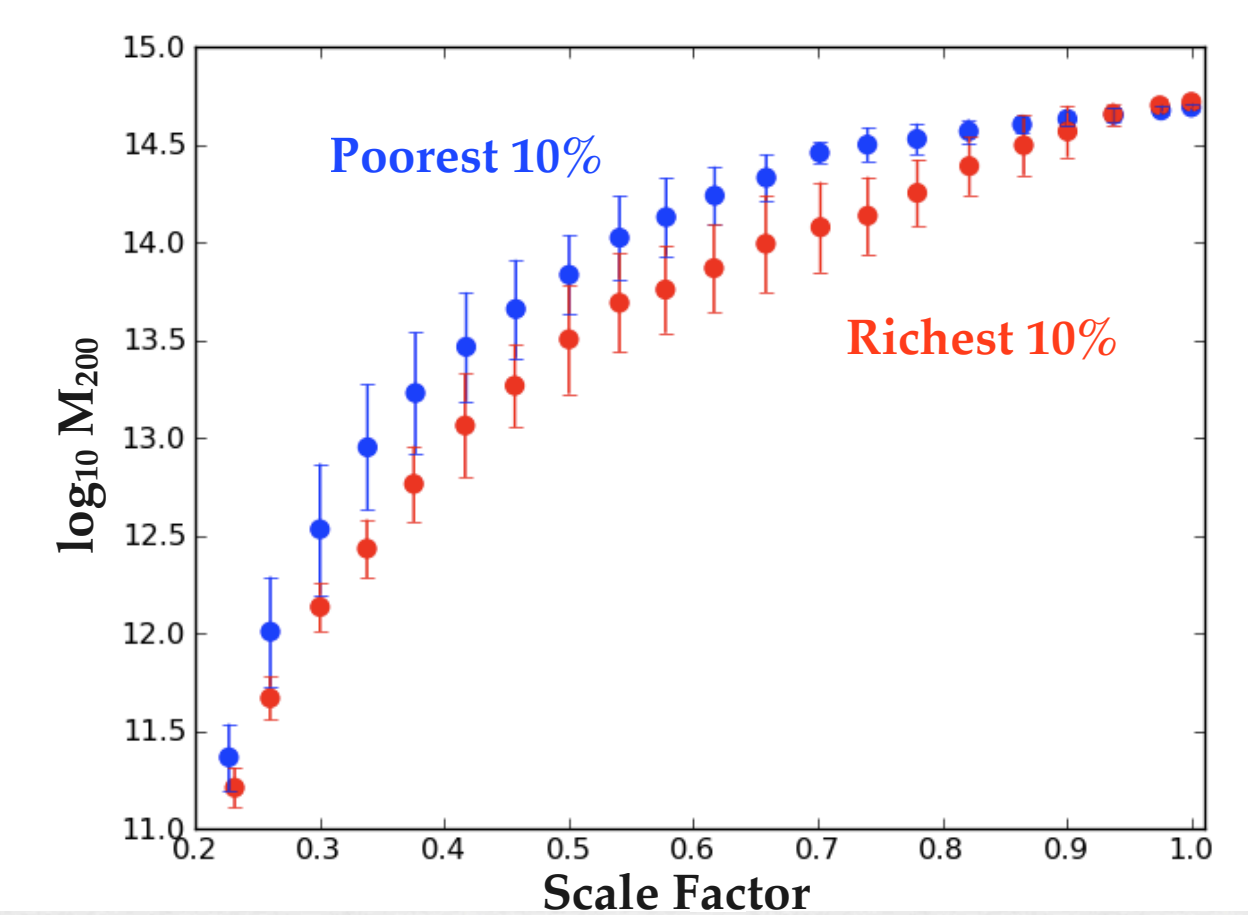
Suitable for:

- Studying the diversity of galaxy content in dark matter halos
- Calibrating halo properties for massive clusters (e.g. SZ and X-ray clusters)
- Studying large-scale structure and small-scale subhalo properties simultaneously
- Understanding galaxy formation inside massive halos



The Build-up of Cluster Mass: Rich vs. Poor

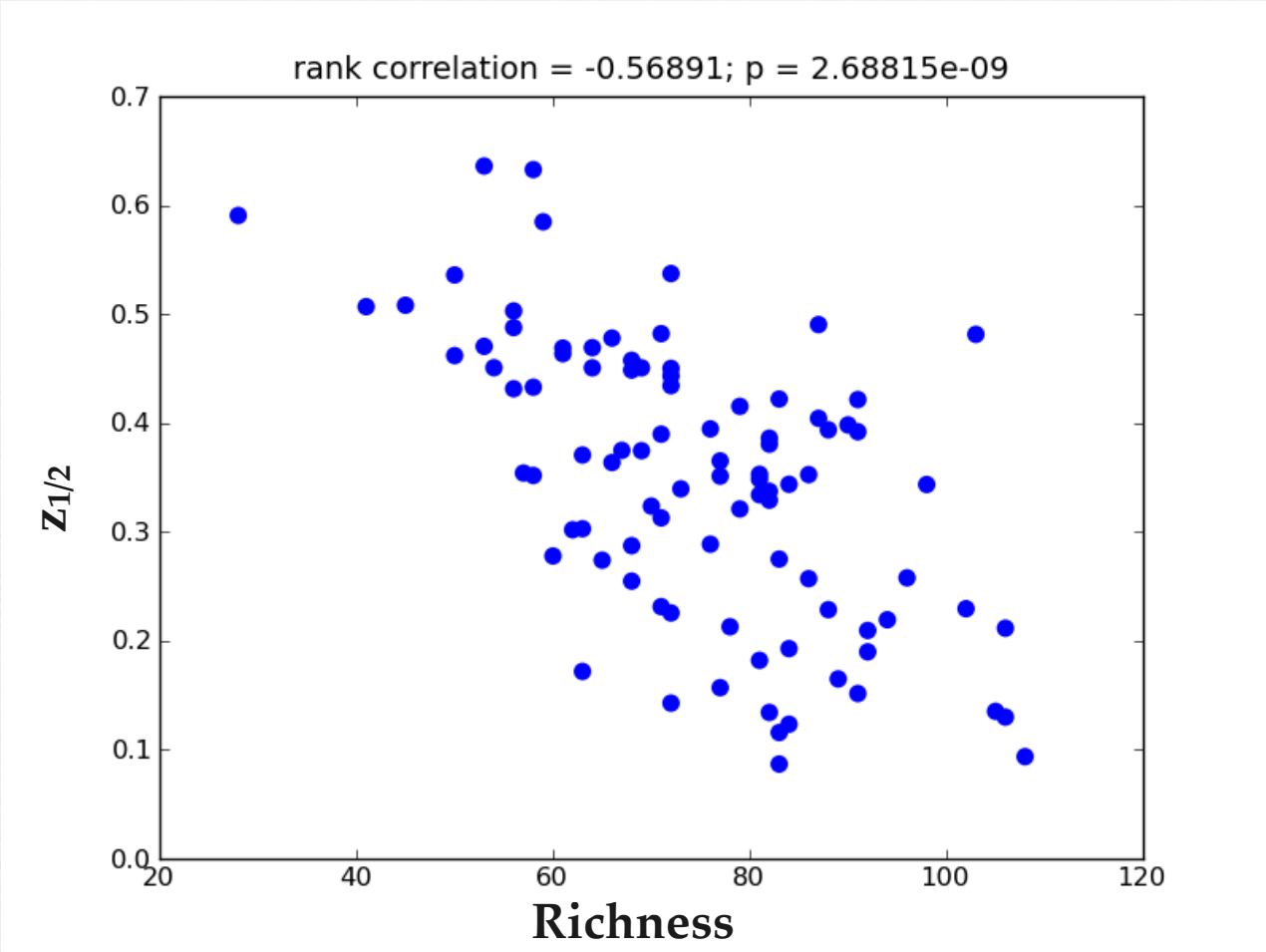
Richness: defined as number of subhalos with current $V_{max} > 80$ km/s



- Poor clusters form early and have little late-time accretion
- Rich clusters form late and have lots of late major mergers

Richness vs. Formation Time

$z_{1/2}$: when halo first reached half of its current mass



also see Zentner et al. 2005; Wechsler et al. 2006

Richness vs. Late-time Growth Rate

Fit mass accretion history with $M(z) = M_0(1+z)^{\beta}e^{-\Upsilon z}$
(as in McBride, Fakhouri, and Ma 2009)
Υ - β characterizes late-time growth rate

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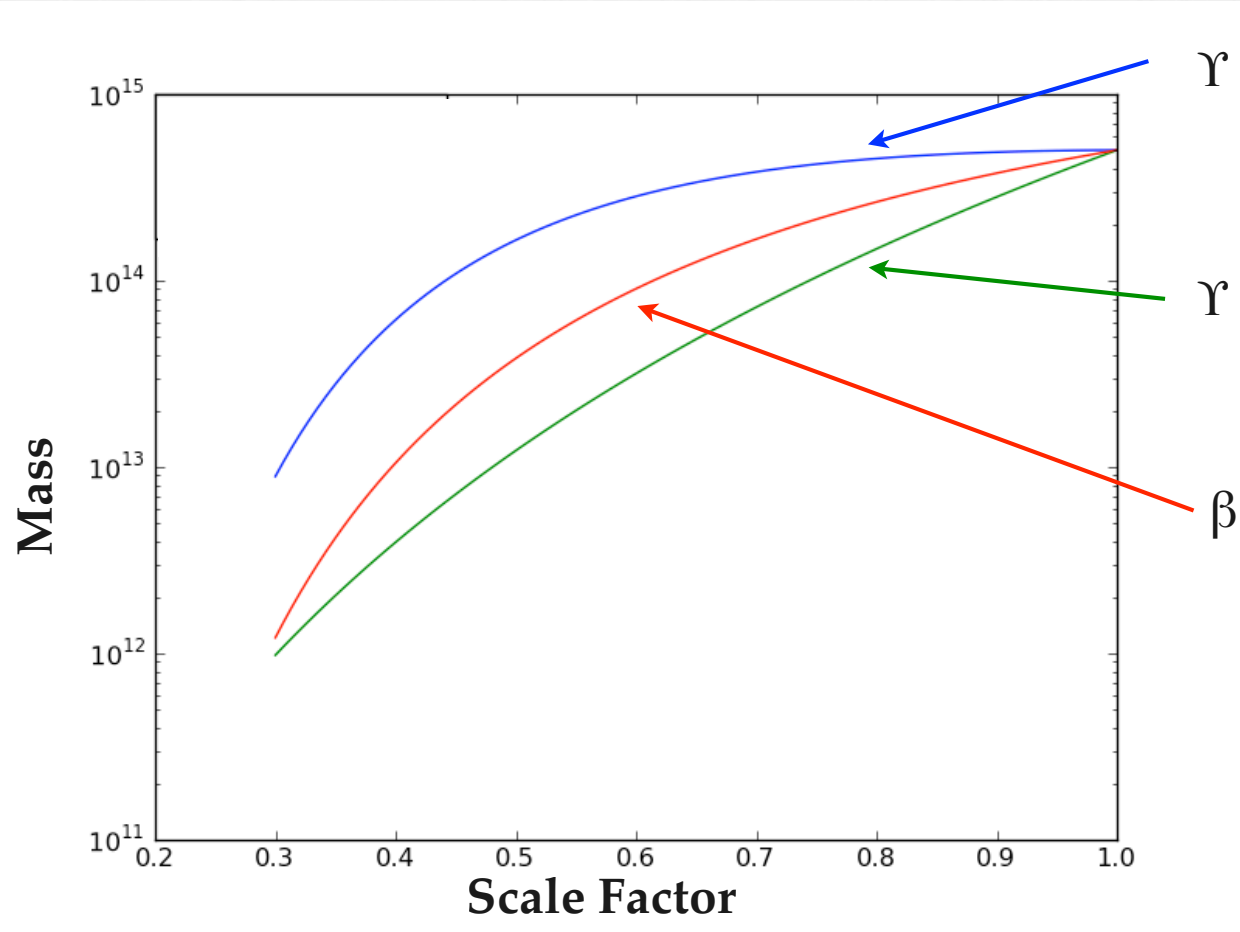
Example: thee scenarios



Υ - β = 0.04: slow late-time growth

Υ - β = 5.5: fast late-time growth

β ~ 0: exponential growth

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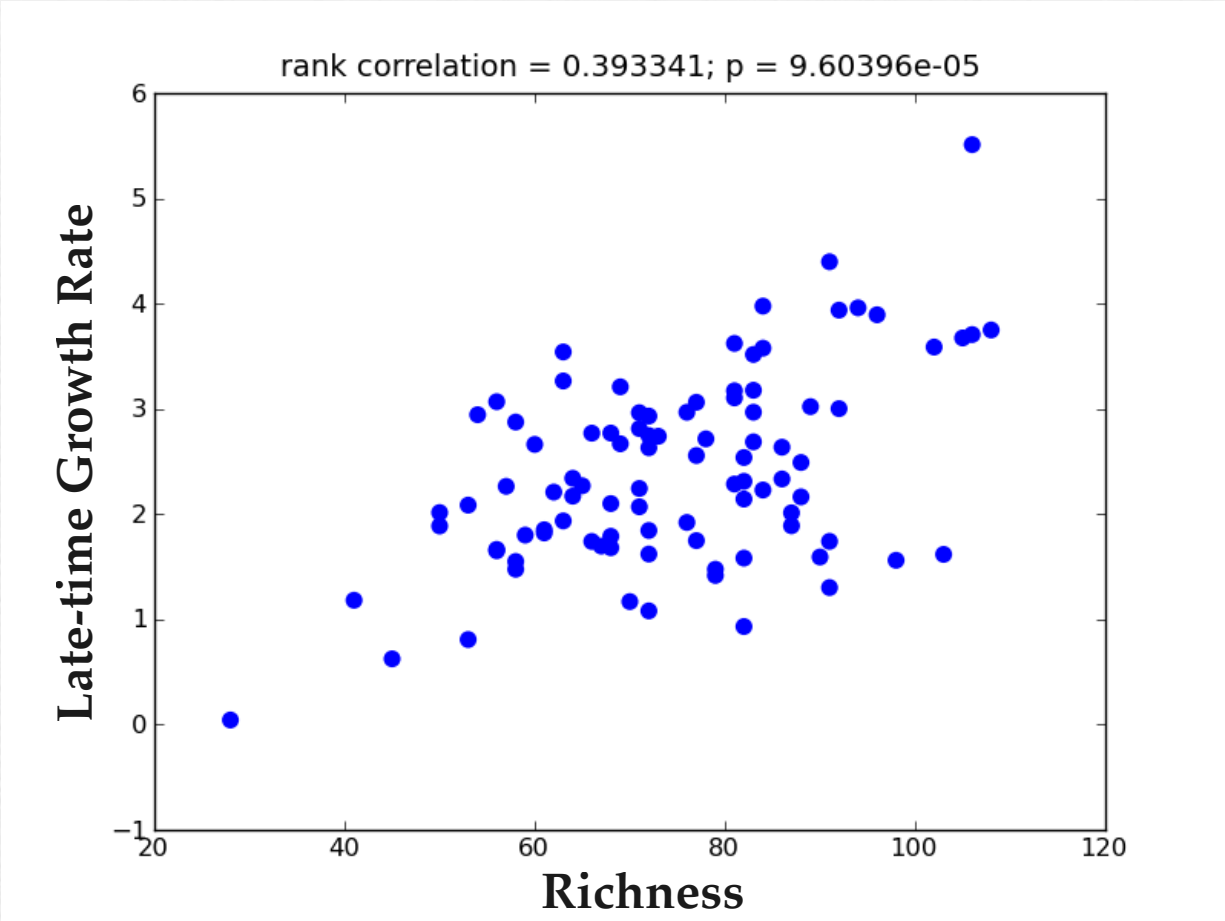
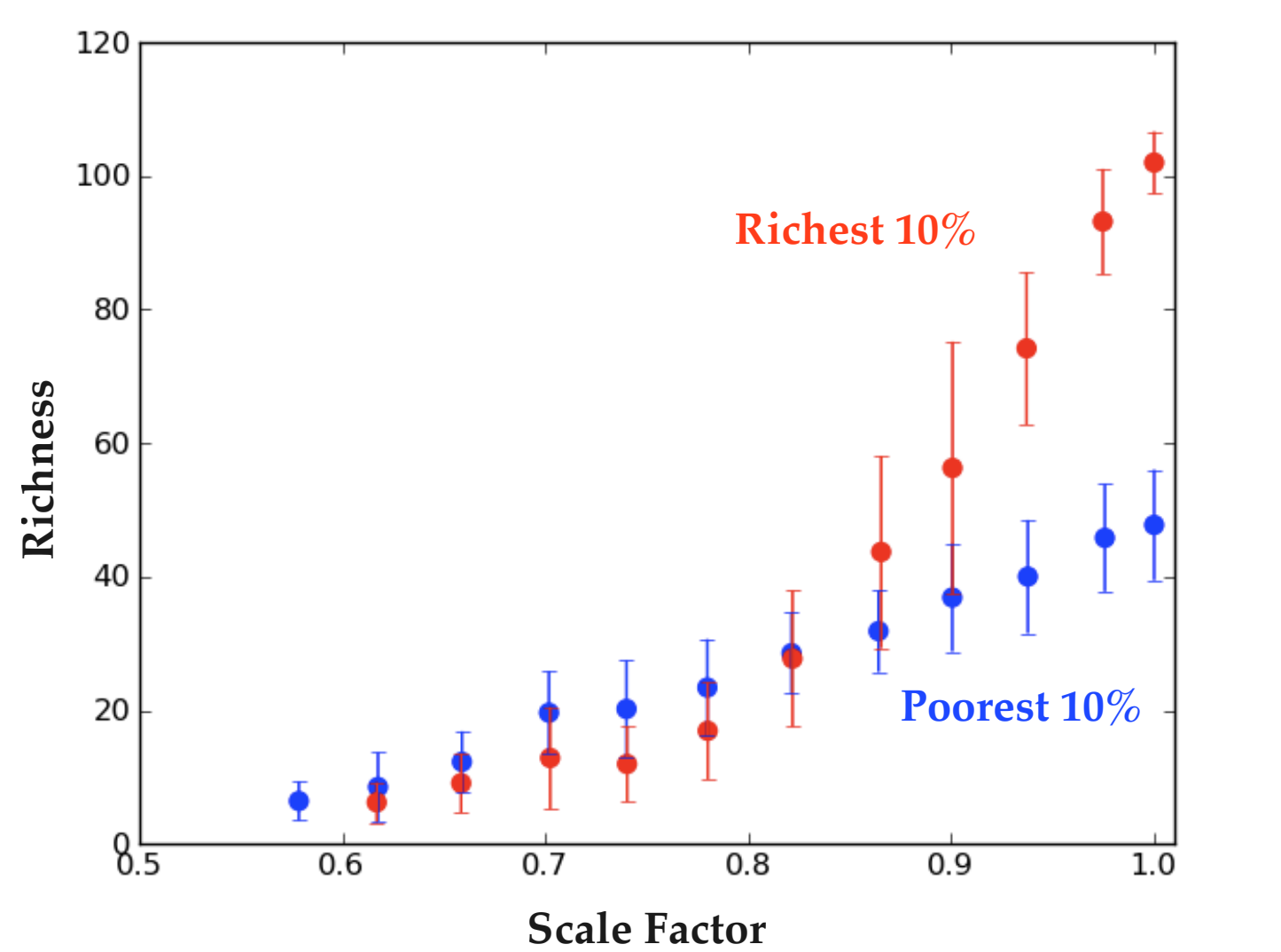
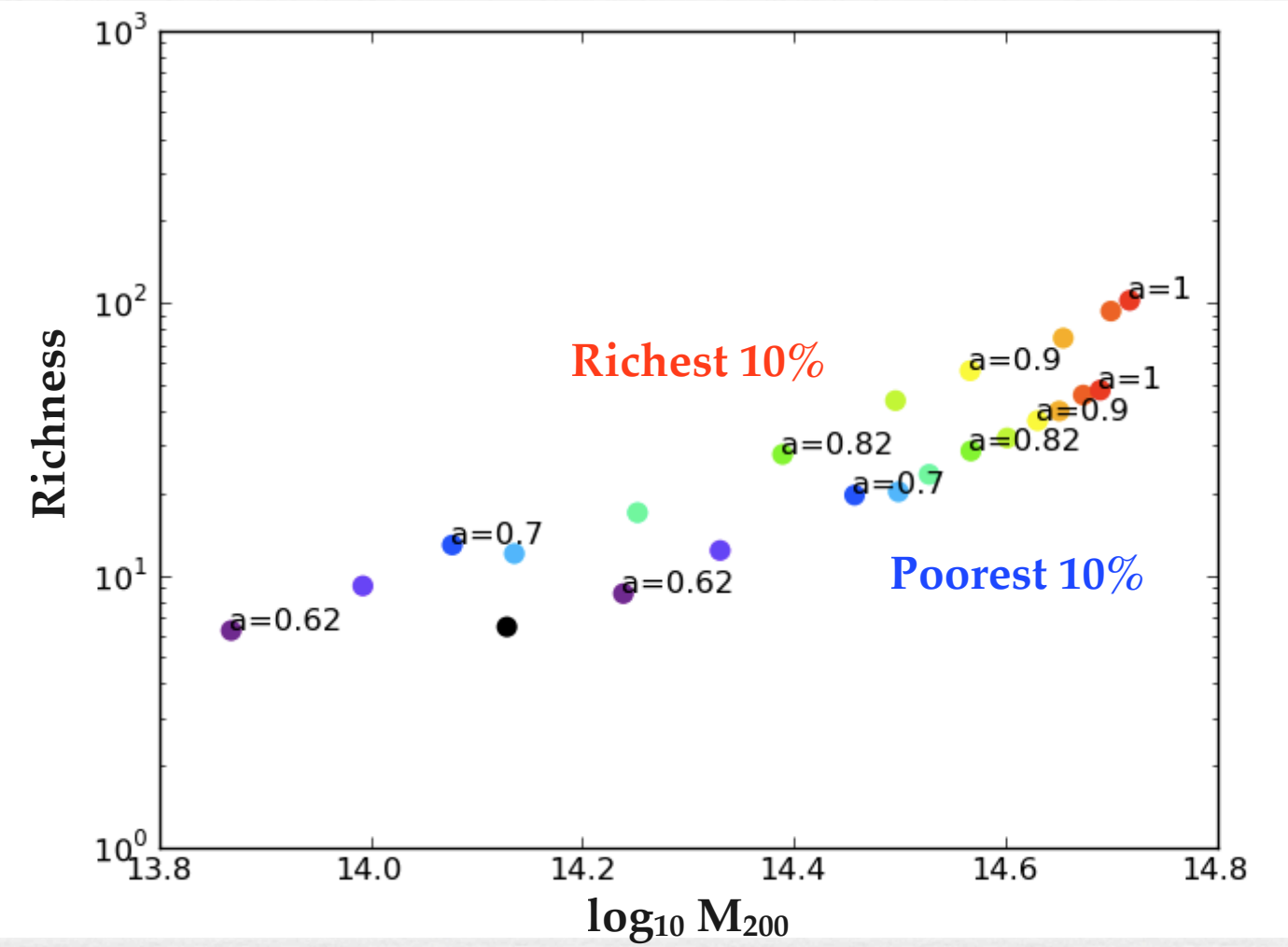


The Build-up of Galaxy Content: Rich vs. Poor

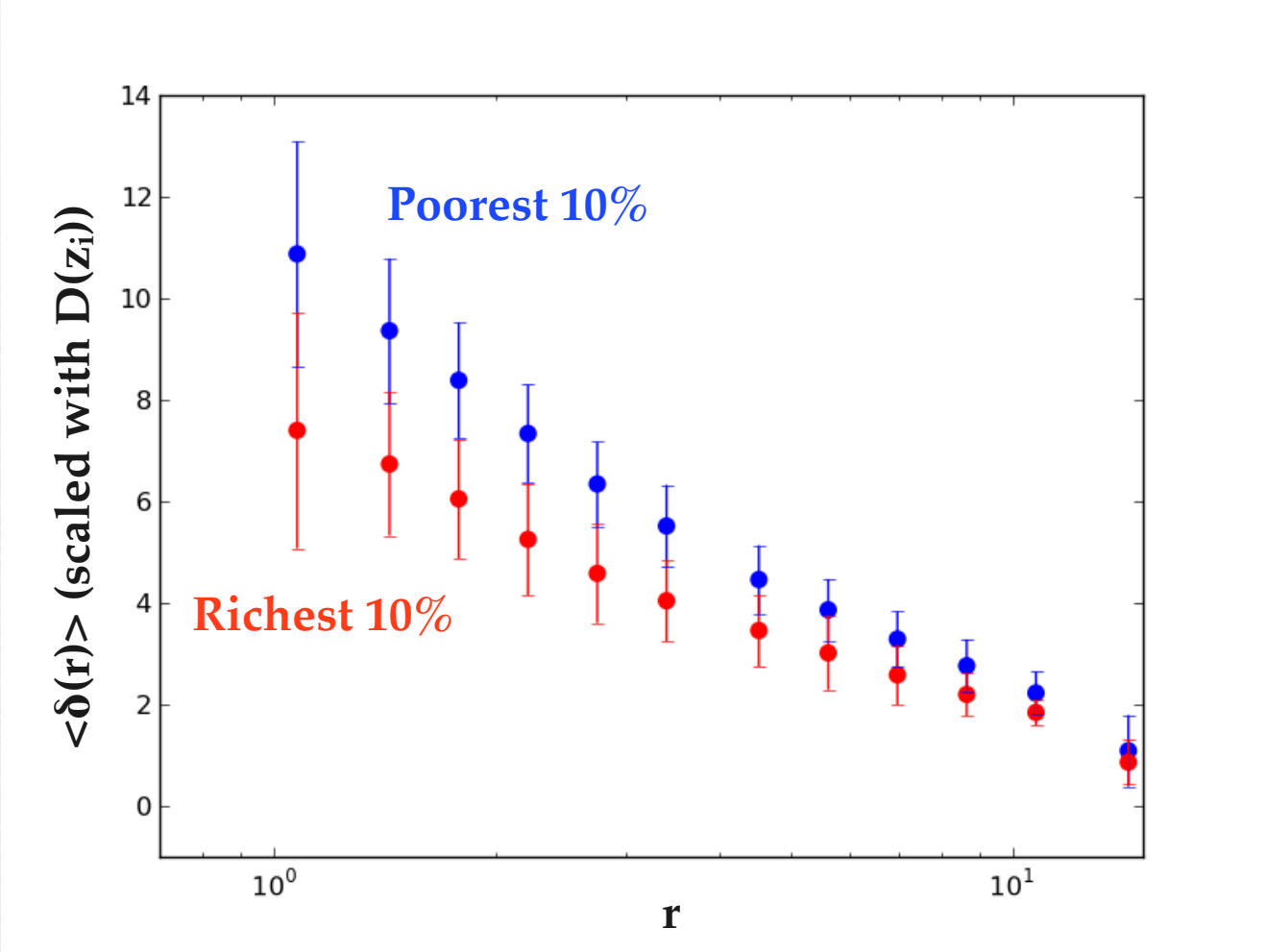


Richness Growth vs. Mass Growth



Richness growth scales linearly with mass growth
also see Wetzel et al. 2009

Peak Profile in the Initial Condition

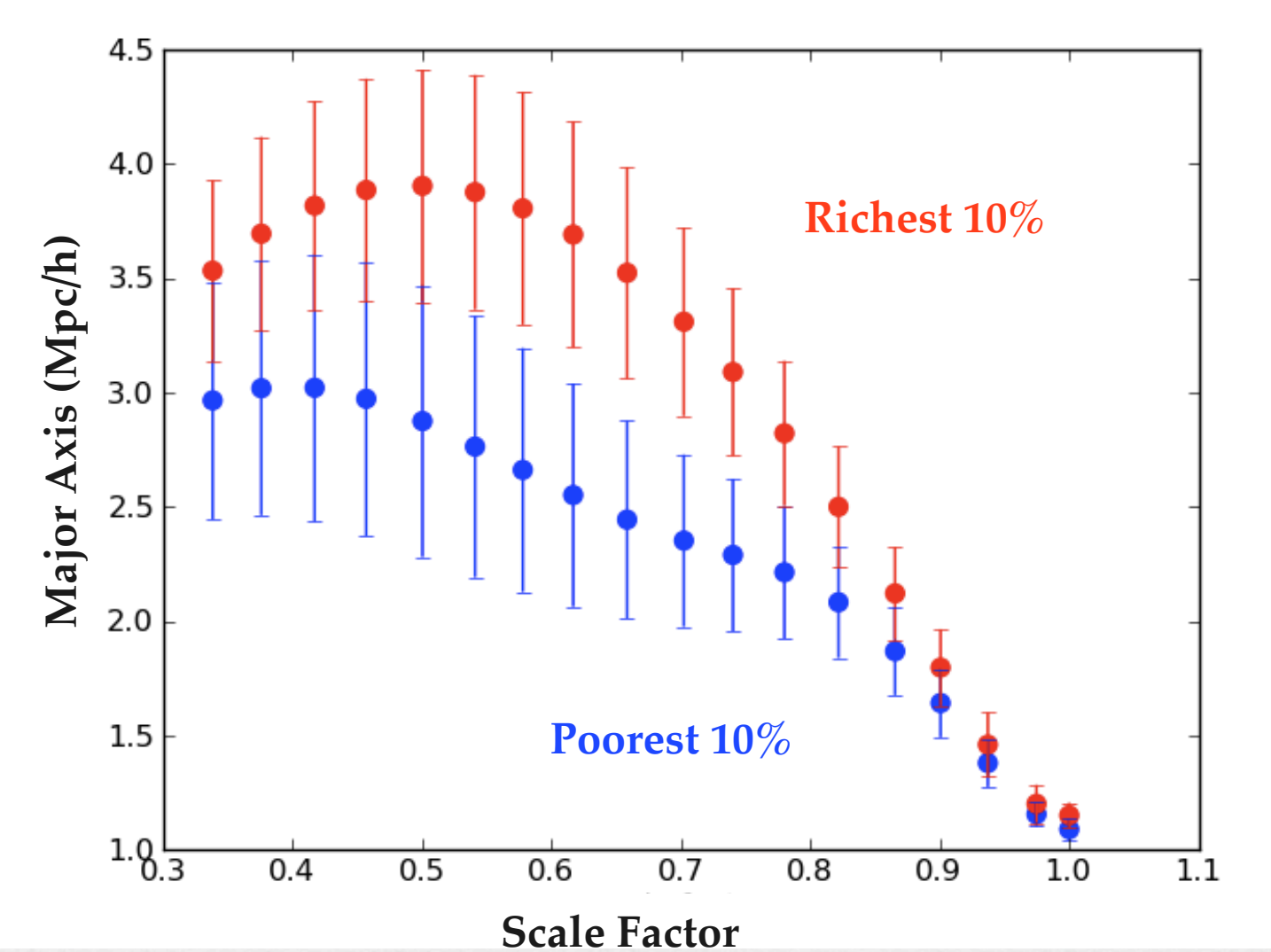


- Poor clusters correspond to steeper peaks and early collapse

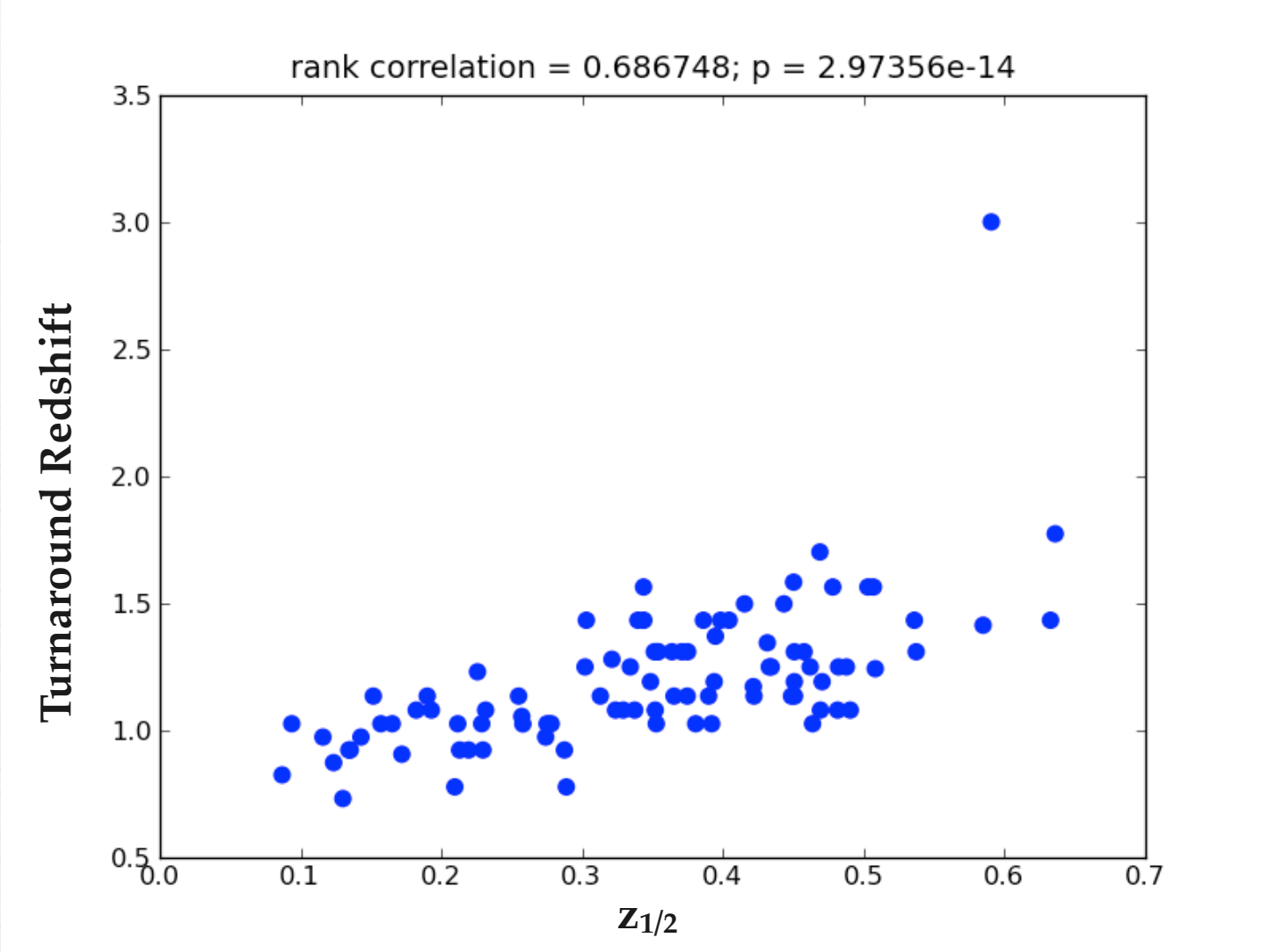
  also see Dalal et al. 2008 for peak properties

History of Collapse

Tracing halo particles at all redshift and measuring the three axes

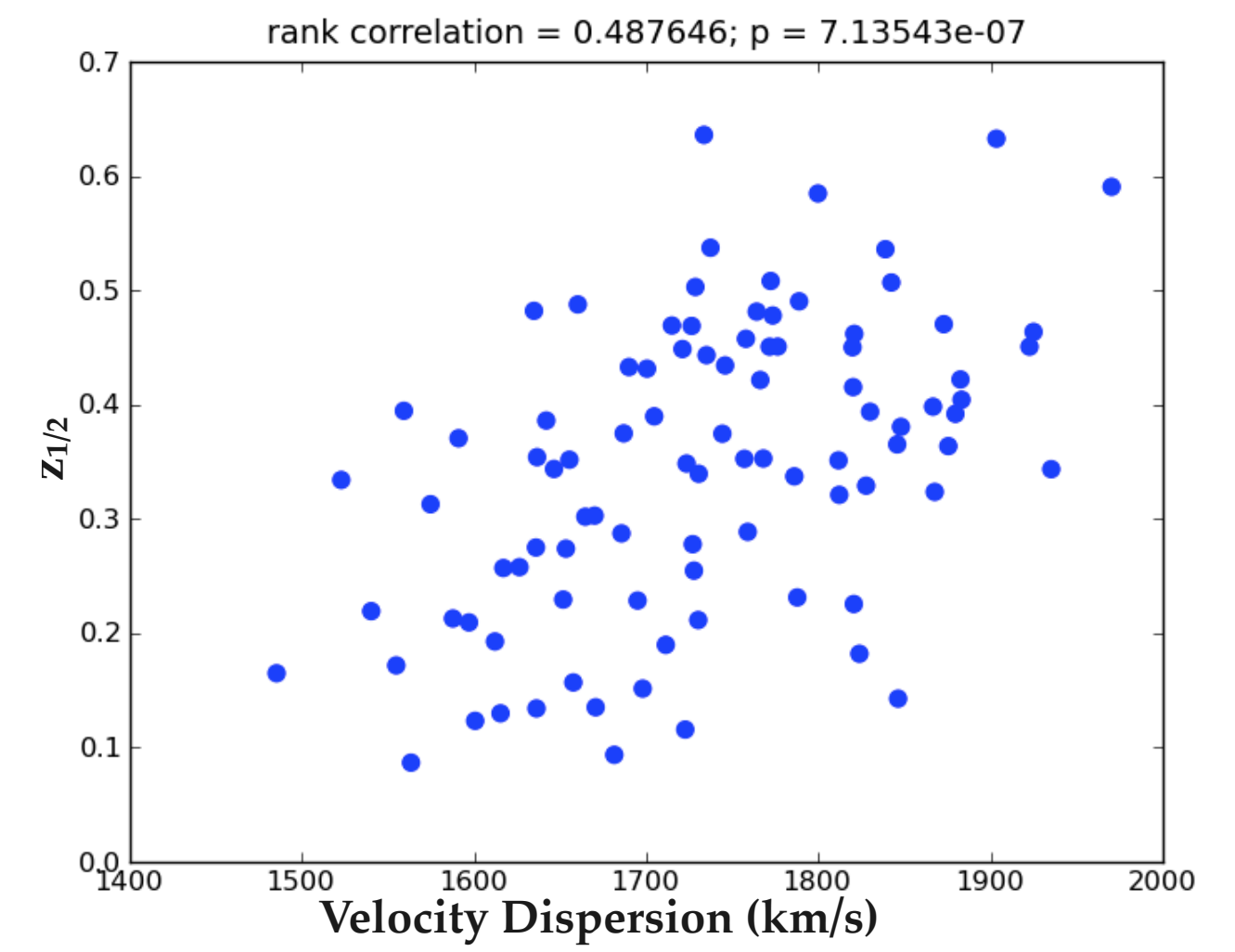


Turnaround Time vs. Formation Time



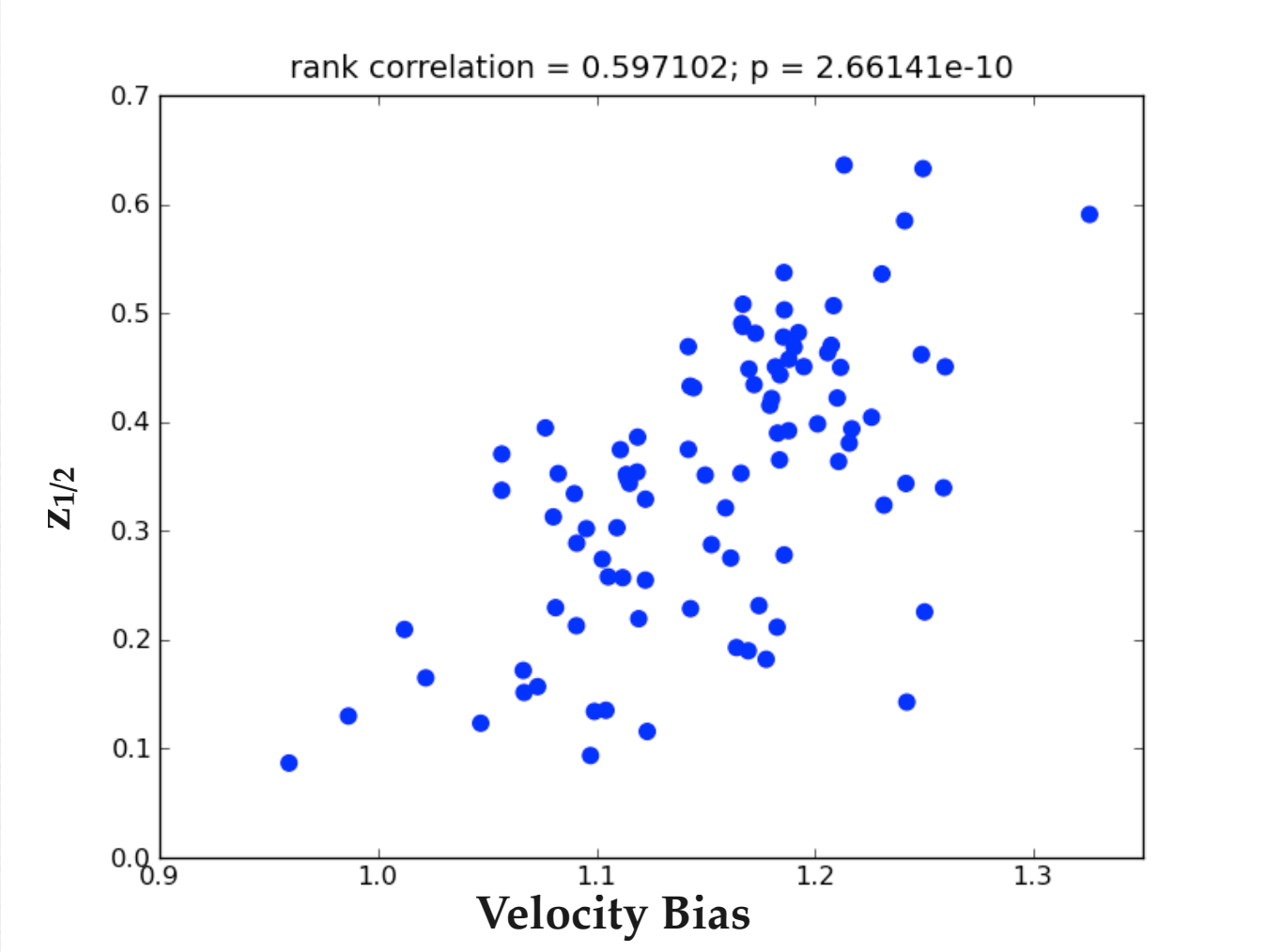
Velocity Dispersion vs. Formation Time

Velocity dispersion measured with subhalos with $V_{max} > 80$ km/s



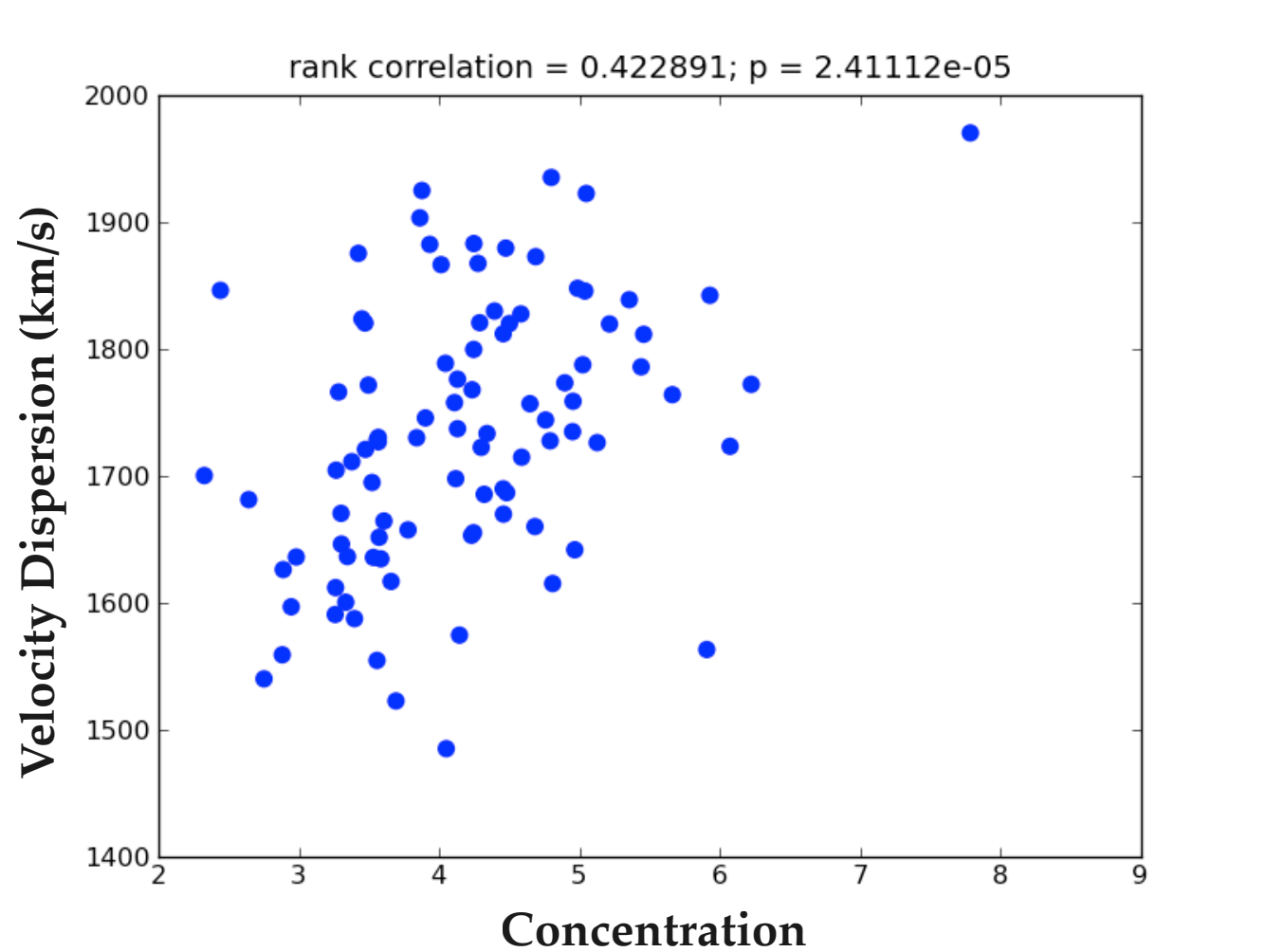
Velocity Bias vs. Formation Time

Velocity Bias := σ_V(subhalos) / σ_V(dark matter)



Velocity Dispersion vs. Concentration

Concentration := r_{200}/r_s; r_s: characteristic radius of an NFW profile



This correlation could potentially affect SZ or X-ray cluster mass calibration!

Summary

- We performed zoom-in re-simulations for 93 halos of mass 5×10^{14} $M_\odot/h$ to study the diversity of galaxy content in dark matter halos of the same mass.
- Richness (number of subhalos): Halos of low richness tend to have
  - early formation time
  - low late-time accretion rate
  - steep peak in the initial condition
  - early collapse
- Velocity dispersion of subhalos are correlated with halo concentration and anti-correlated with formation time. This will potentially affect cluster mass calibration using velocity dispersion.
- Outlook:
  - Applying semi-analytic model to populate galaxies inside subhalos
  - Comparing different subhalo selection
  - Estimating weak lensing signals