The SPT-GMOS Survey: Velocity Segregation and Calibrating Velocity Dispersion Biases

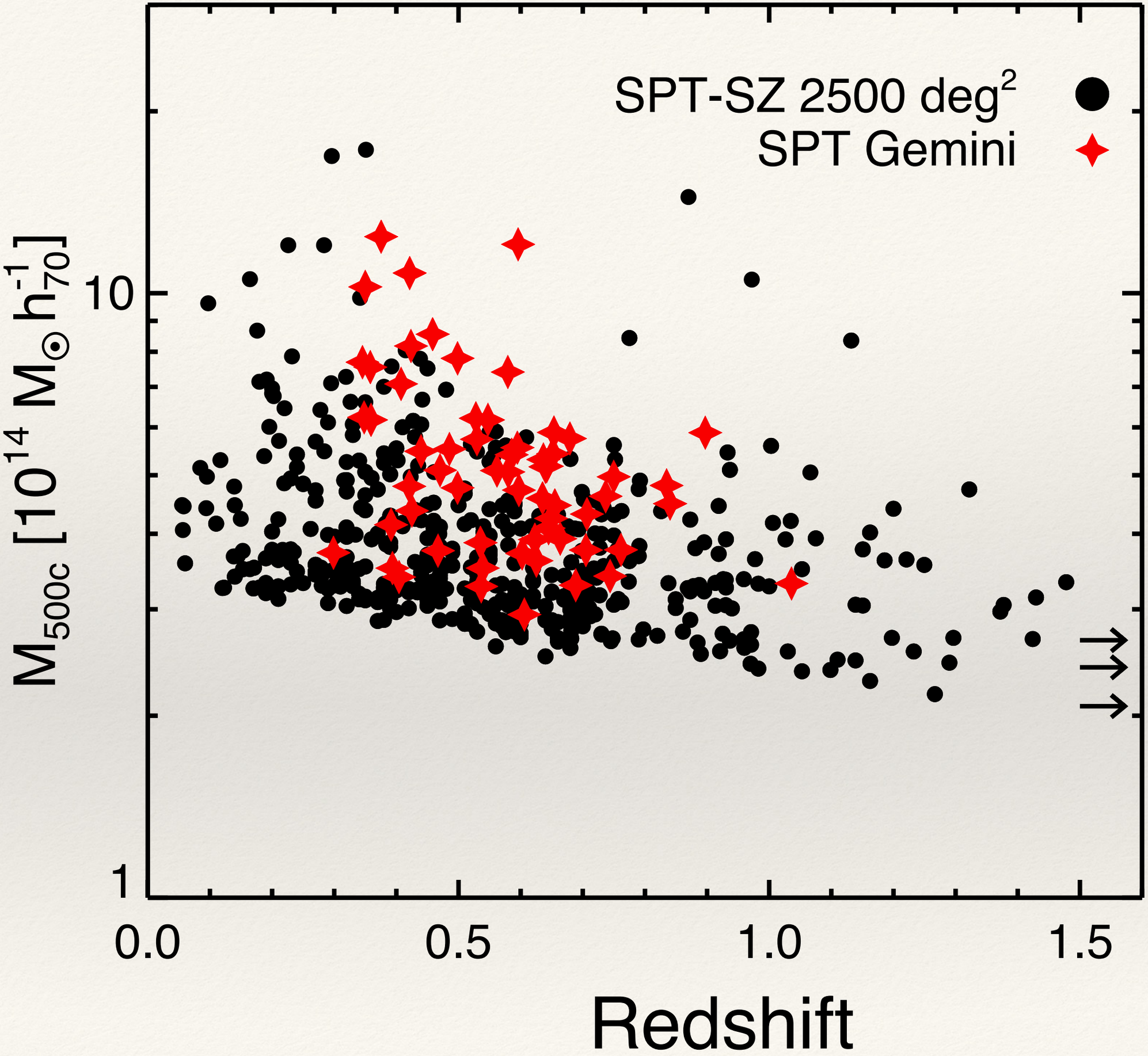
Matthew Bayliss

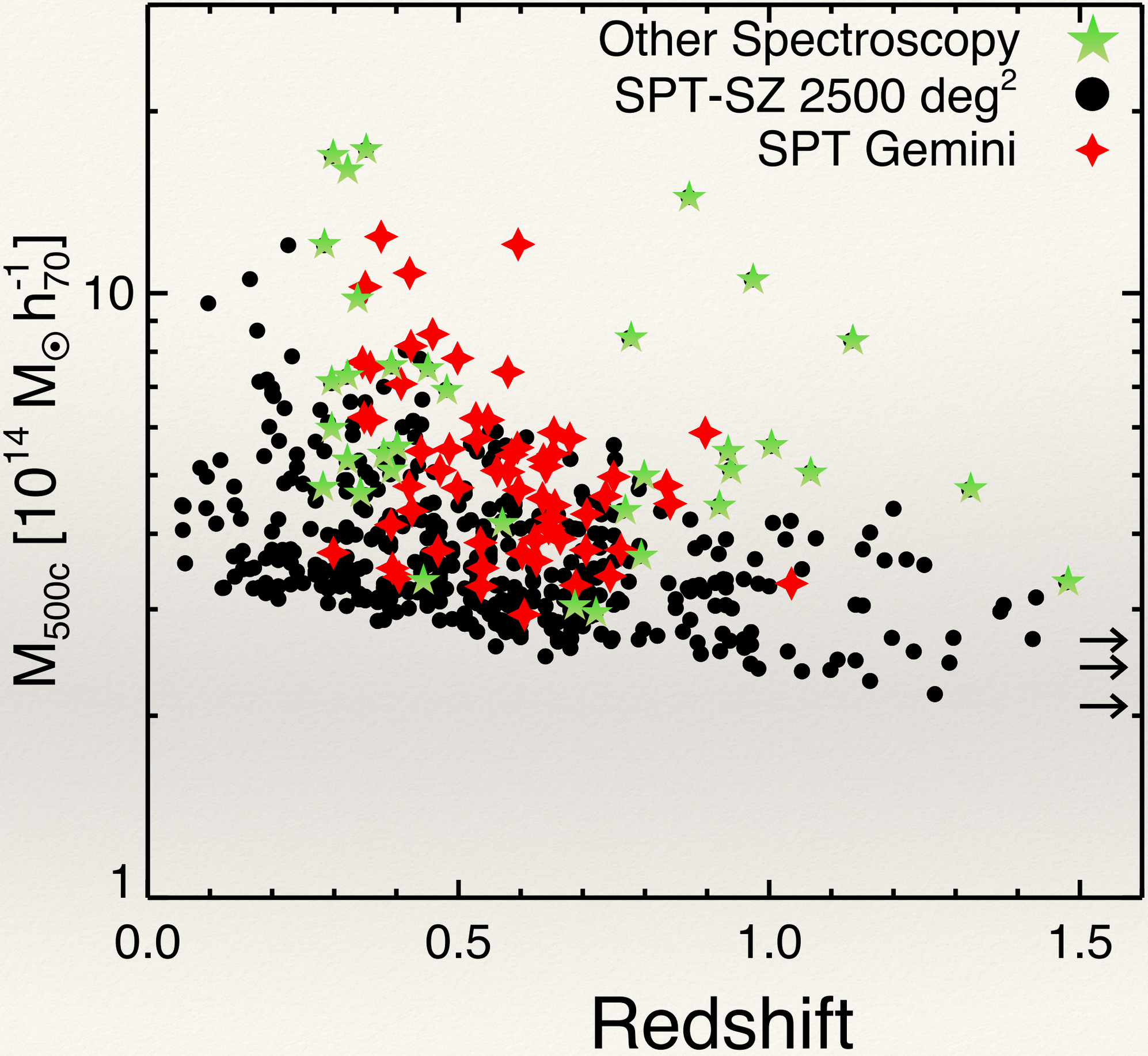
Massachusetts Institute of Technology

Galaxy Clusters 2017 — Santander — July 7, 2017

Talk Outline

- **SPT-GMOS: A spectroscopic survey of SPT-SZ galaxy clusters.**
- **Science with the SPT-GMOS spectra: velocity segregation by galaxy type and luminosity, plus other spin-off projects.**
- **Sticking my neck out: can we help to calibrate velocity dispersions as a mass-observable using comparisons of astrophysical effects (i.e., velocity segregation) in the data vs simulations?**


SPT-SZ 2500 deg^2
SPT Gemini
M_{500c} [10^{14} $M_\odot$ h_{70}^{-1}]
10
1
0.0
0.5
1.0
1.5
Redshift


Other Spectroscopy
SPT-SZ 2500 deg^2
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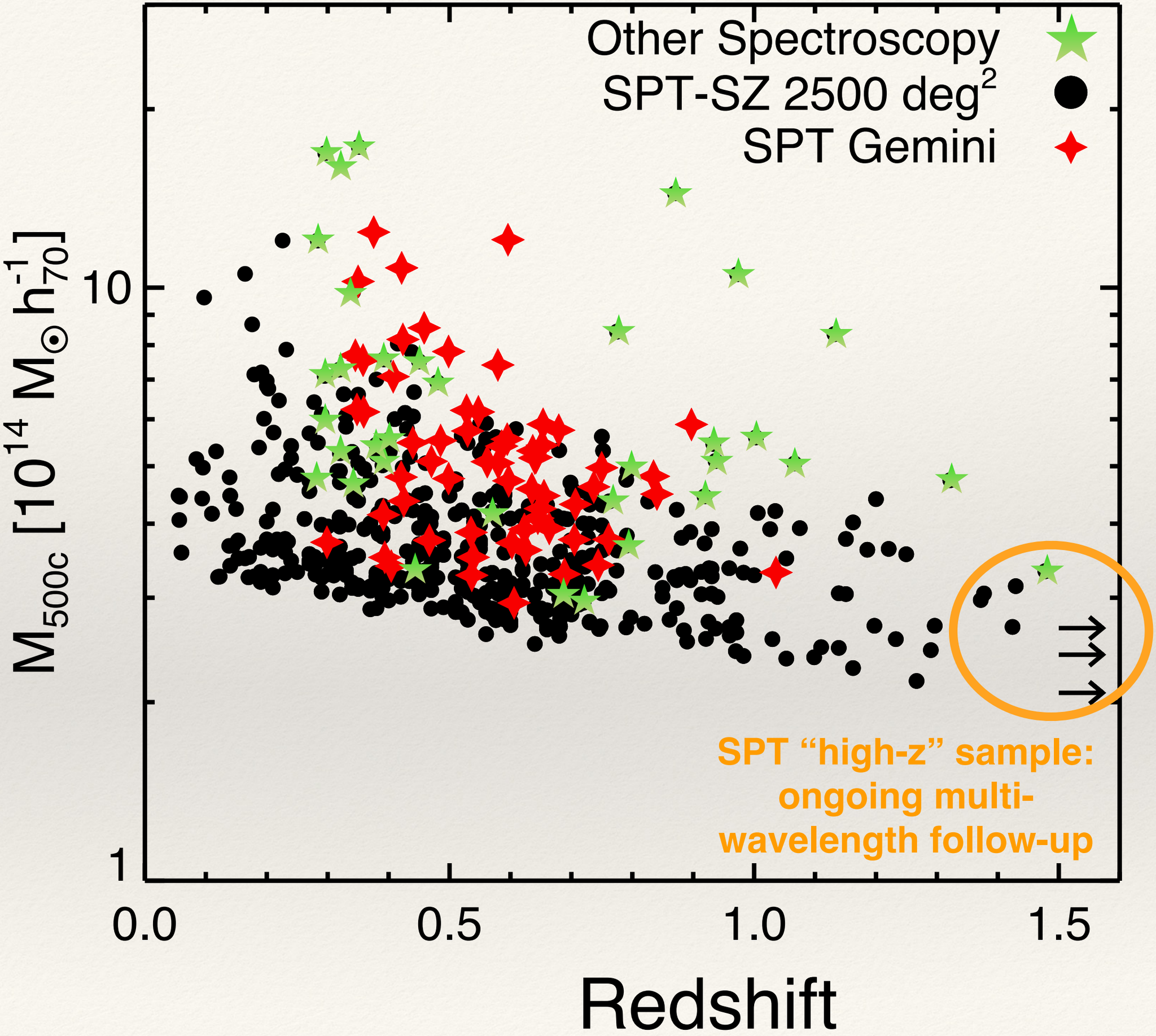
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0.0
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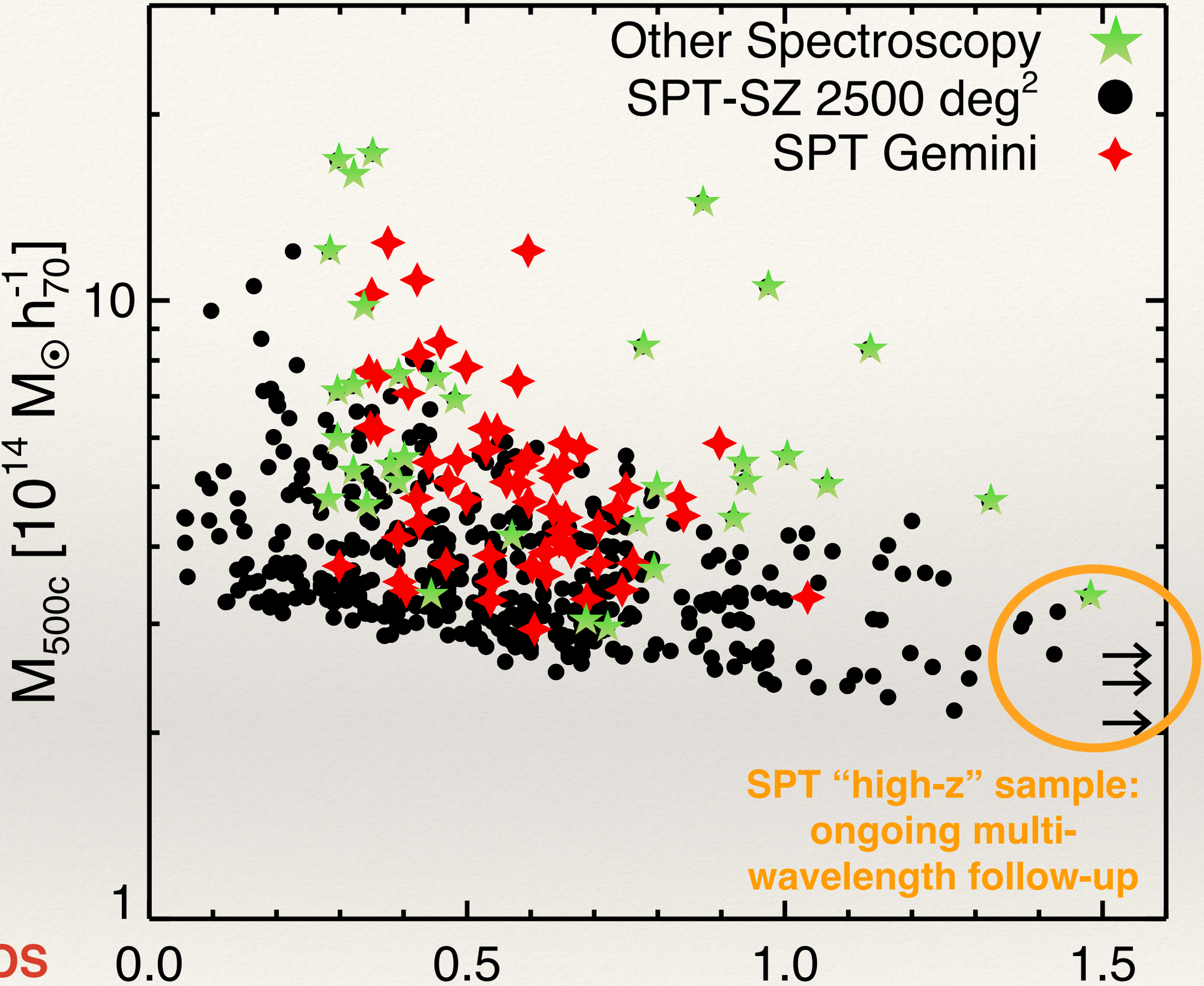
Redshift
SPT "high-z" sample:
ongoing multi-
wavelength follow-up



In Total:

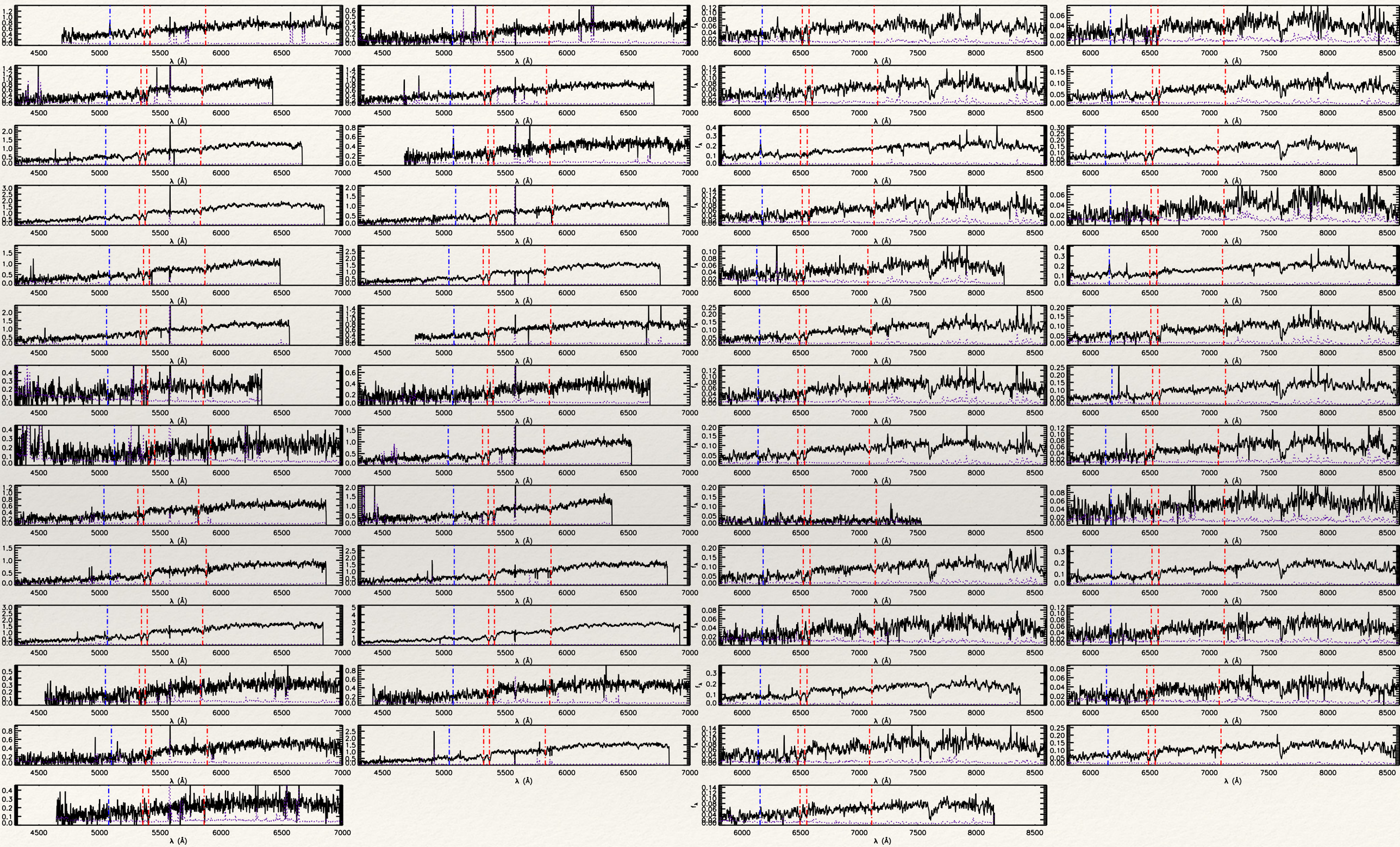
62 SPT-GMOS

98 with minimal velocity dispersion measurement

SPT-GMOS Spectroscopic Survey: Quick Facts

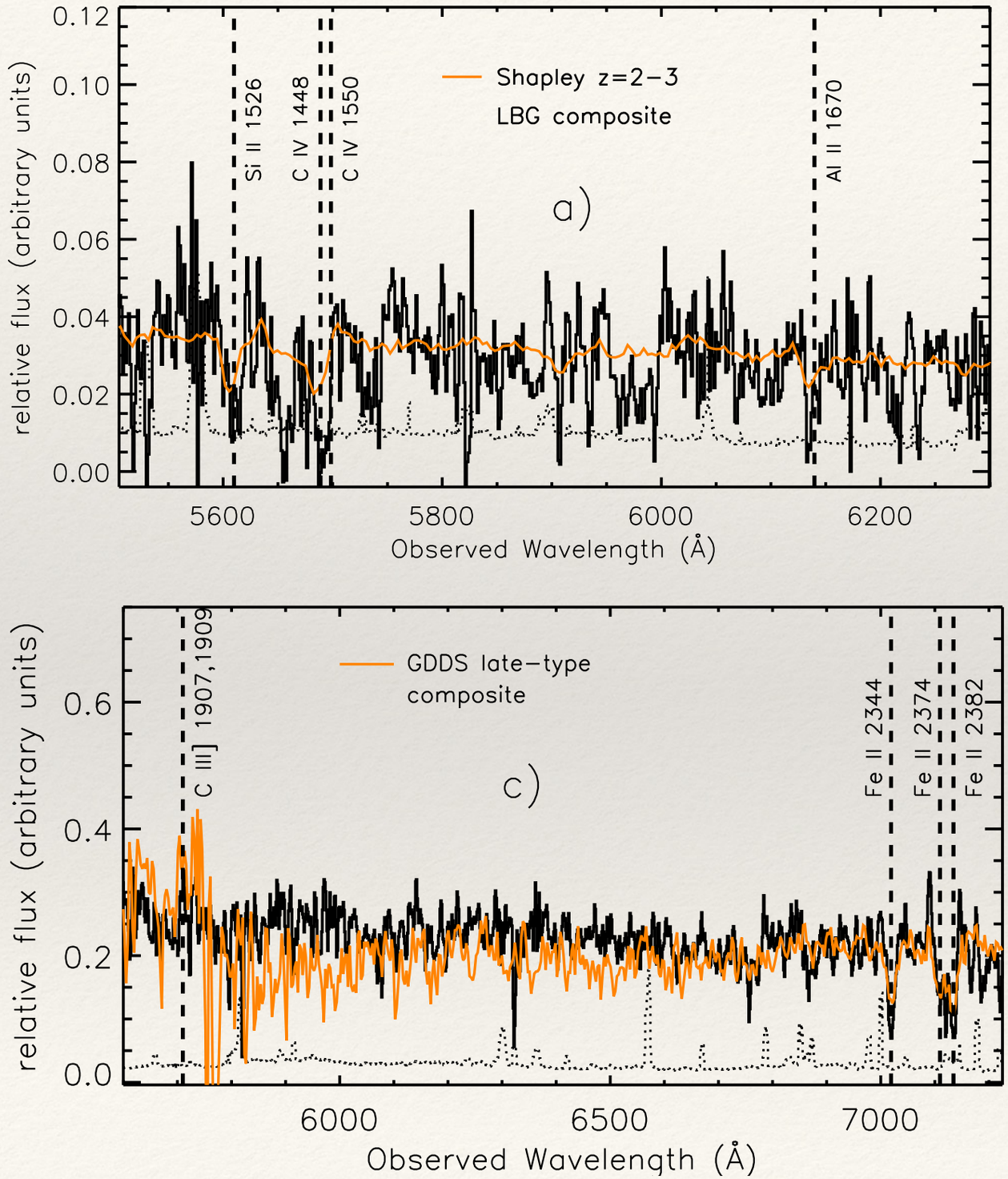
- 121 spectroscopic masks targeting 62 clusters (~75% of the goal)
  - clusters span $0.3 < z < 1$ in redshift
- ~2600 spectra —> 2243 galaxies, 1579 cluster members
- All other (non-SPT-GMOS) spectroscopic followup provides another ~1150 cluster members
- Upshot:
  - 108 / 98 / 82 / 63 clusters w/ measured velocity dispersions, depending on the minimum number of members you're comfortable with
  - Leave us with velocity dispersions for ~20-25% of the full SPT-SZ cosmological cluster sample

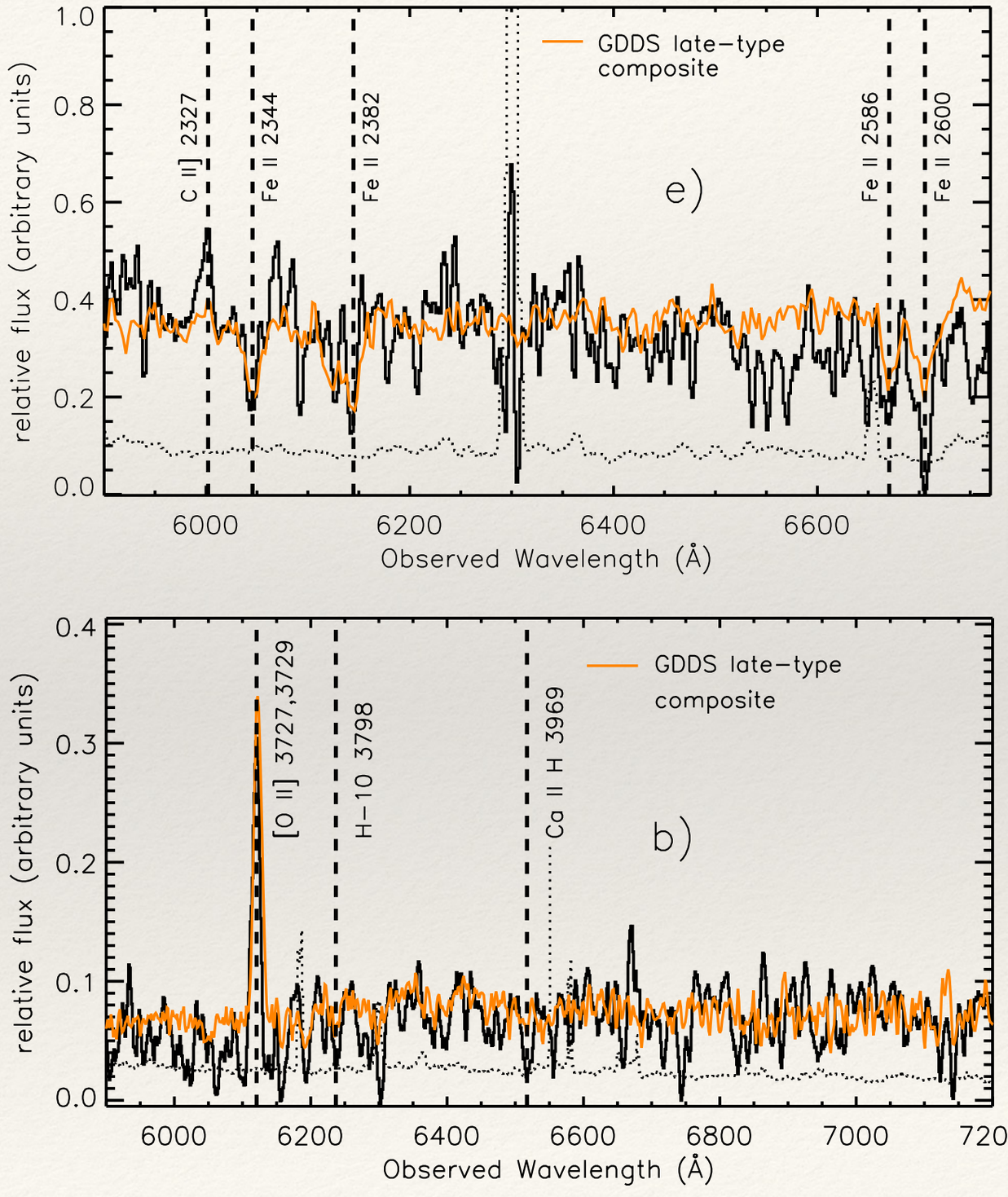
It’s A Survey, So It’s Customary to Show the Data



Bayliss et al. (2016)

Not Just Cluster Members: For Free Get Some Cool Things Like Strongly Lensed Galaxies





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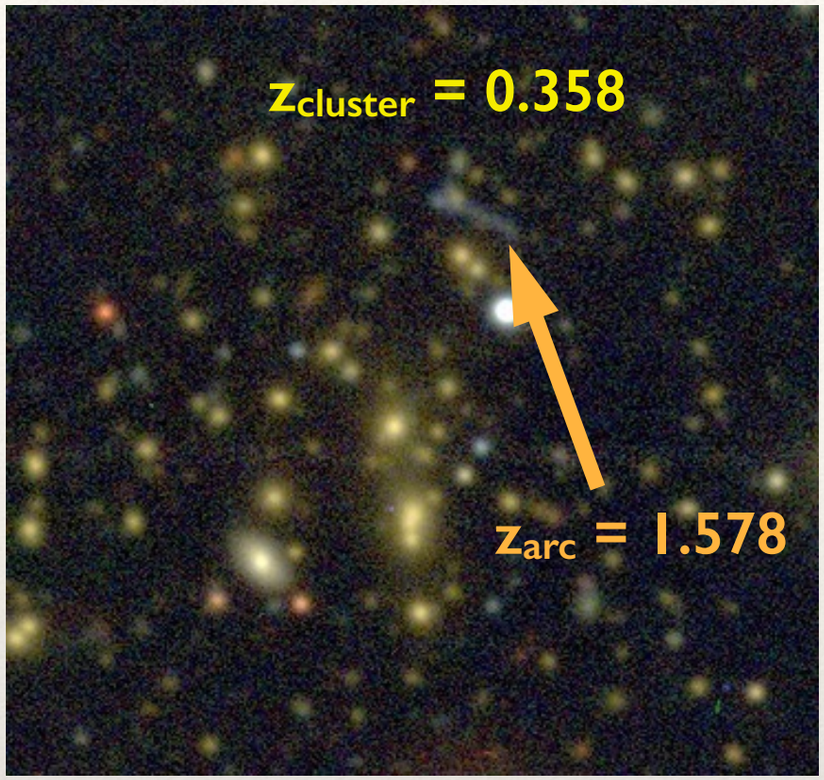
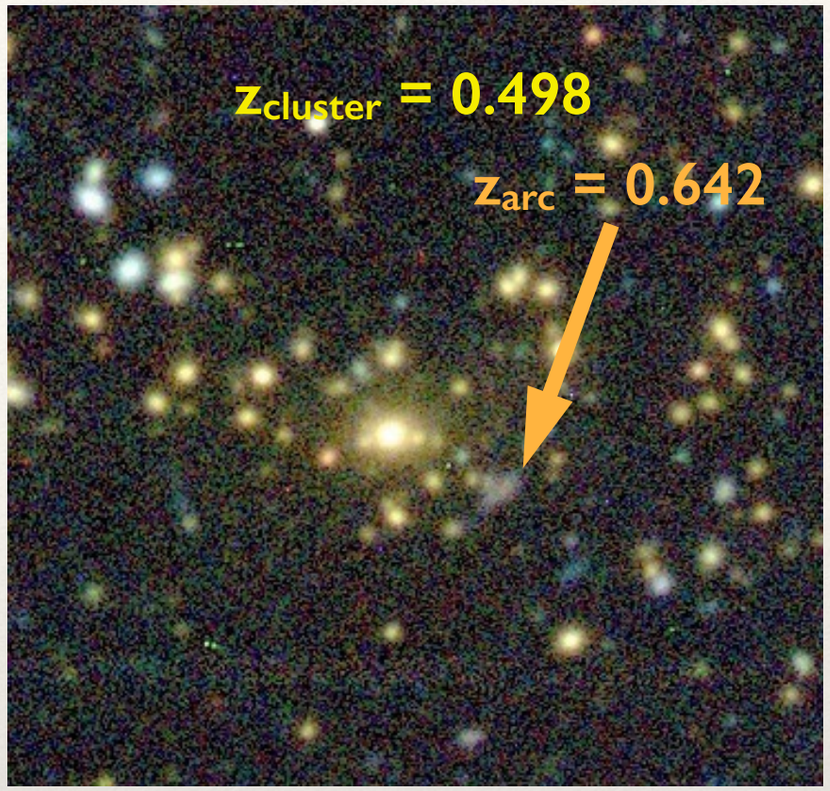
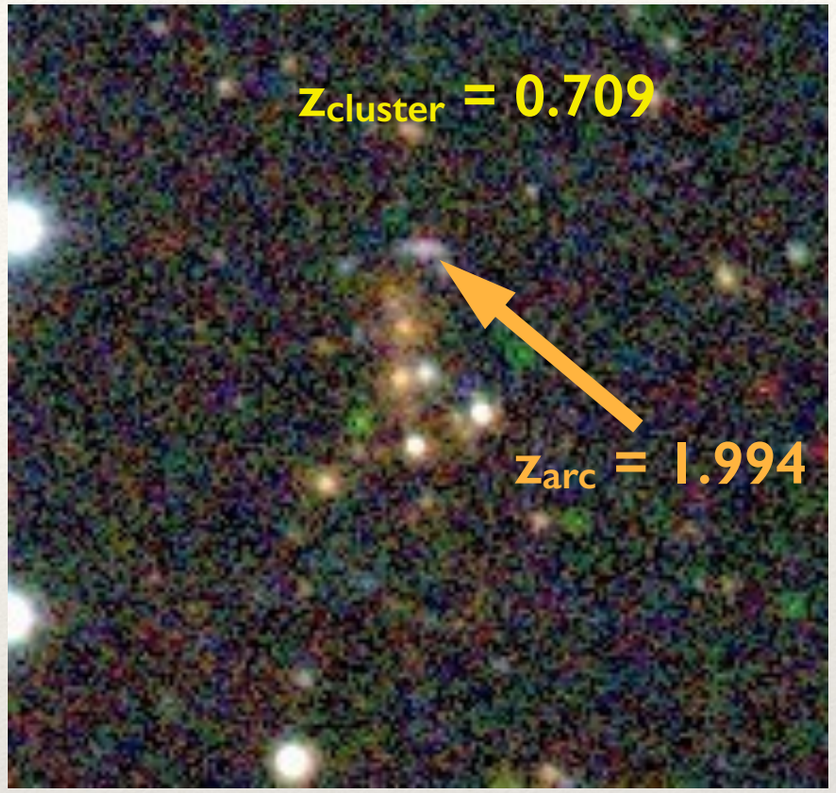
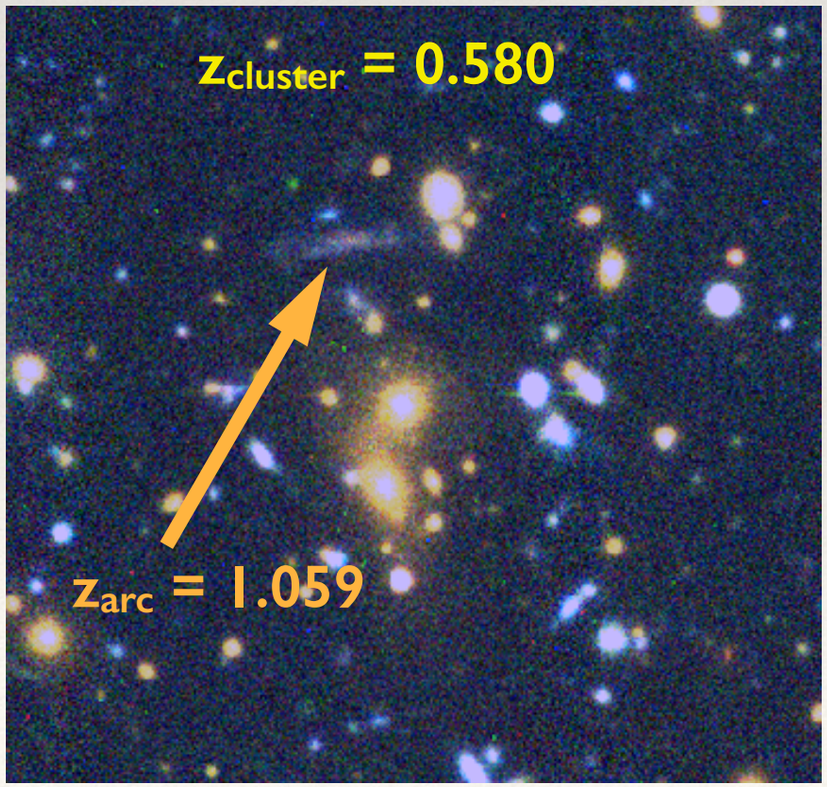
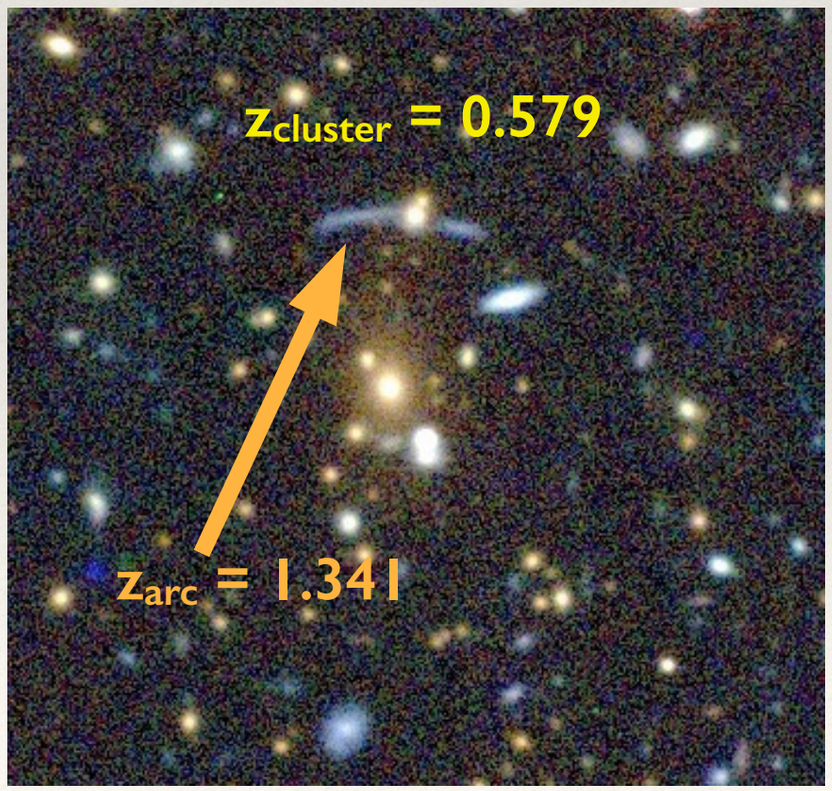




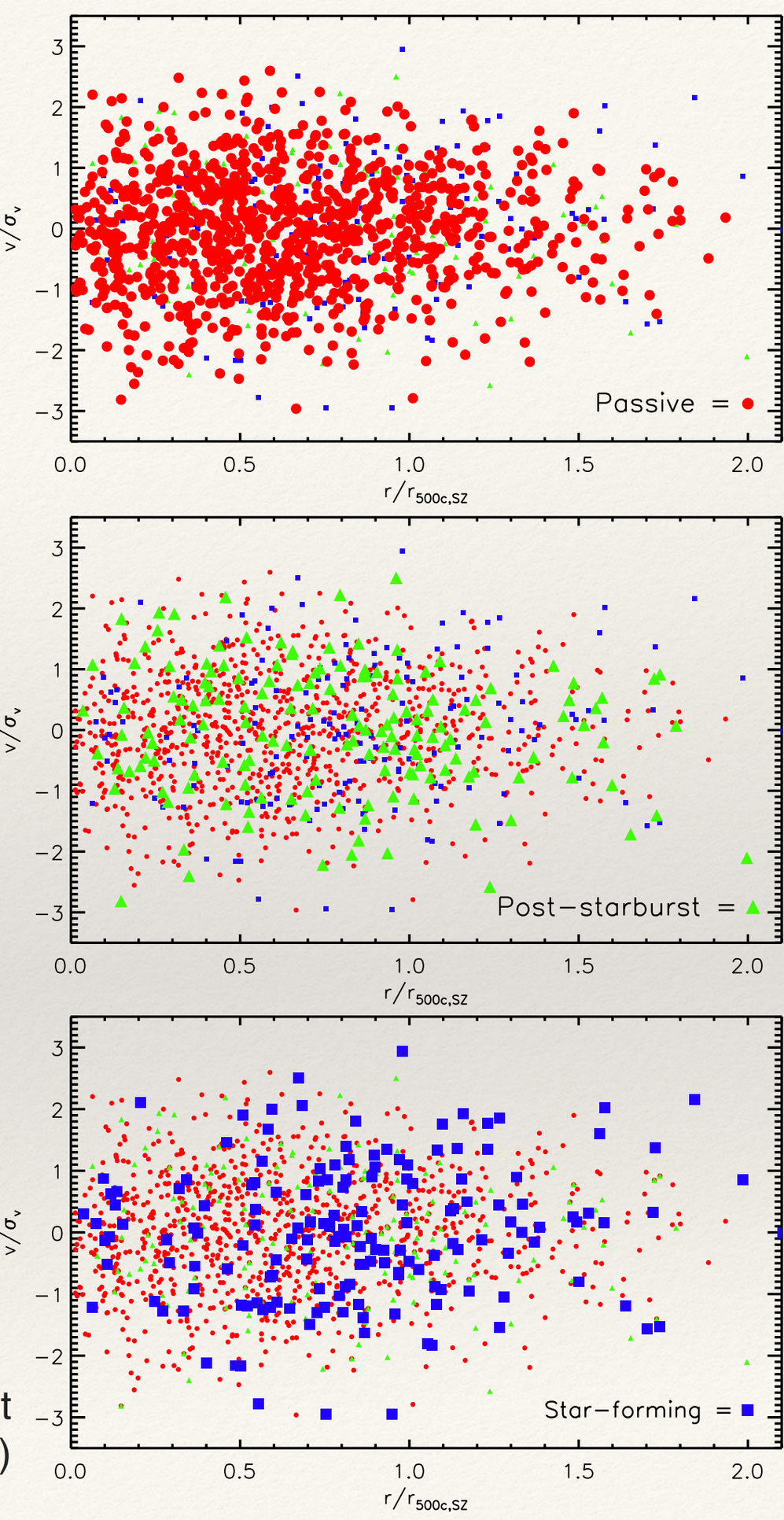






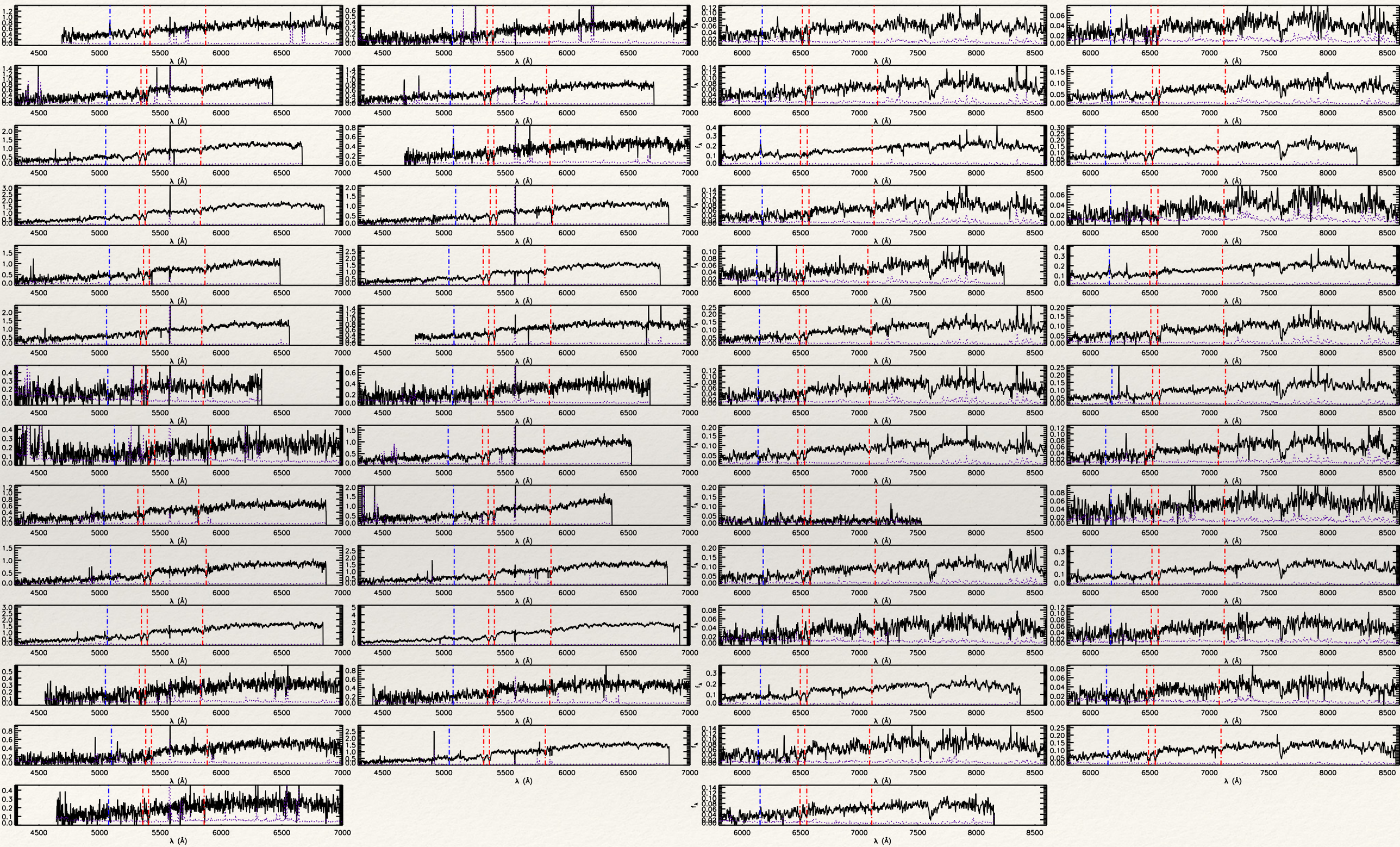
Nine giant arc redshifts measured from SPT-GMOS spectra, and redshift constraints (i.e. redshift desert limits) inferred for five more arcs.

Bayliss et al. (2016)



Bayliss et al. (2016)

One Spectrum ≠ One Datapoint; the Spectra Contain Information About the Individual Galaxies



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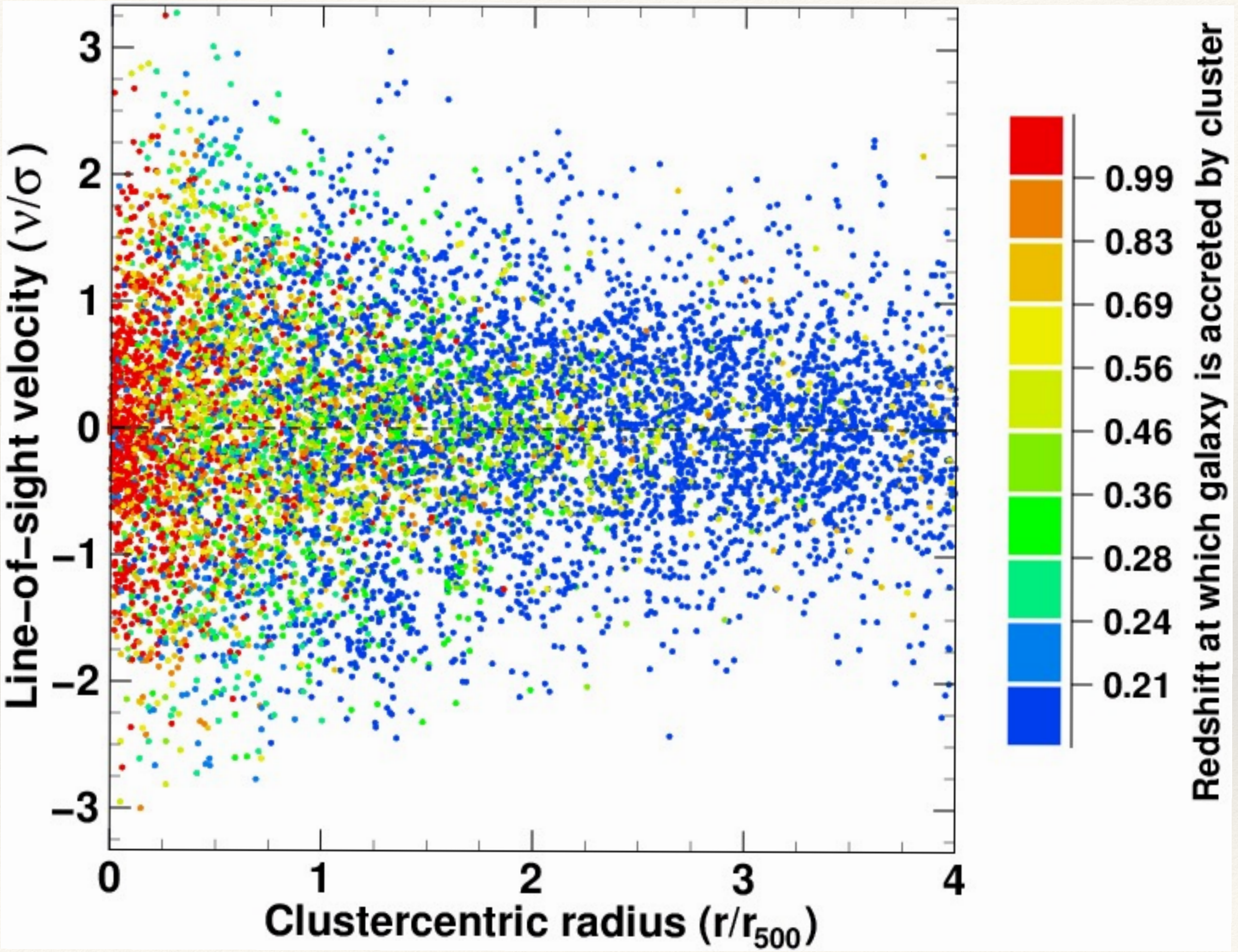
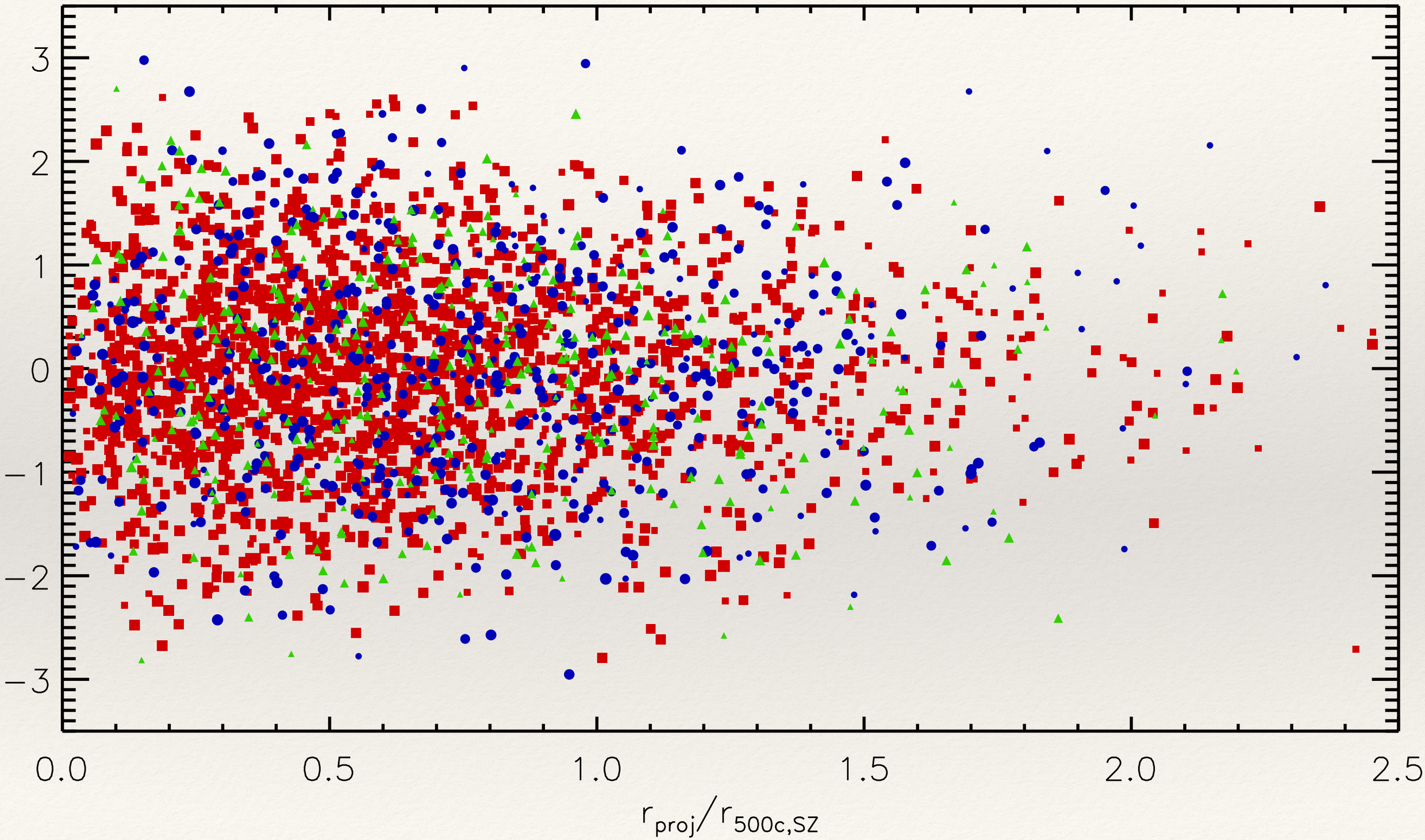


Haines et al. (2012) simulations [LoCuSS Collaboration]

Ensemble Analyses: Global Phase Space Properties of Cluster Members



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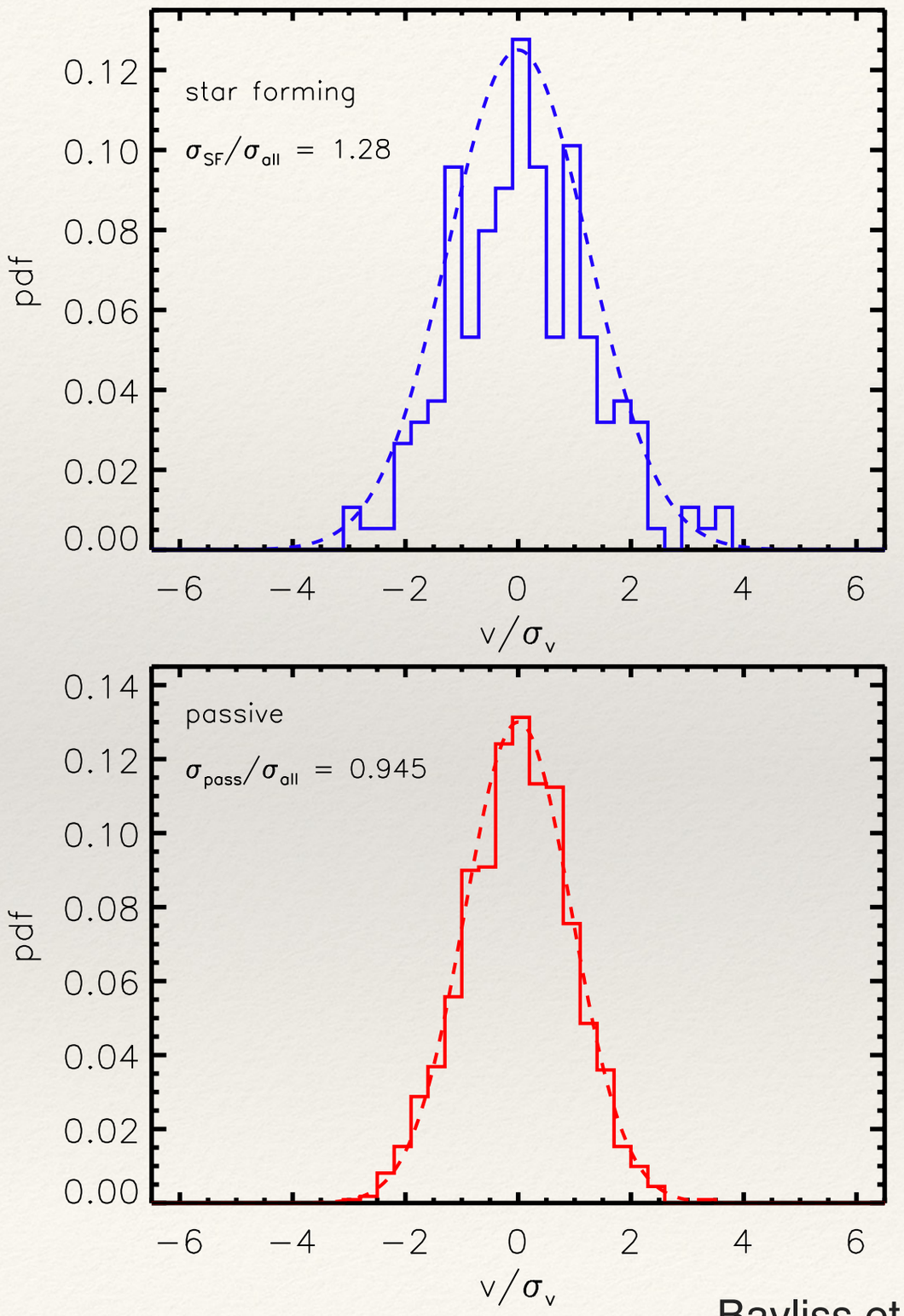
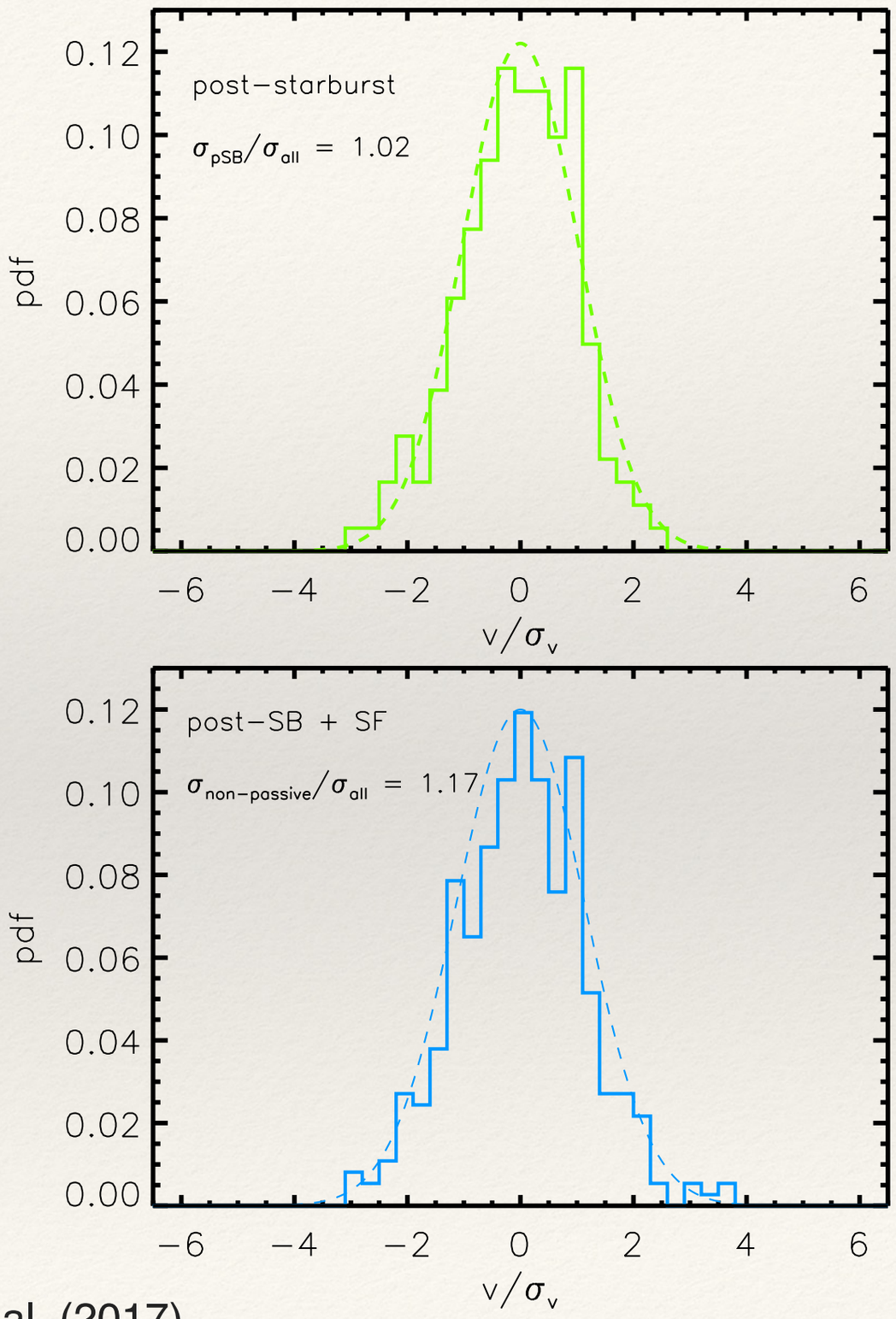
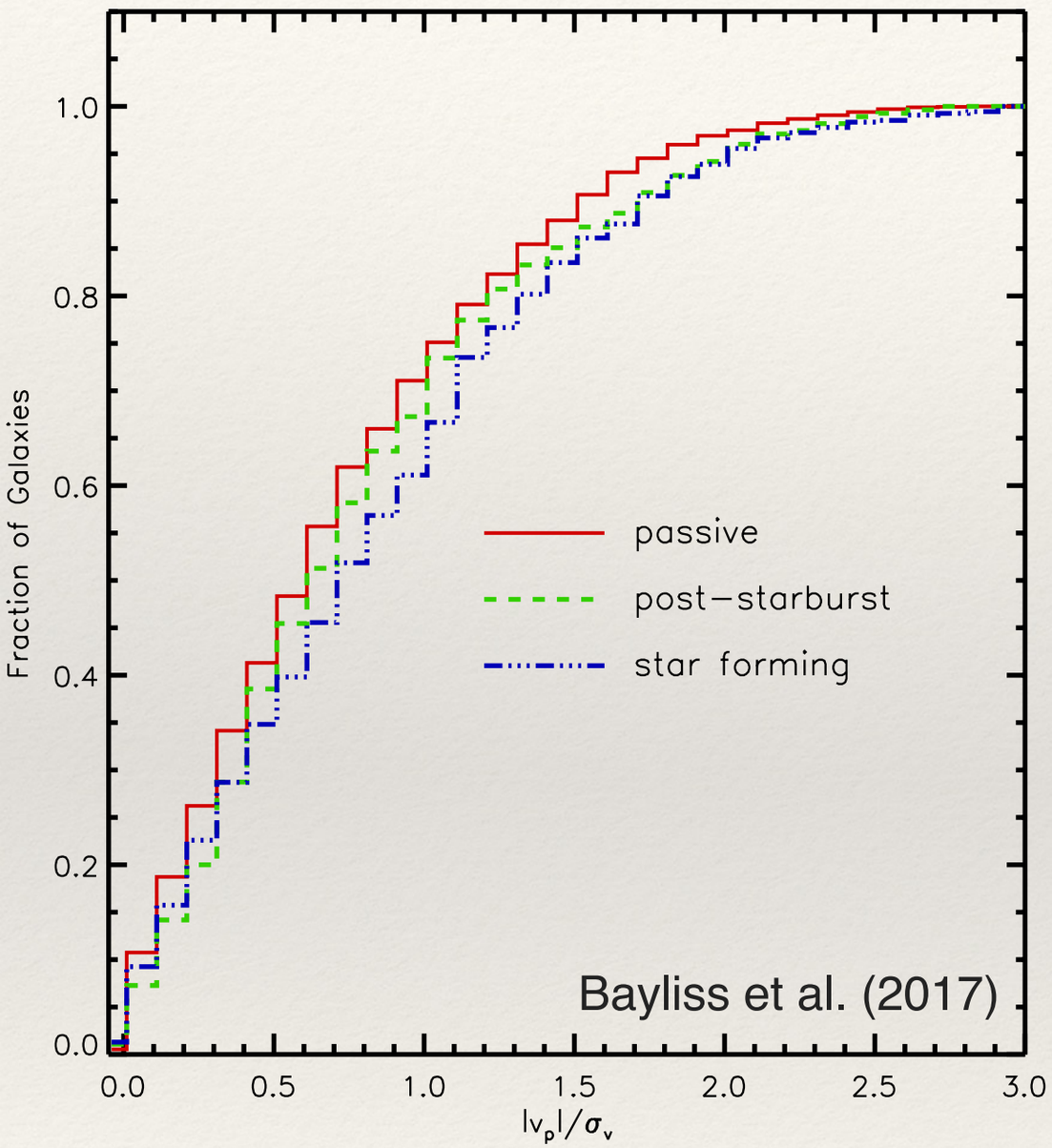
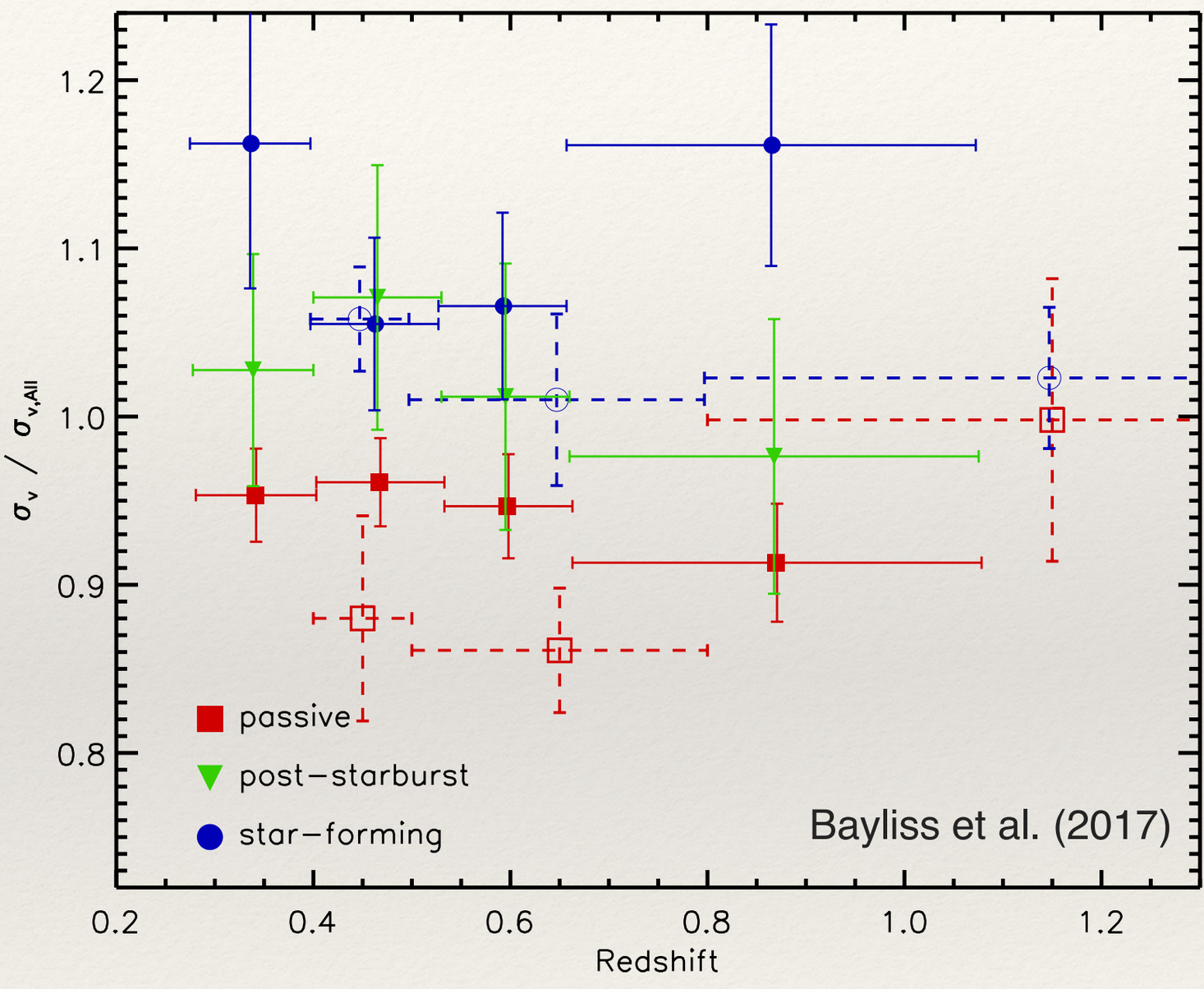




Bayliss et al. (2017)

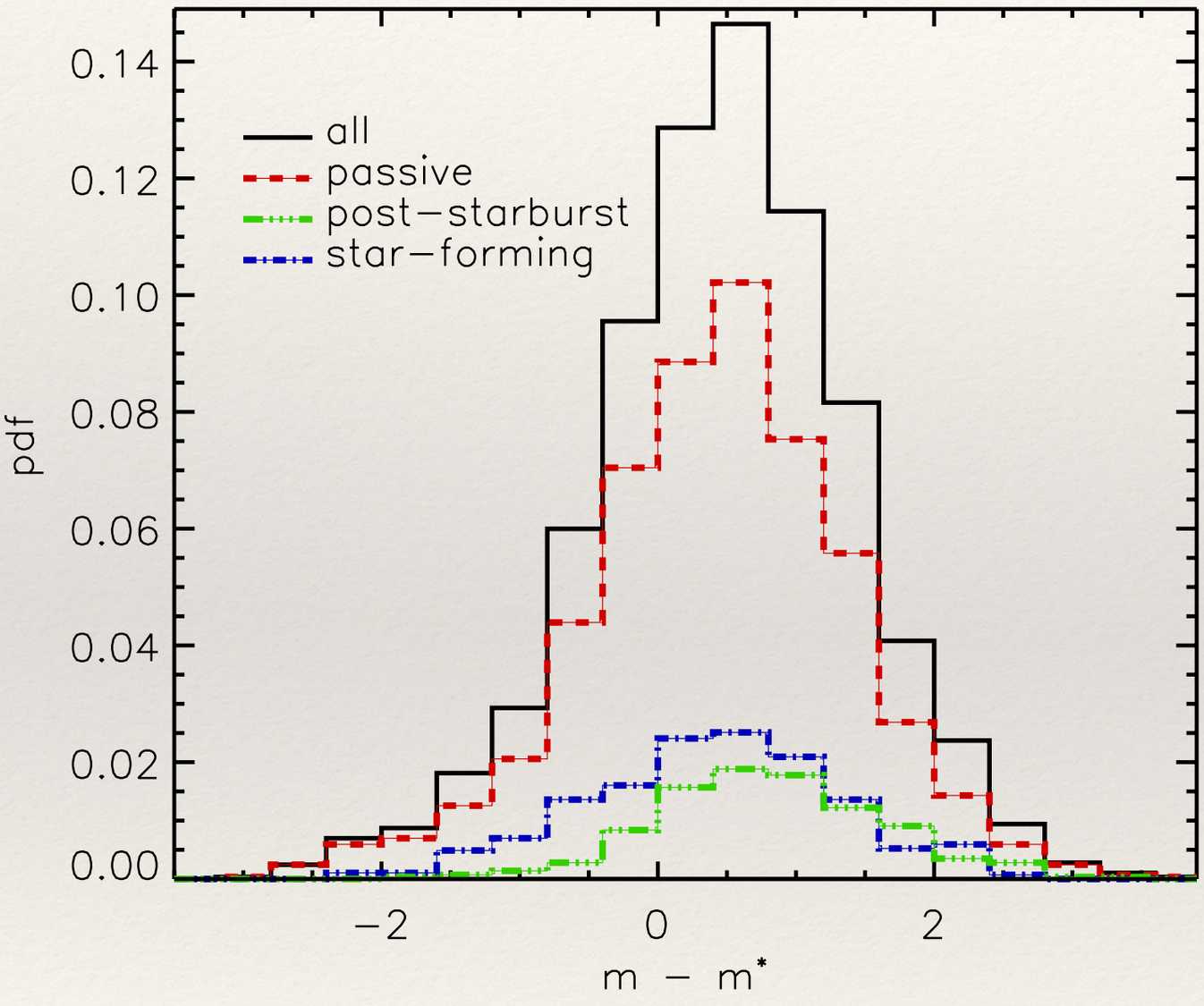
Different (Spectral) Types of Cluster Member Galaxies Have Different Velocity Distributions

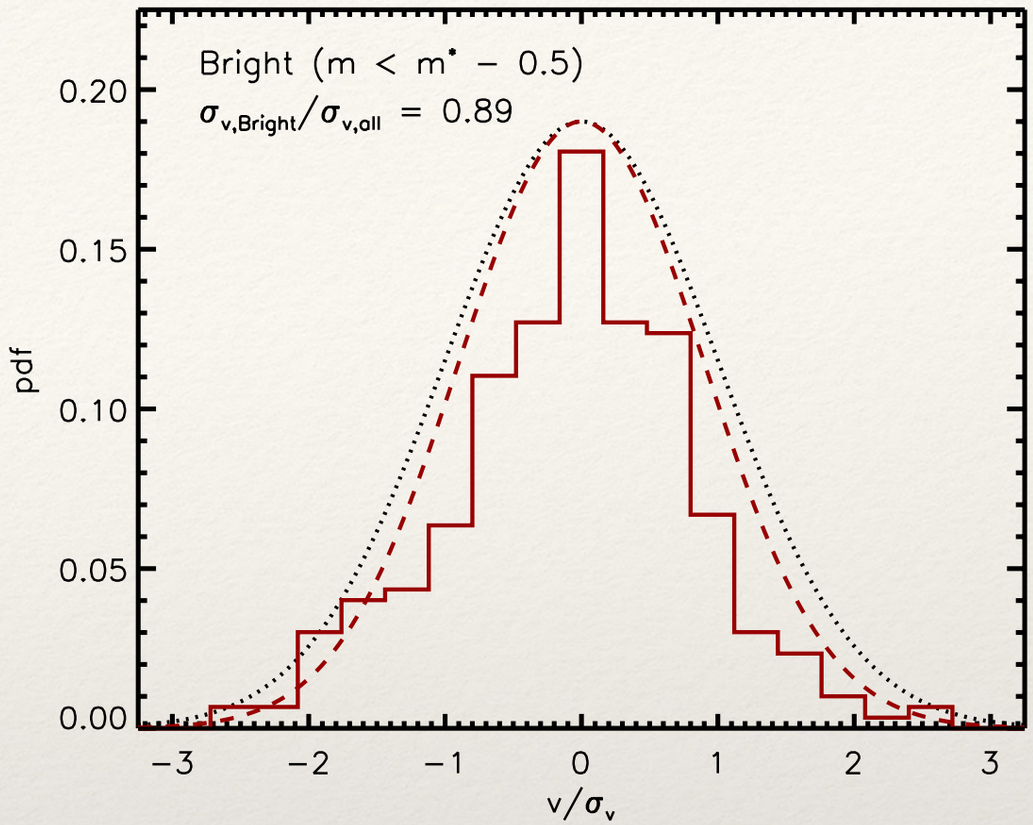


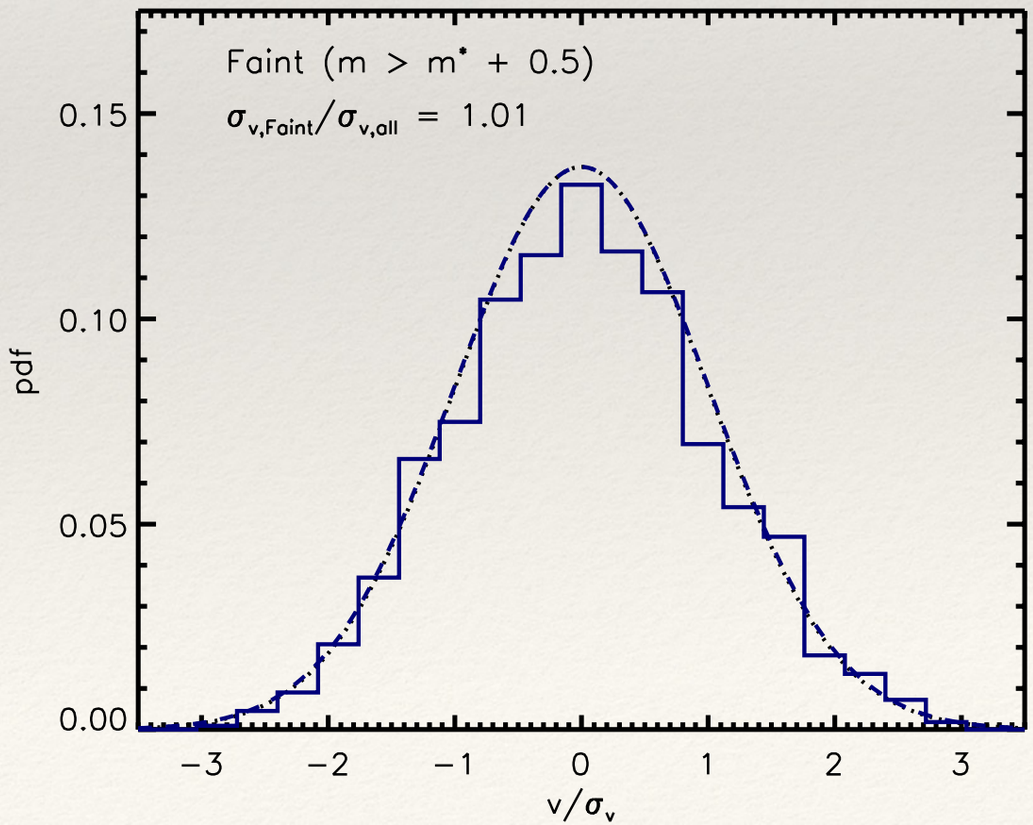


see also Barsanti et al. (2016)

Velocity Segregation With Galaxy Luminosity







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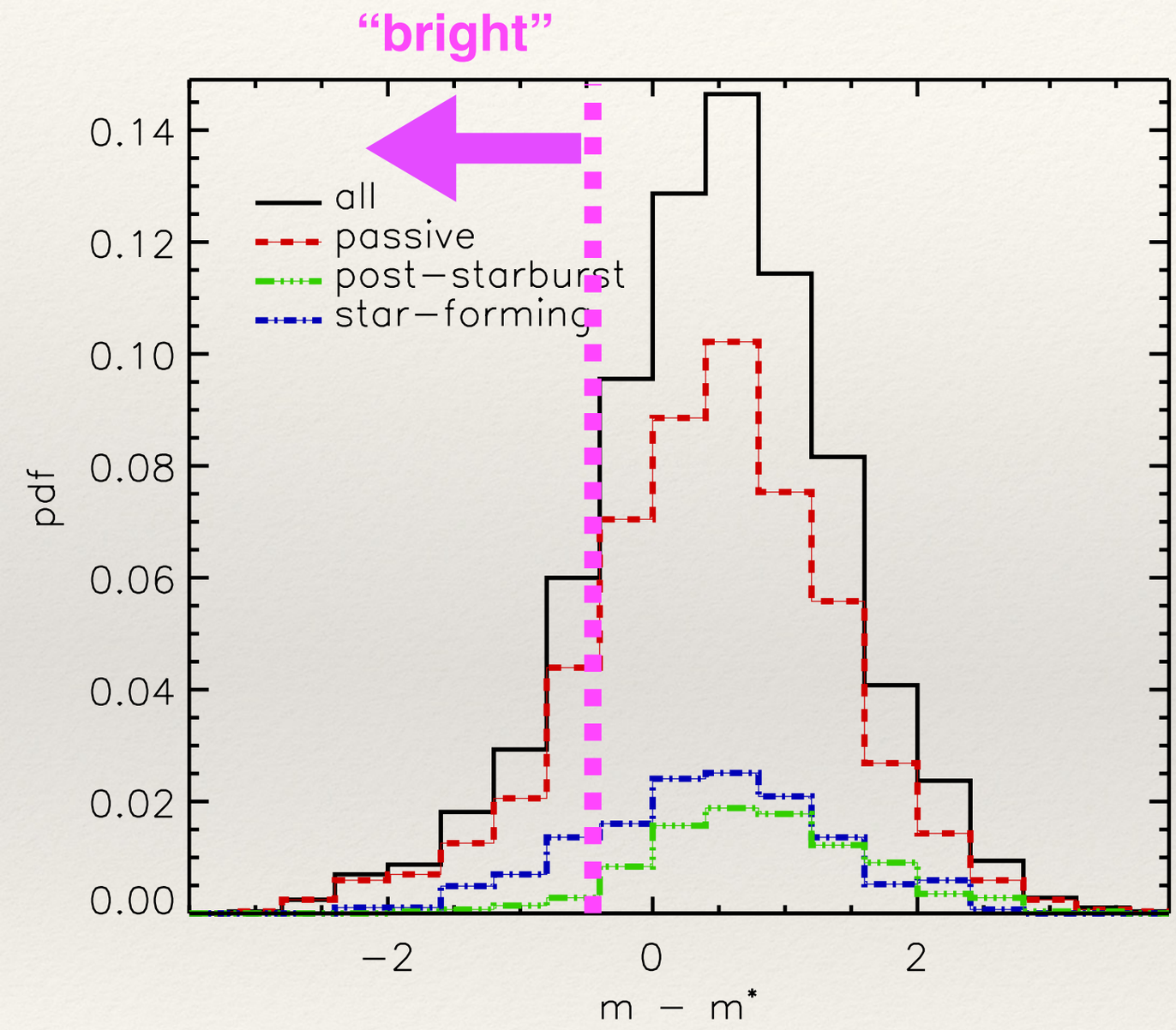

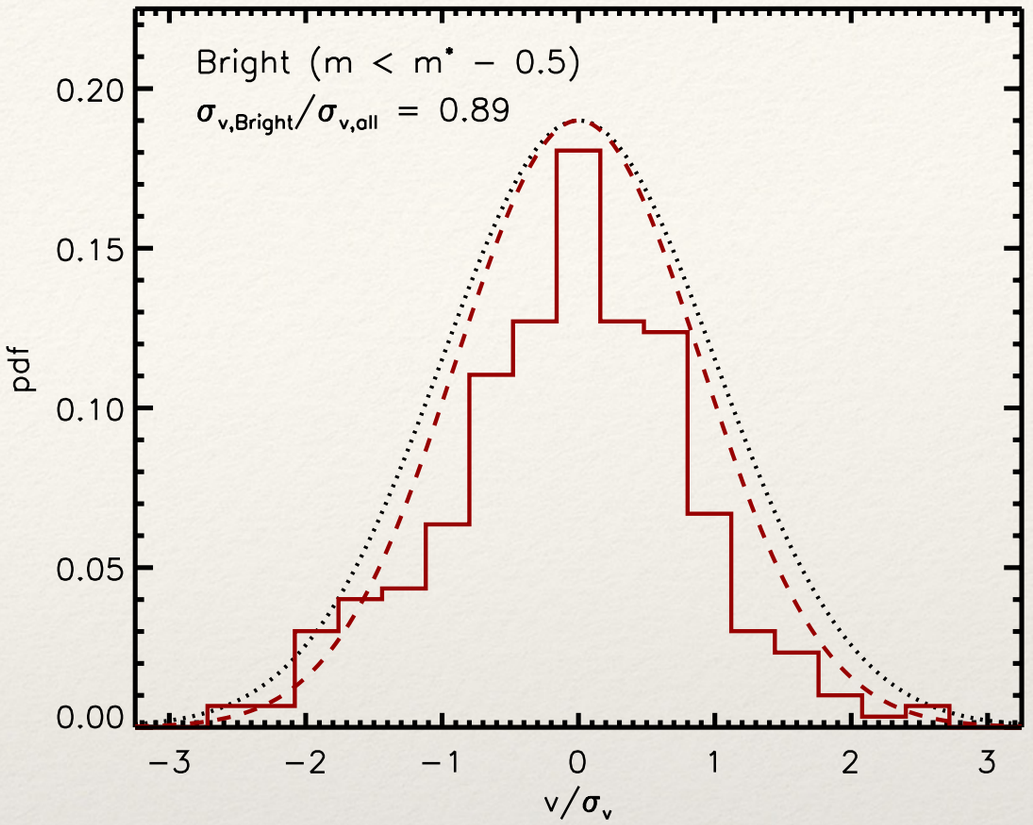

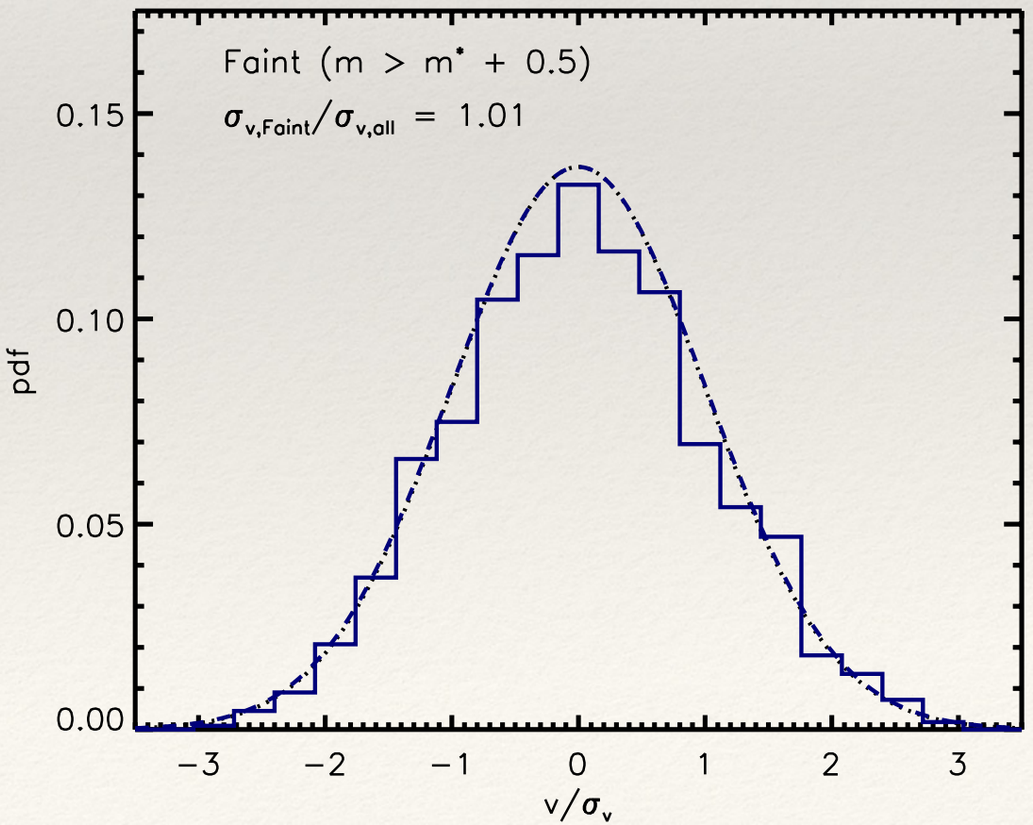

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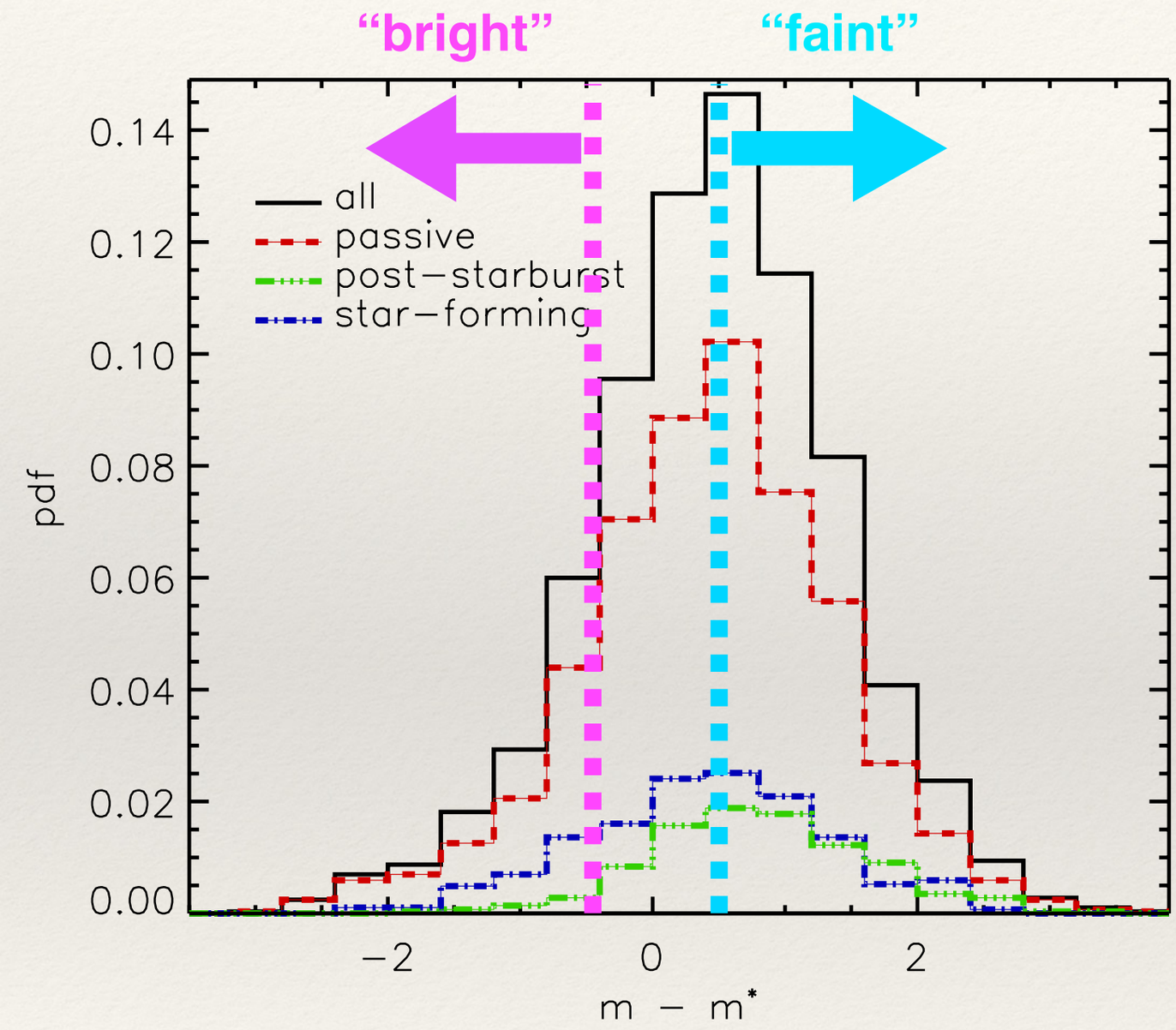

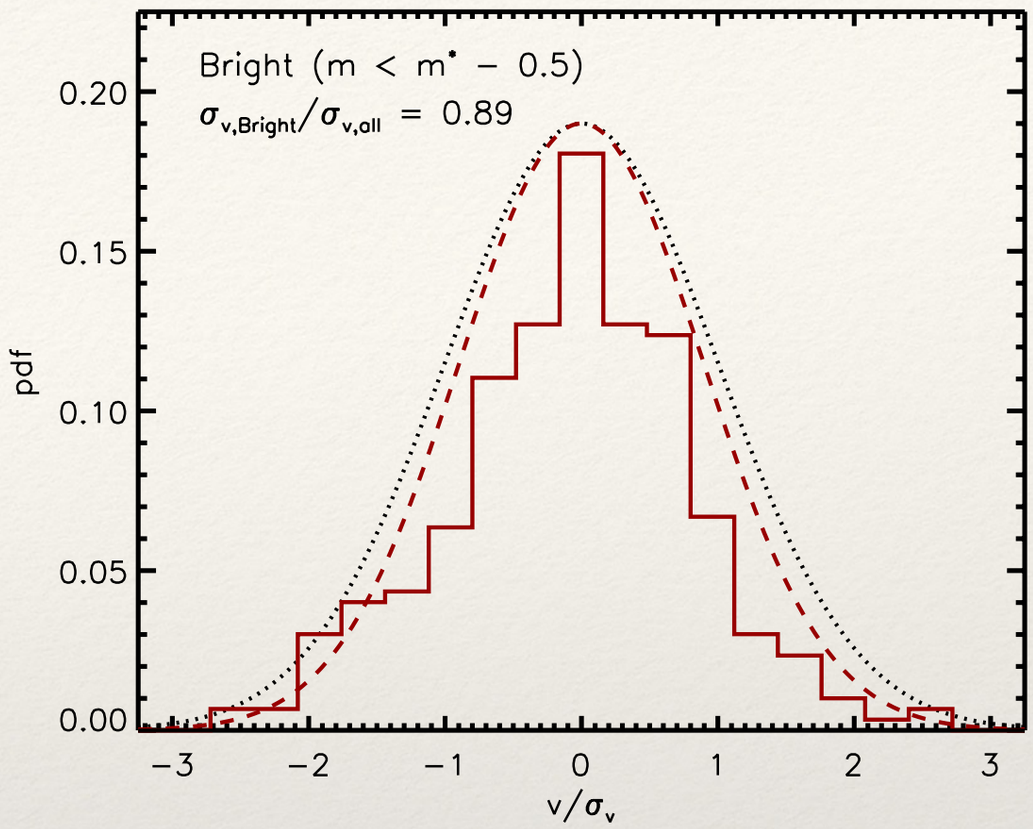

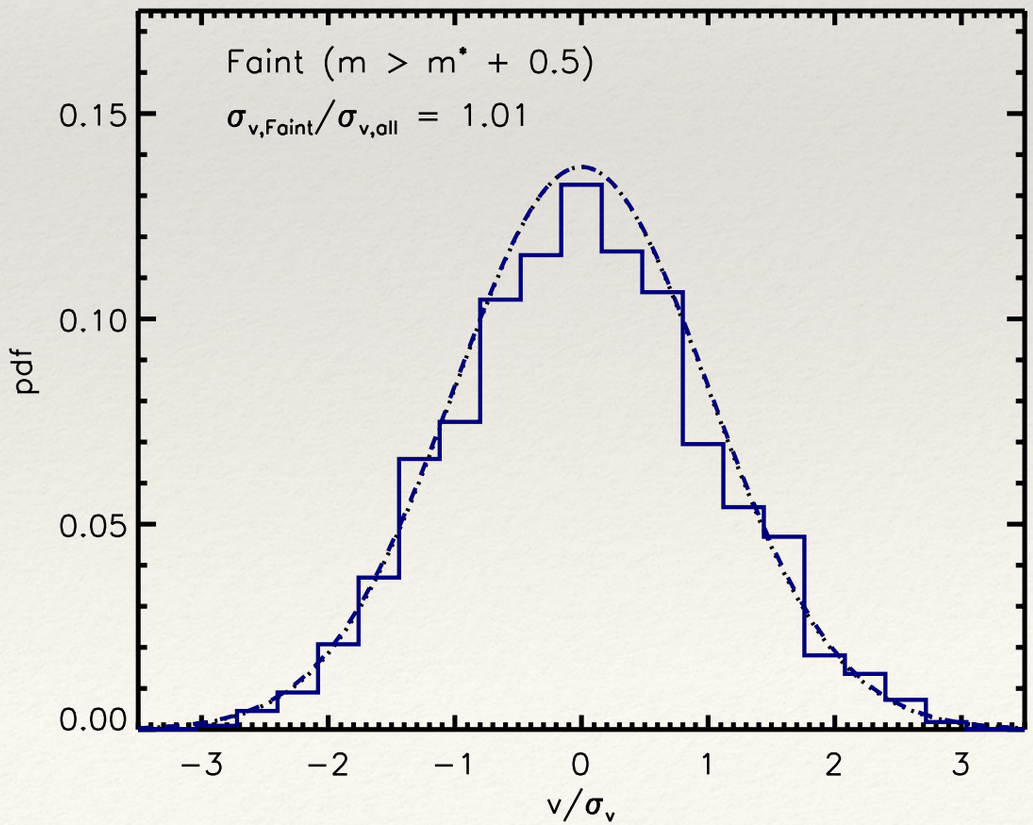

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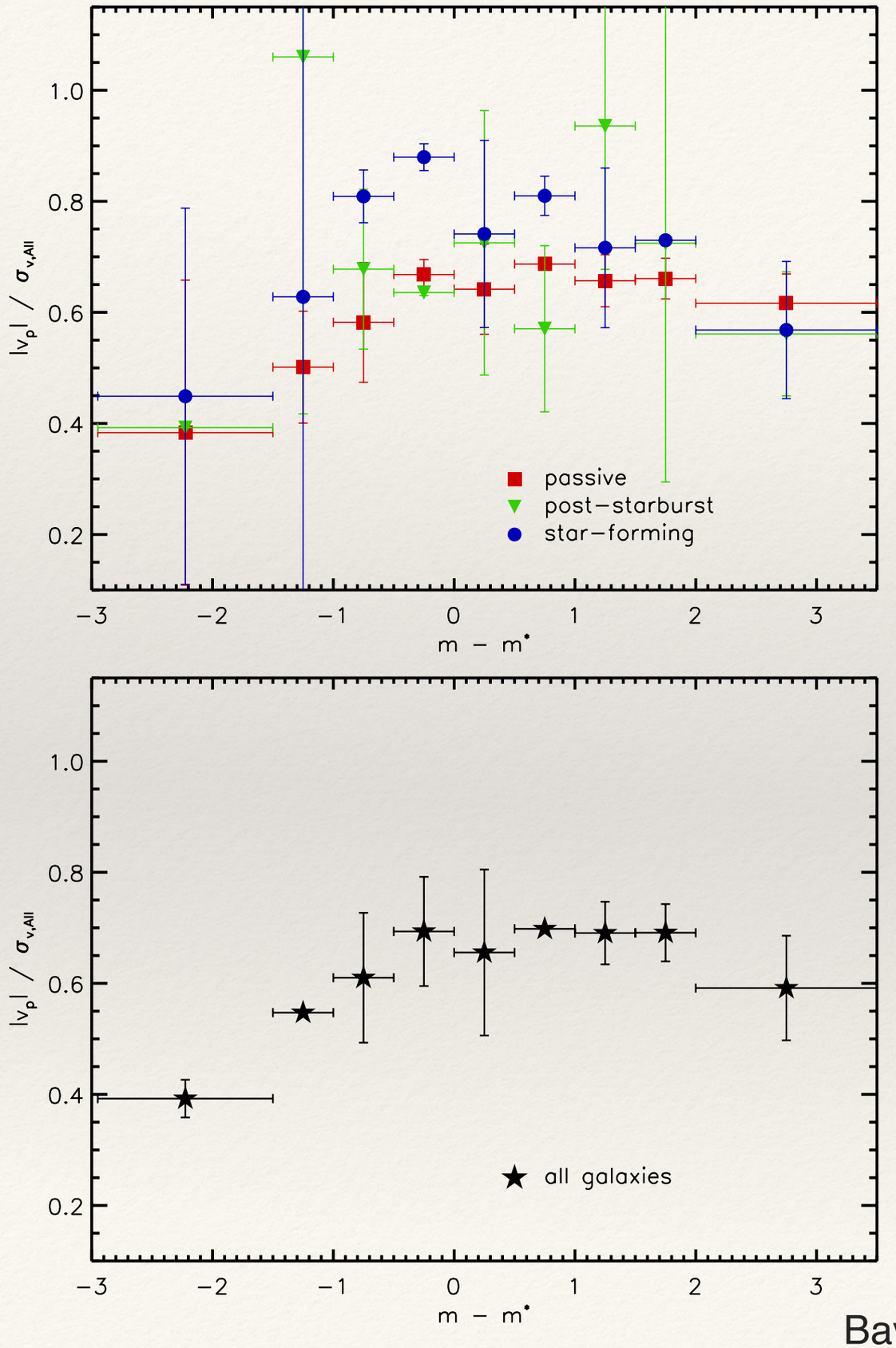

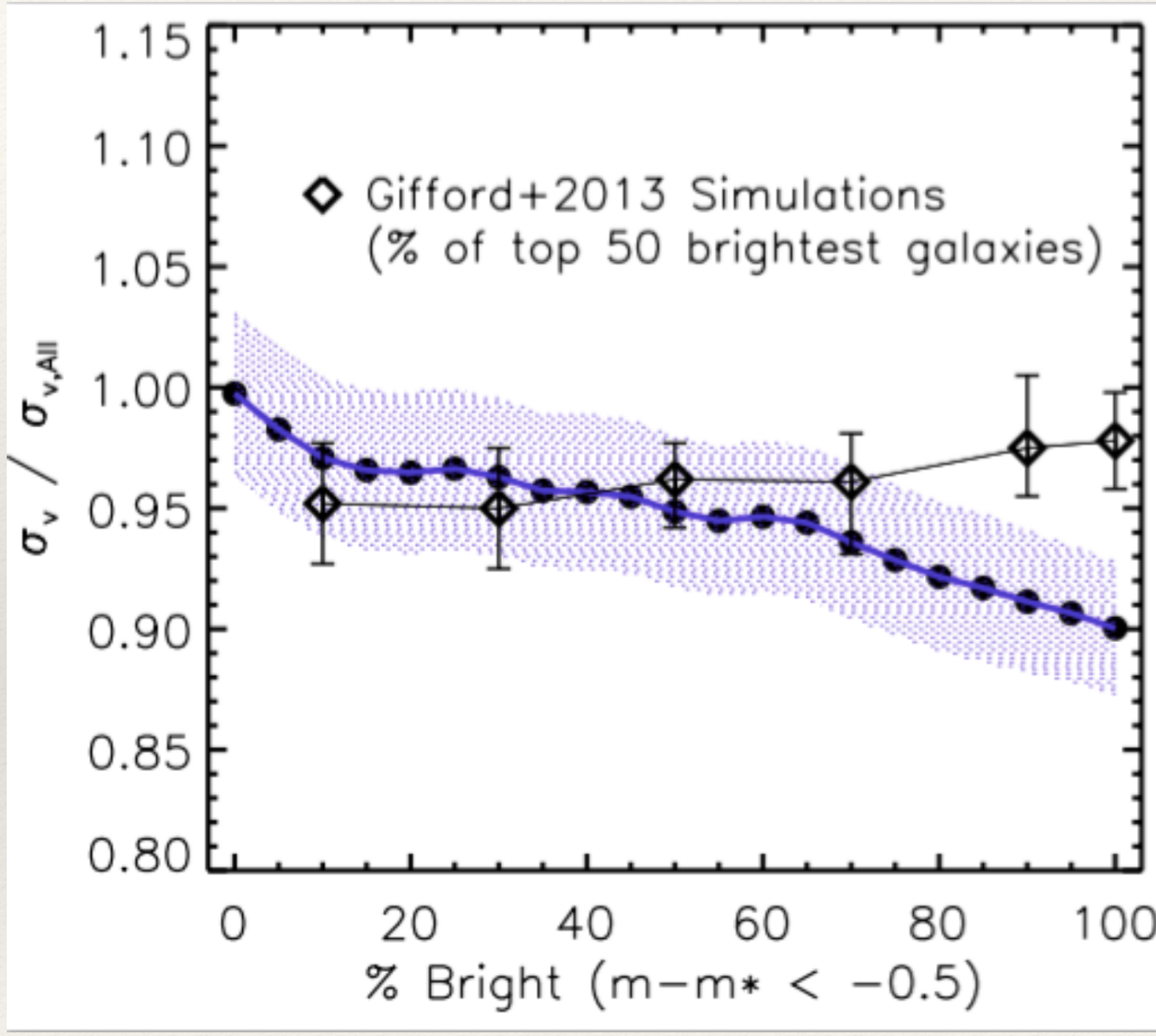

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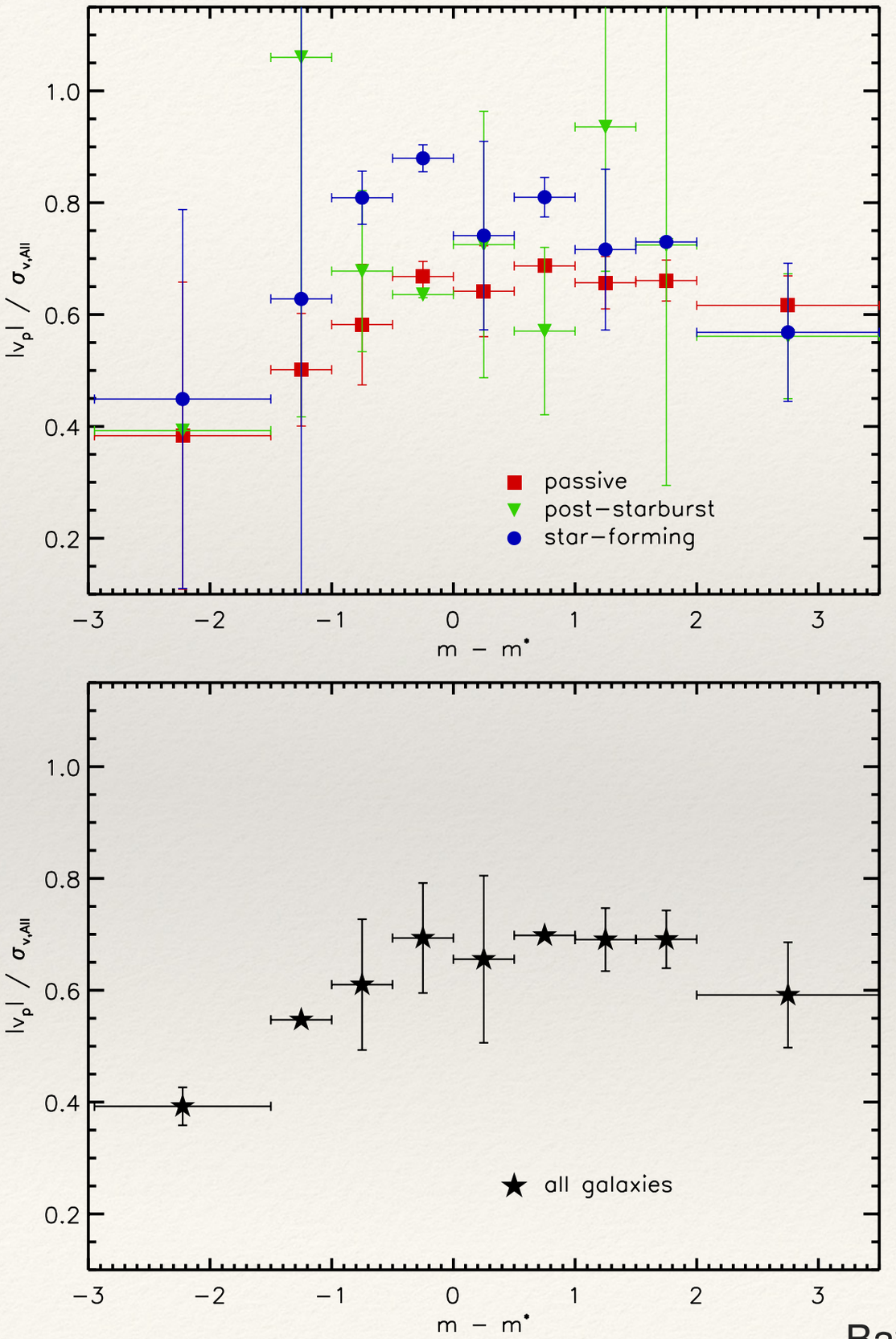
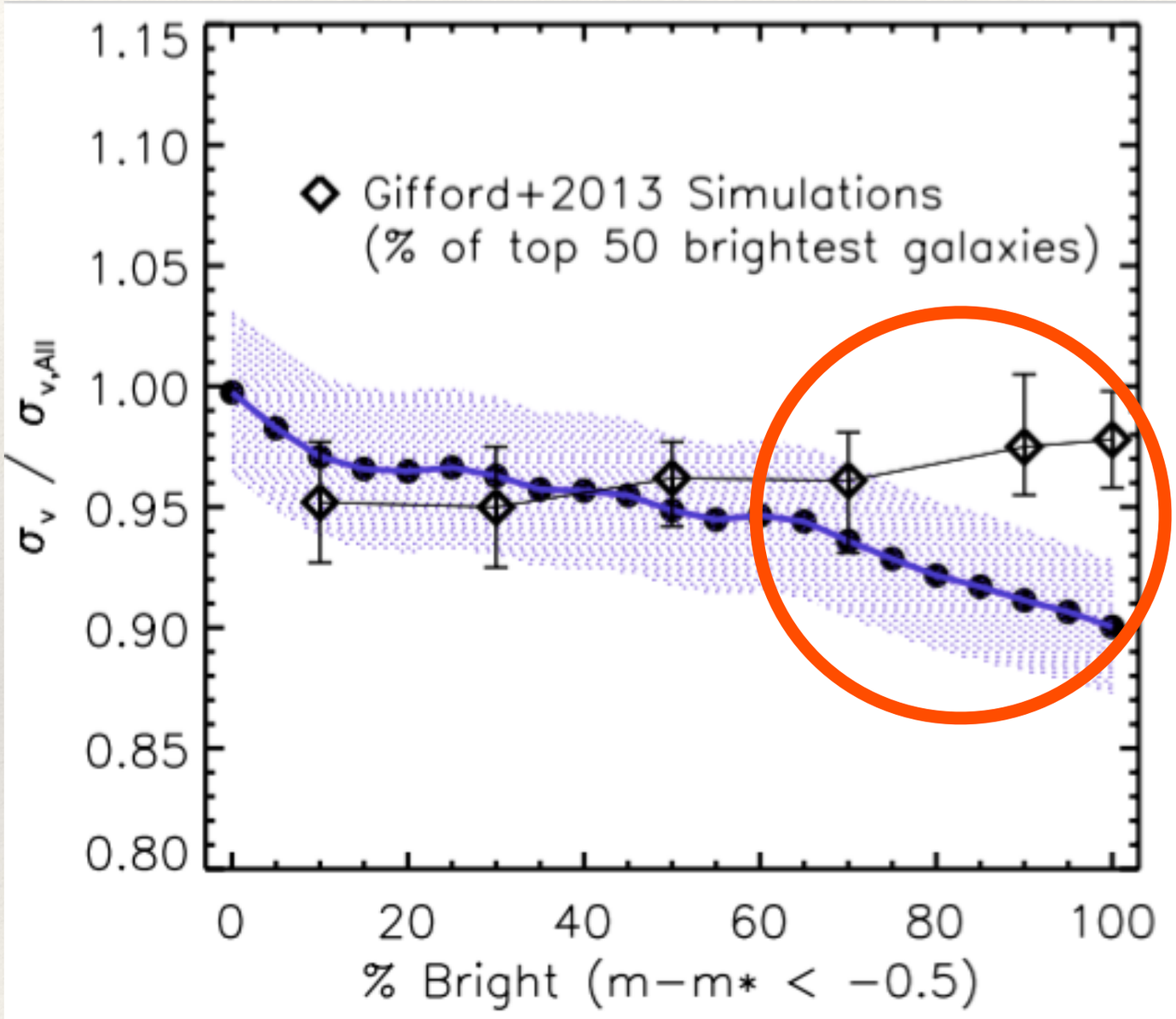
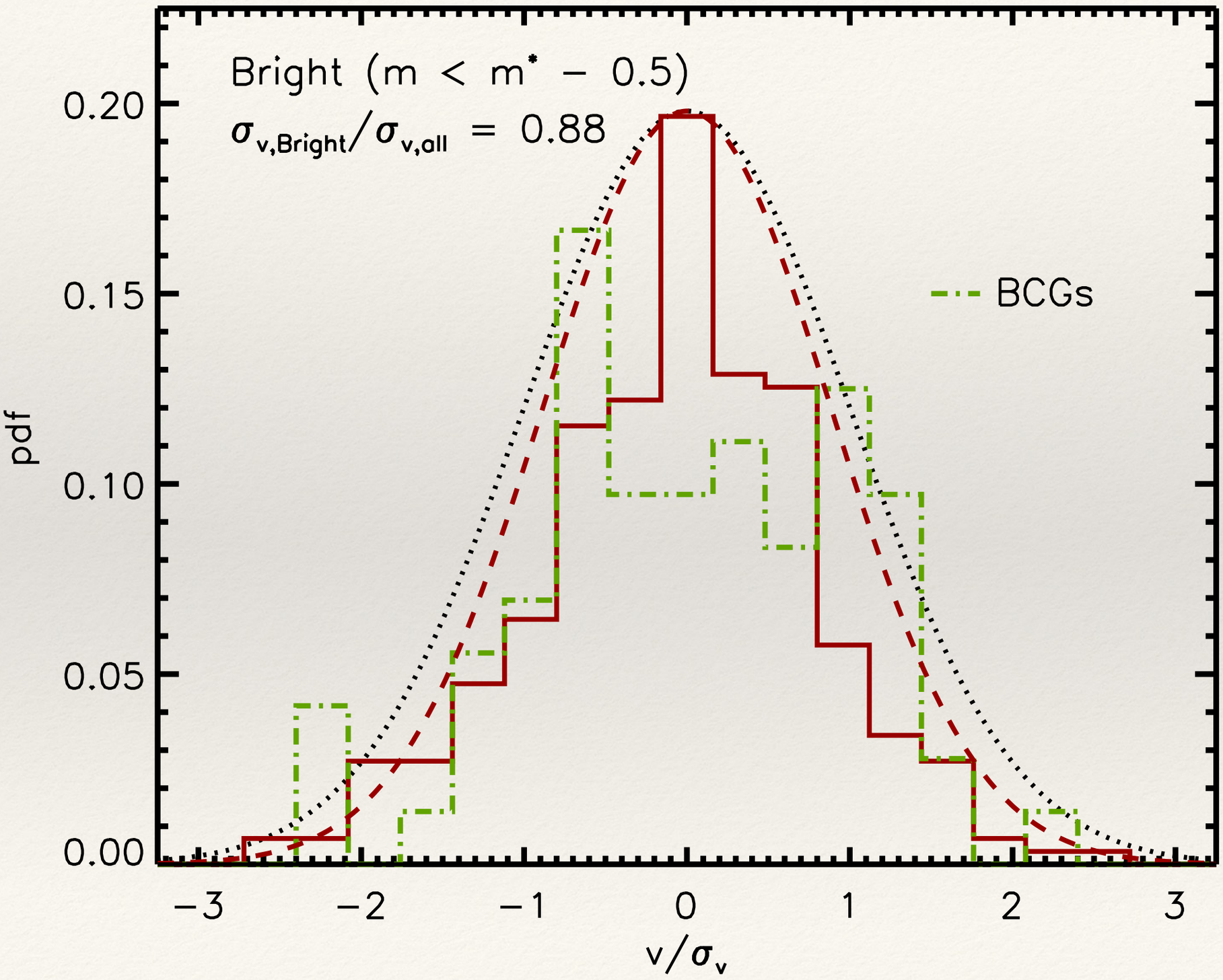
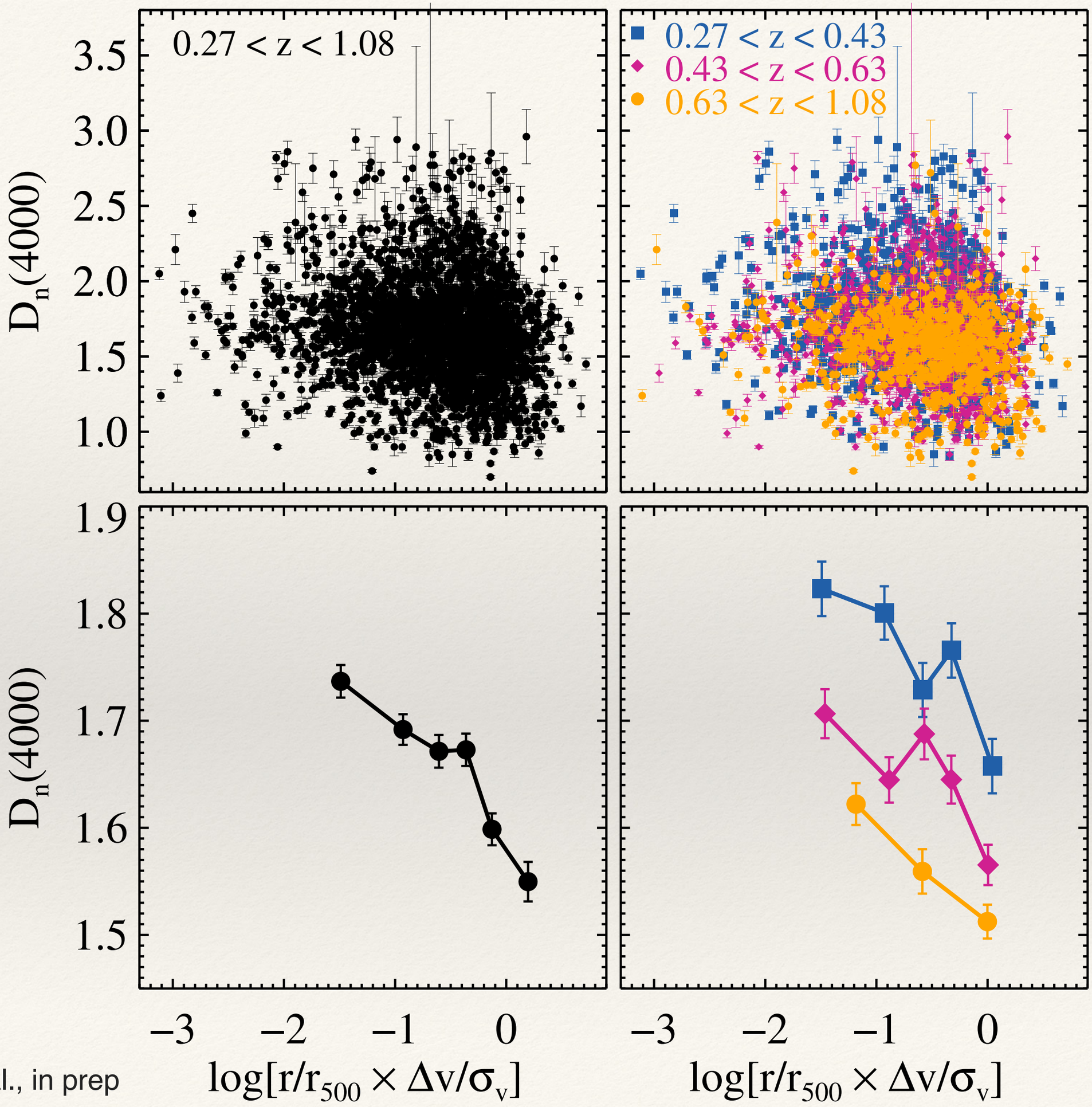




Bayliss et al. (2017)

Other Results/Tangents — Some Other Potentially Interesting Projects





Noble et al., in prep

Summary So Far

- We have a lot of spectroscopy, which gives us velocity dispersion measurements for a substantial fraction (~20-25%) of the SPT-SZ cluster sample.

- The value of a large spectroscopic dataset like this is magnified by the overlap with other multi-wavelength (SZ, X-ray, WL, HST). There is plenty of science to do (and the data are public, so consider this an invitation to go do it).

- The spectra include additional information about the individual galaxies (i.e., their spectral types), so we can examine the properties of cluster members of different types.

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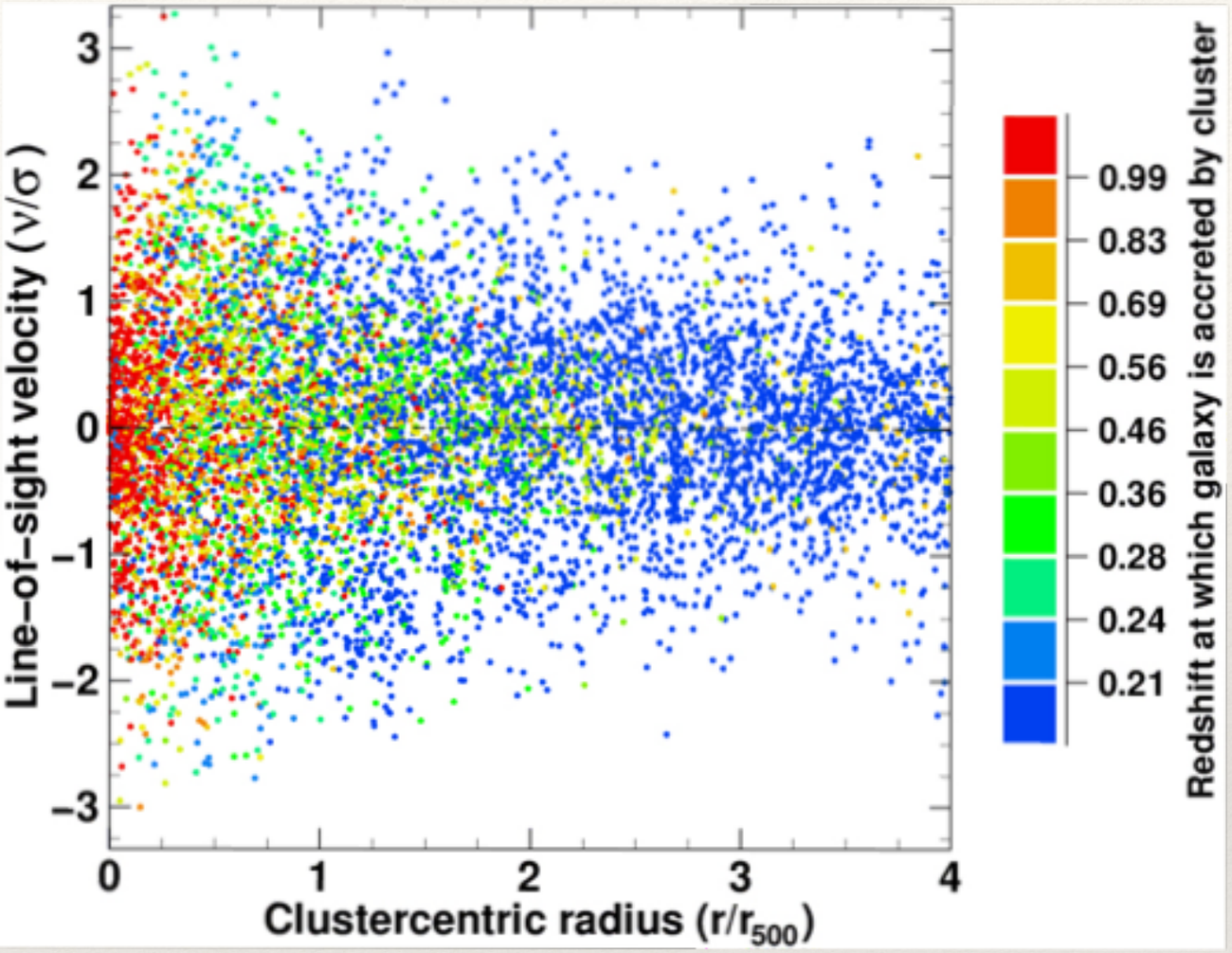
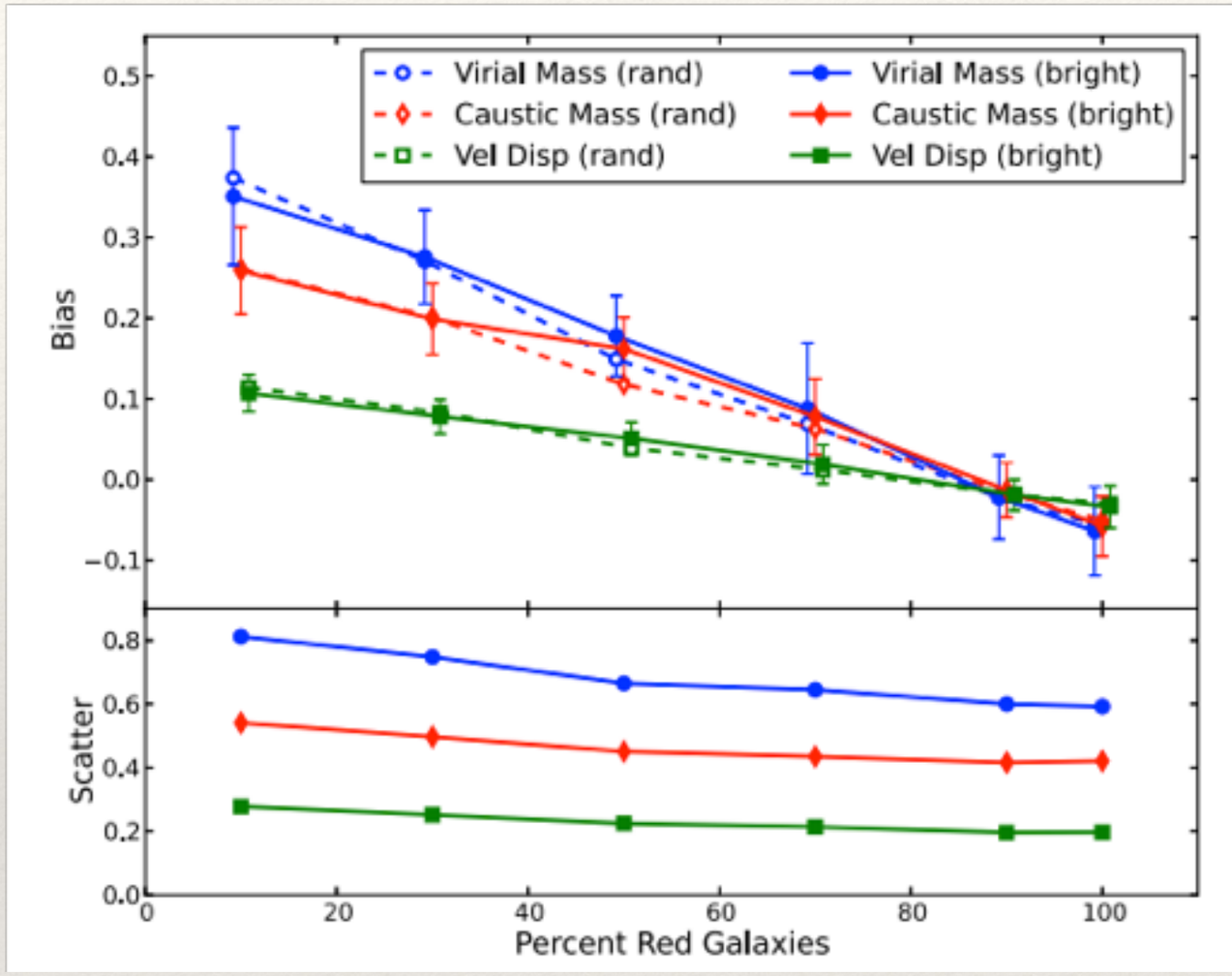
Comparing Phase Space Properties of Different Types of Cluster Member Galaxies: Data and Sims



Haines et al. (2012) simulations [LoCuSS Collaboration]



Gifford, Miller & Kern (2013) simulations

The phase space properties of cluster member galaxies vary systematically as a function of galaxy type, reflecting the formation history of massive clusters.

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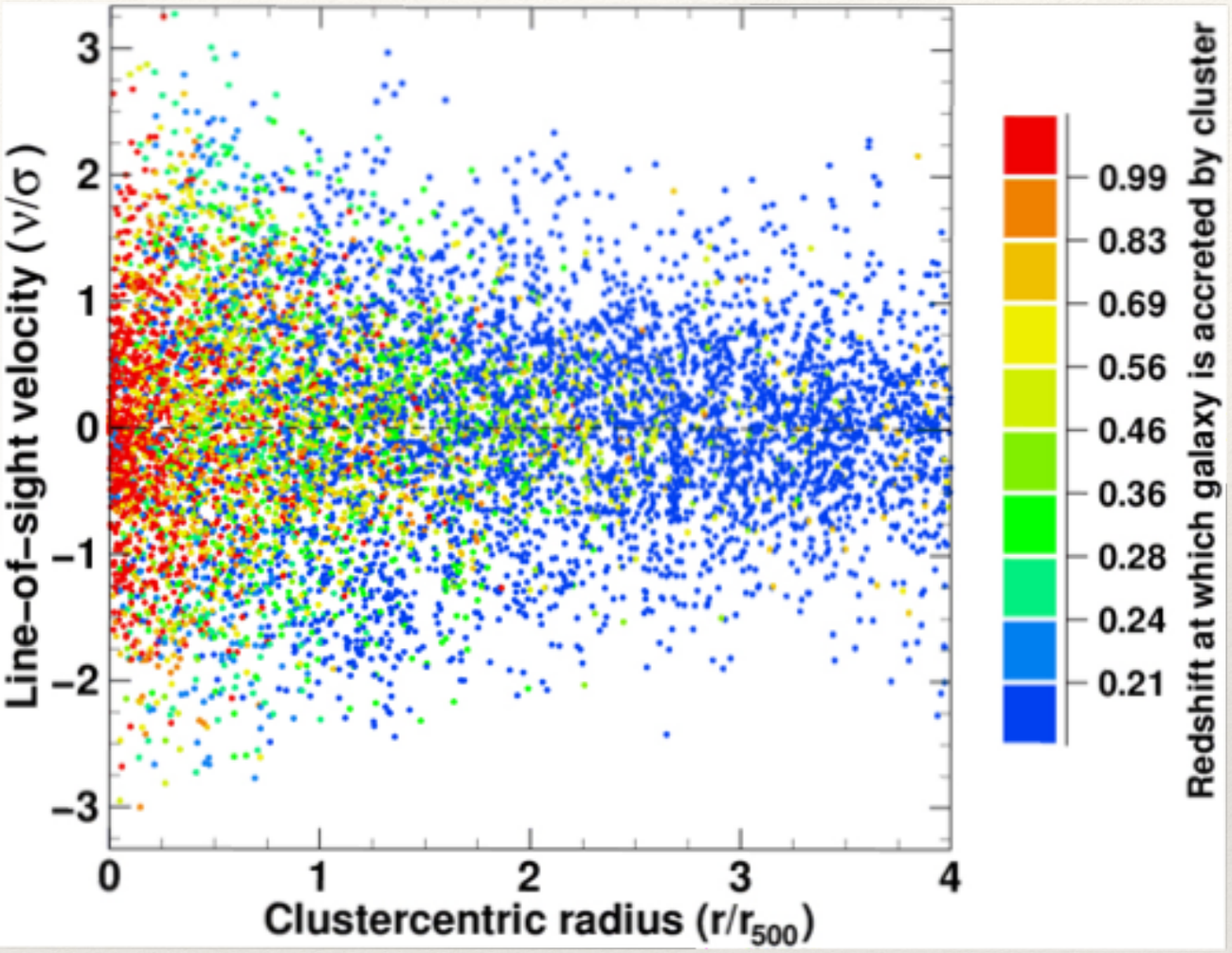

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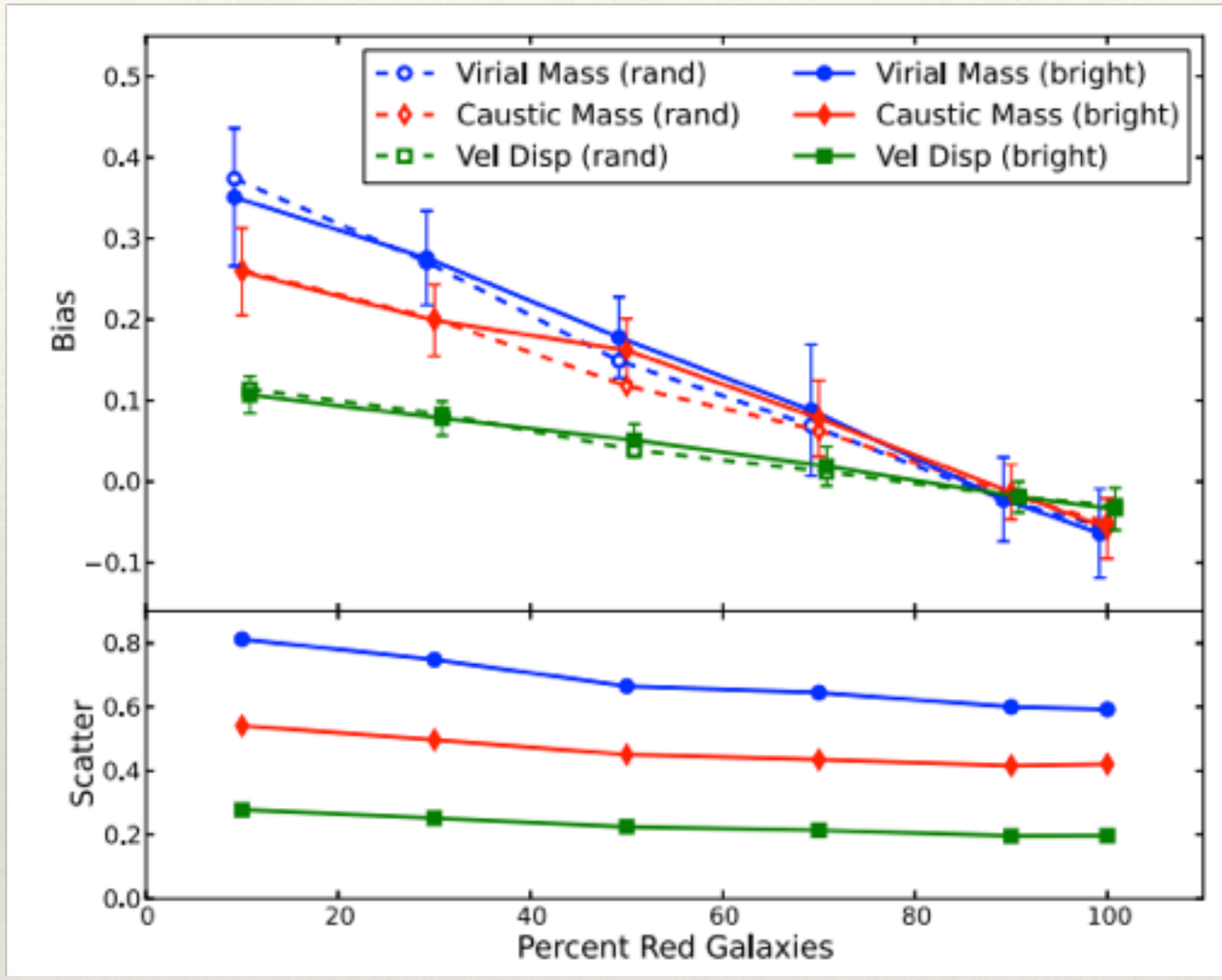


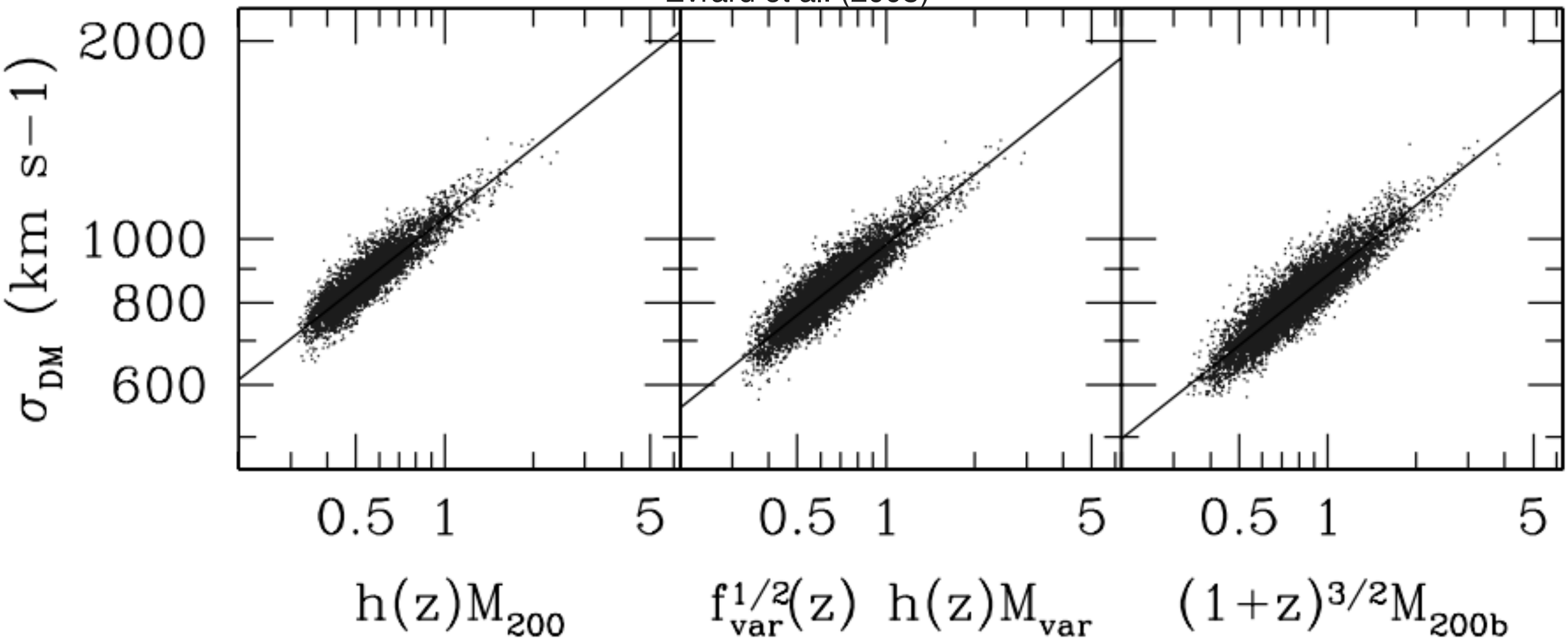
Gifford, Miller & Kern (2013) simulations

The phase space properties of cluster member galaxies vary systematically as a function of galaxy type, reflecting the formation history of massive clusters.

Can we use this information to approach the issue of calibrating velocity dispersion-mass relations from a new angle?

Calibrating Velocity Dispersion Measurements Between Data and Sims

Evrard et al. (2008)



$$\sigma_{\rm DM}(M,z) = \sigma_{\rm DM,15}\left[\frac{h(z)M_{200}}{10^{15}\ M_\odot}\right]^{\alpha}$$

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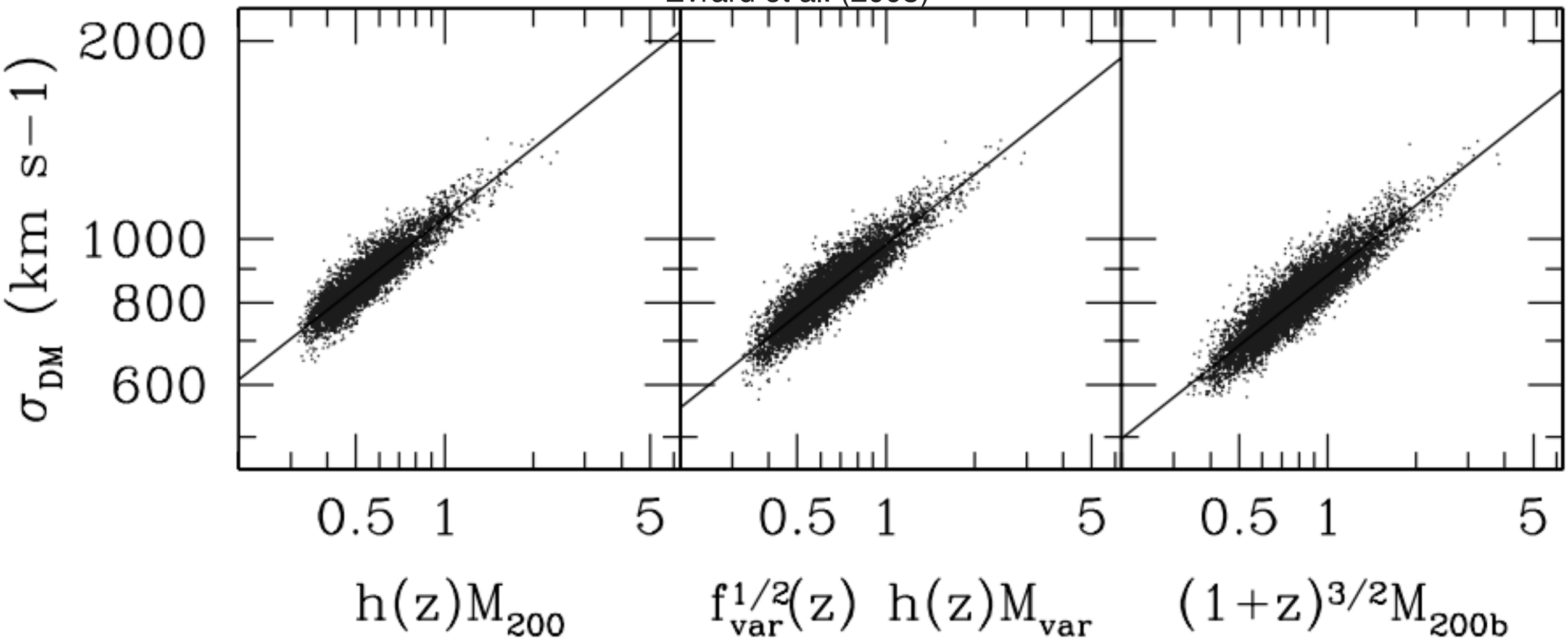

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0.3361 +/- 0.0026

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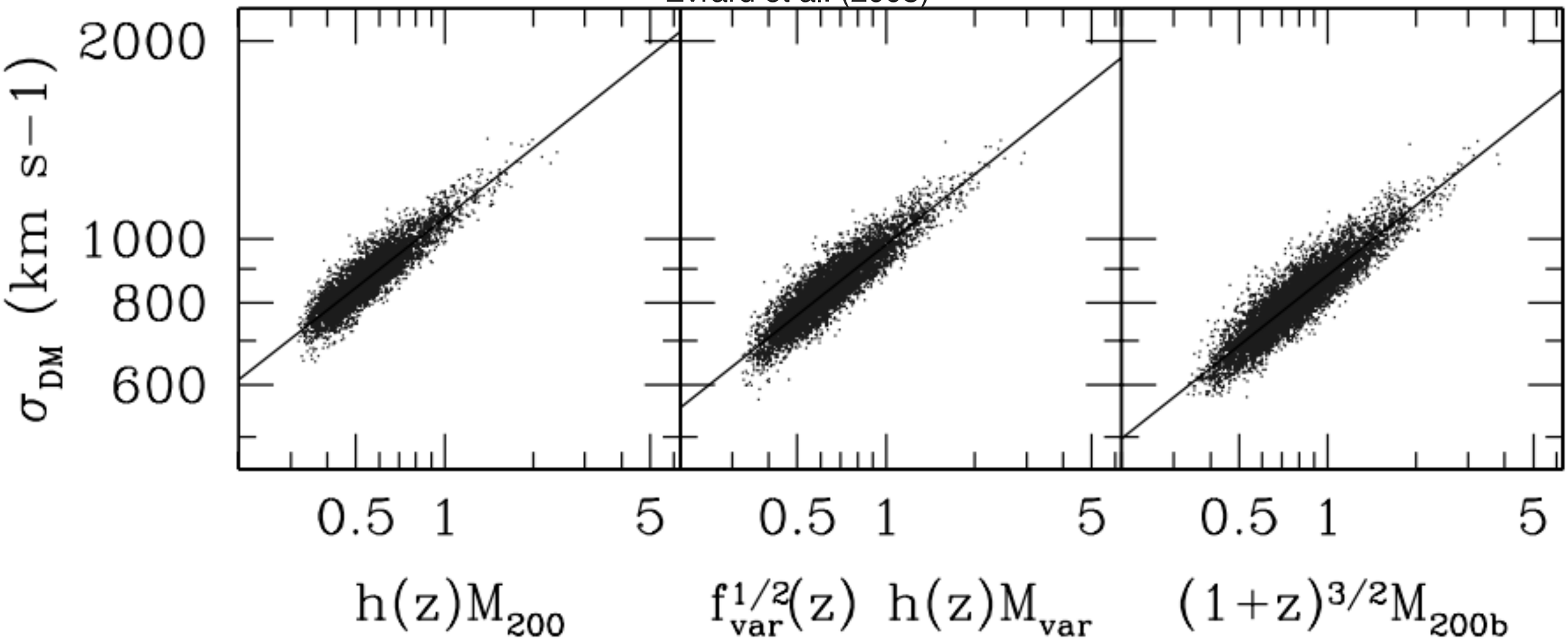

We never measure this.

$$\sigma_{\rm DM}(M,z) = \sigma_{\rm DM,15}\left[\frac{h(z)M_{200}}{10^{15}\ M_\odot}\right]^{\alpha}$$

0.3361 +/- 0.0026

Calibrating Velocity Dispersion Measurements Between Data and Sims

$$b_v = \frac{\sigma_{gal}}{\sigma_{DM}}$$

The velocity bias, written in this way, has a long history in the literature, but as a practical matter it is difficult to measure in a meaningful way.

Calibrating Velocity Dispersion Measurements Between Data and Sims

$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}}$$

I prefer to think about the velocity bias written as above, where the “obs” makes it explicitly clear that all we really need to do is tie our observed line-of-sight galaxy distributions back to the “true” velocity dispersion of dark matter particles in halos.

Calibrating Velocity Dispersion Measurements Between Data and Sims

$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}}$$

$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}} = \frac{\sigma_{gal,obs}}{\sigma_{gal,sims}} \times \frac{\sigma_{gal,sims}}{\sigma_{DM}}$$

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You can measure this in a given simulation, but by itself this quantity is not very useful.

Calibrating Velocity Dispersion Measurements Between Data and Sims

$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}}$$

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The challenge is to measure this quantity, but it's hard to do, though it has been heroically attempted (e.g., Saro et al. 2013, Munari et al. 2013).

You can measure this in a given simulation, but by itself this quantity is not very useful.

Calibrating Velocity Dispersion Measurements Between Data and Sims

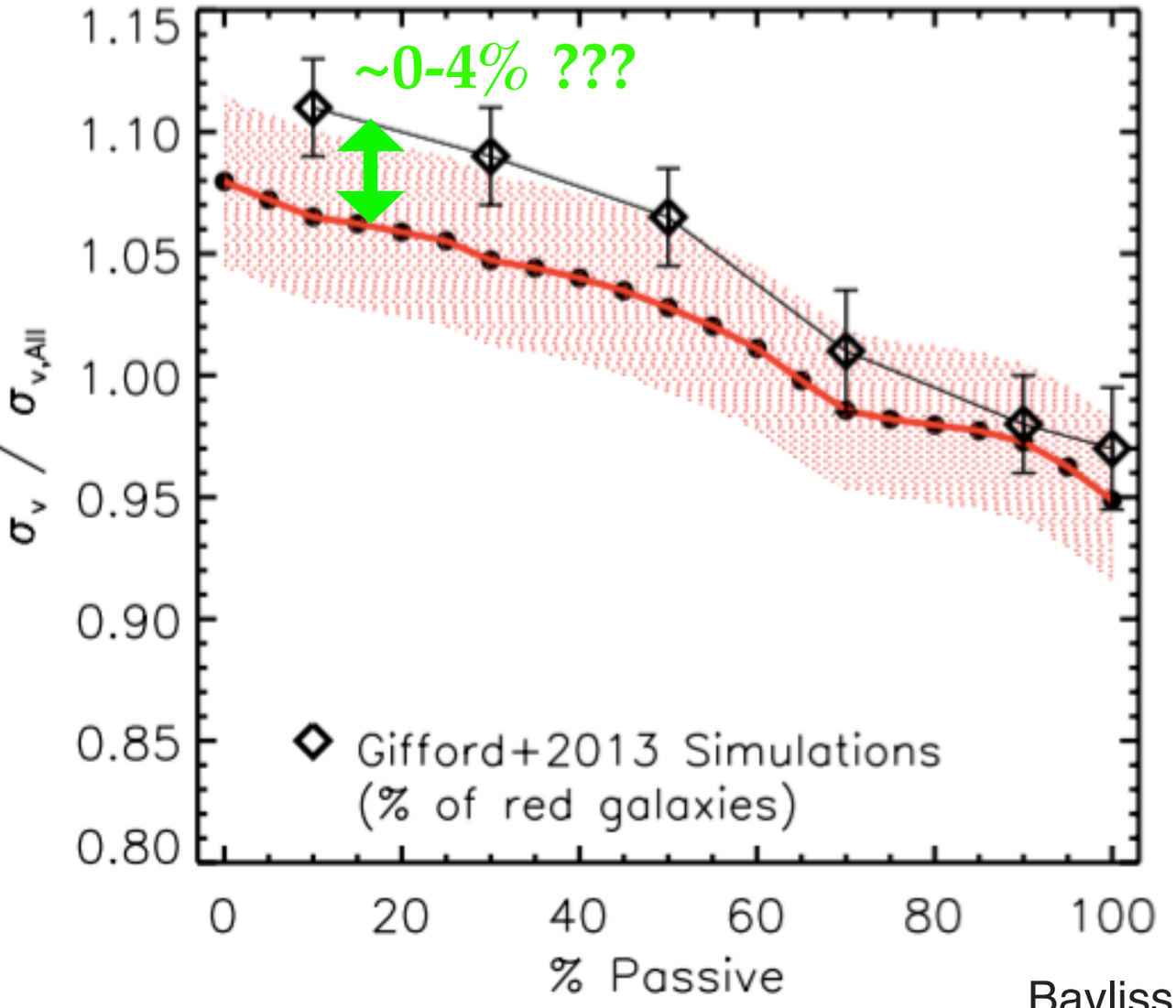
$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}}$$

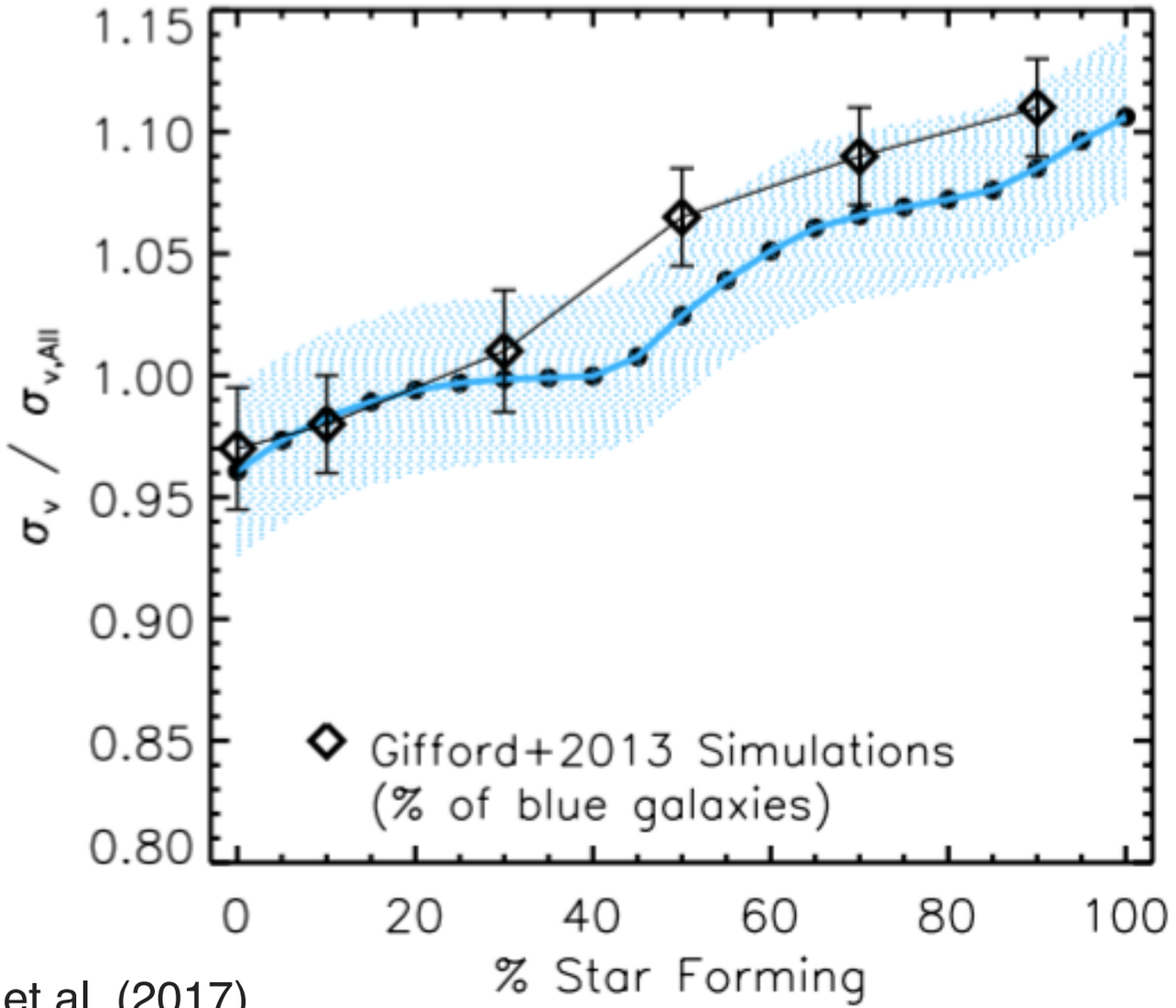
$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}} = \frac{\sigma_{gal,obs}}{\sigma_{gal,sims}} \times \frac{\sigma_{gal,sims}}{\sigma_{DM}}$$

The dispersion we measure is subject to numerous sources of bias, including but not limited too:
interlopers
radial sampling
target selection

The galaxy dispersion measured in simulations is sensitive to the choices made about handling hydrodynamics and sub-grid physics in a given simulation.

Comparing Phase Space Properties of Different Types of Cluster Member Galaxies: Data and Sims





Bayliss et al. (2017)

Can we use comparisons of the phase space properties by galaxy type to help solve this problem?

End

Thank you to the conference organizers!