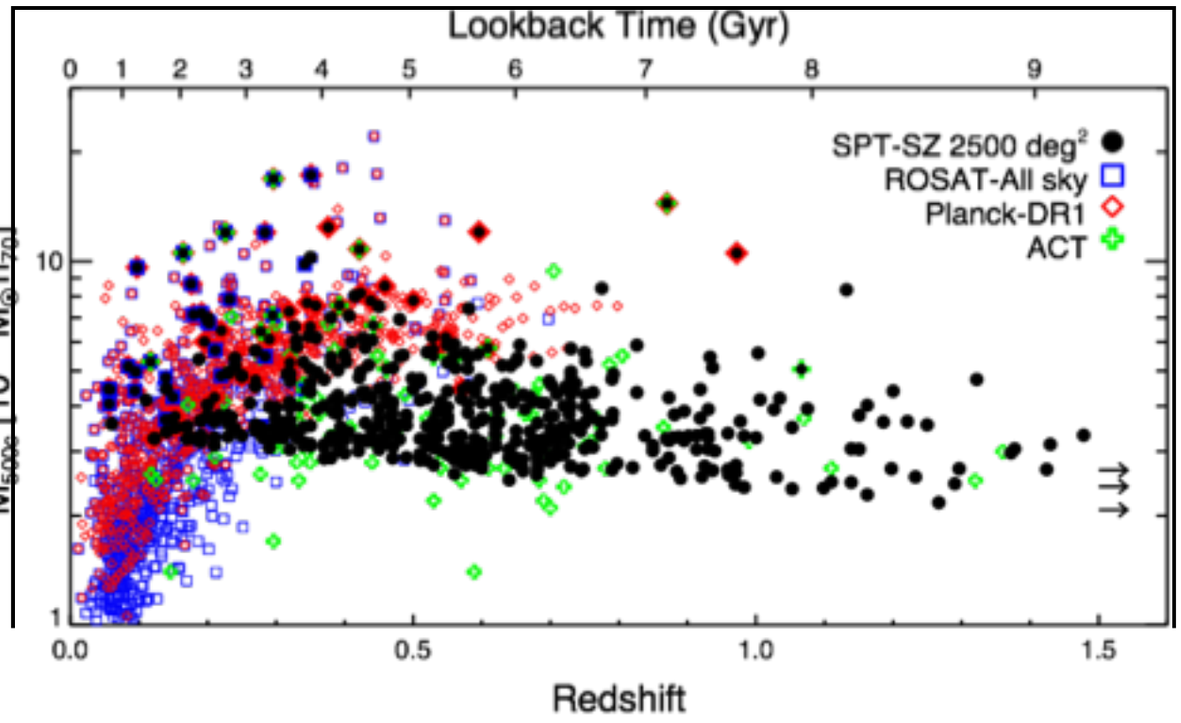
The SPT-GMOS Survey: Velocity Segregation and Calibrating Velocity Dispersion Biases



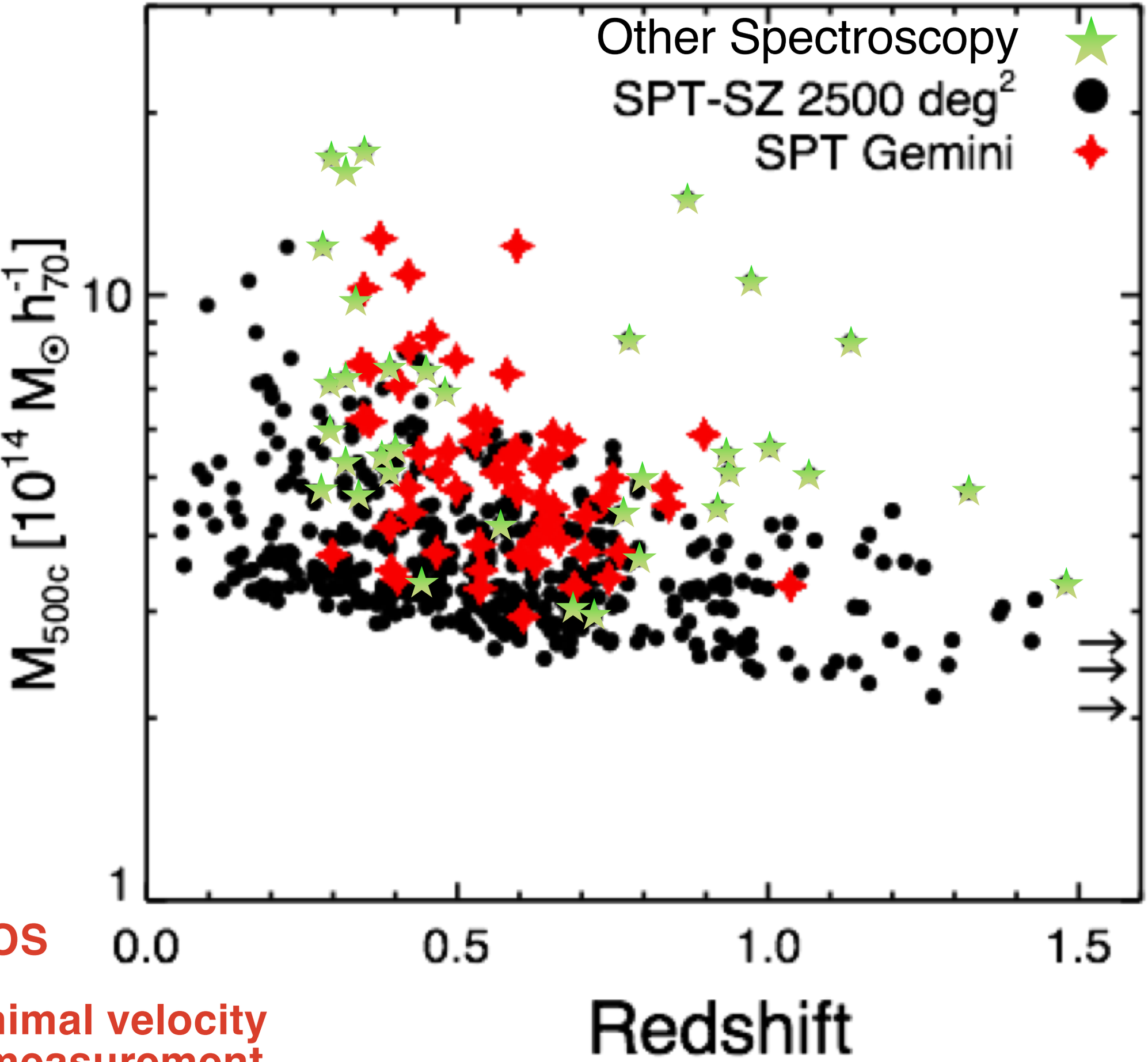
Matthew Bayliss

Massachusetts Institute of Technology

Science and Evolution of the Gemini Observatory — San Francisco — July 26, 2018

Talk Outline

- **SPT-GMOS: A spectroscopic survey of SPT-SZ galaxy clusters.**
- **Science with the SPT-GMOS spectra: velocity dispersions, velocity segregation by galaxy type and luminosity, and other spin-off projects.**
- **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?**

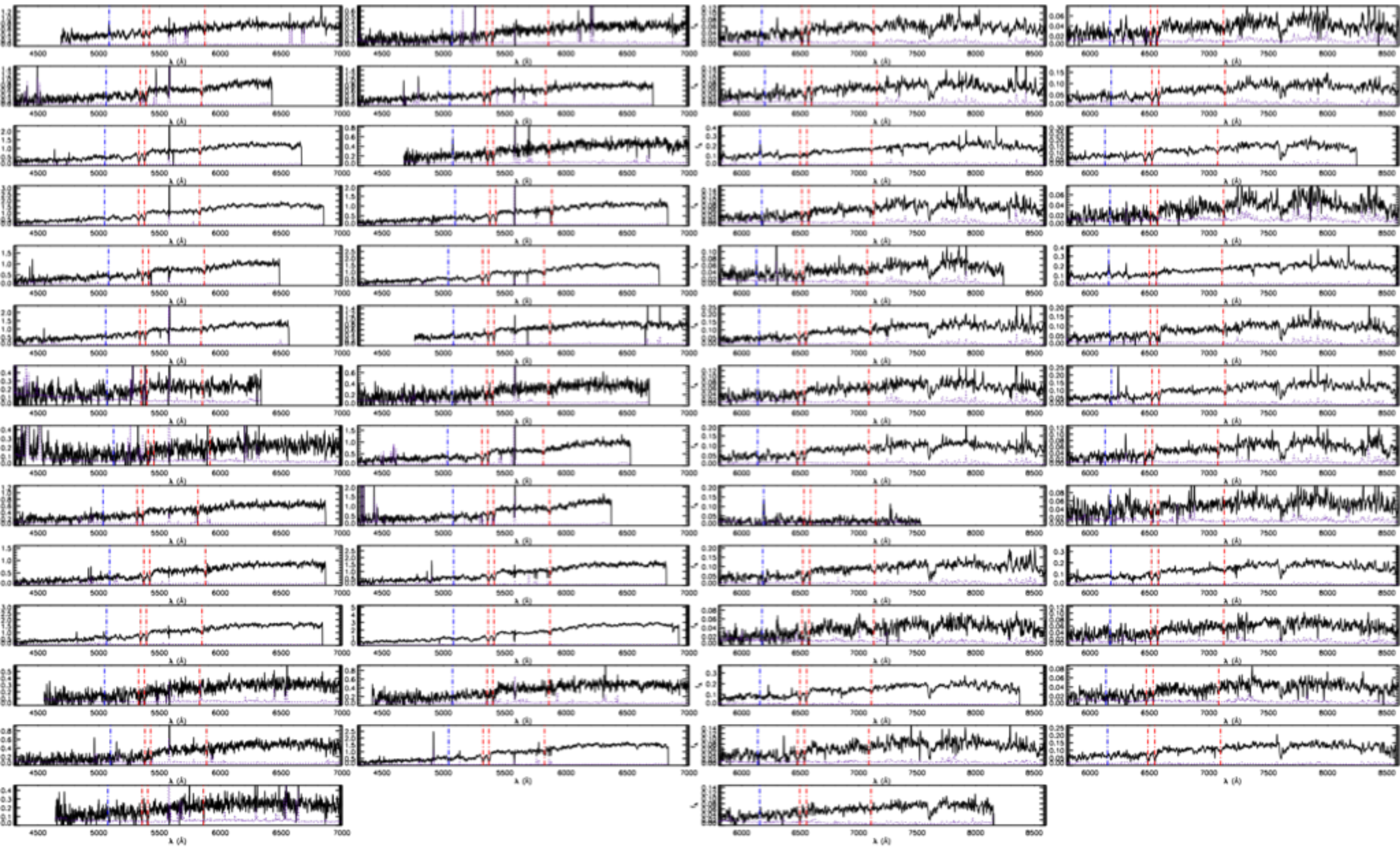


In Total:

63 SPT-GMOS

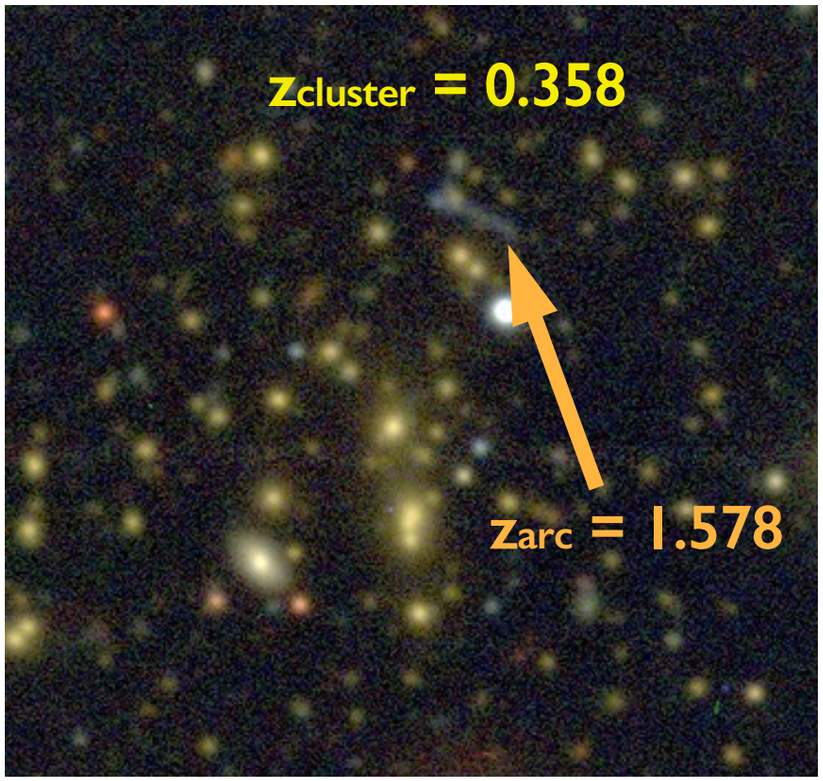
~90 with minimal velocity dispersion measurement

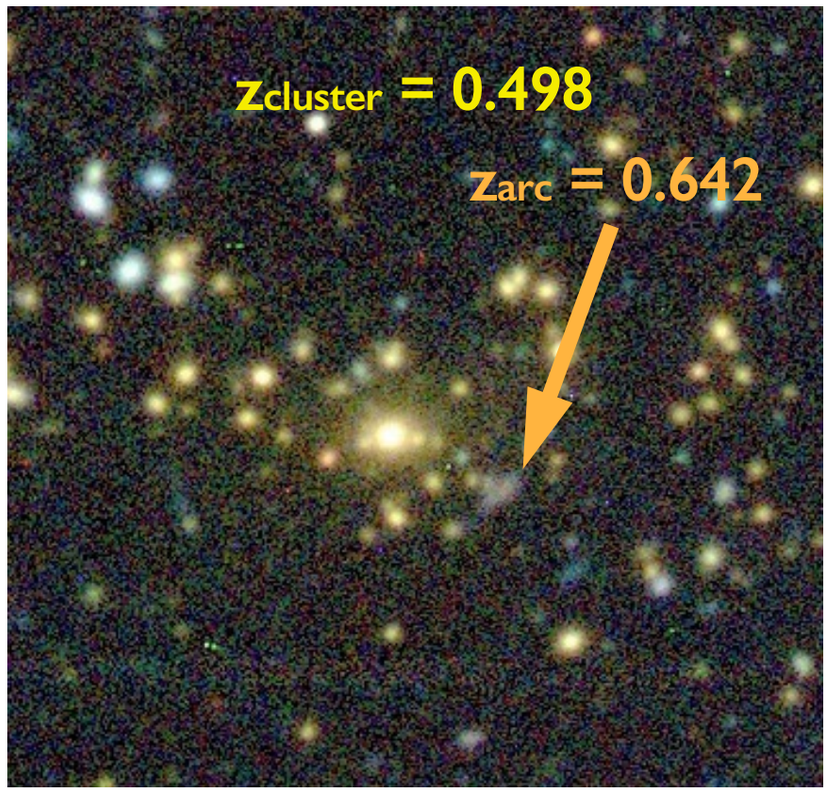
The Data

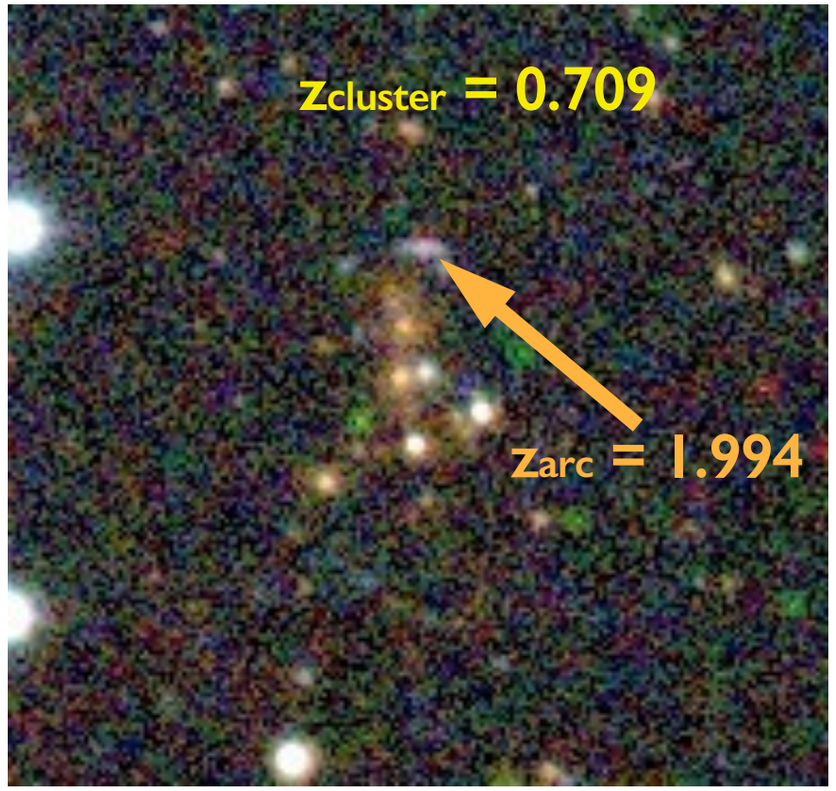


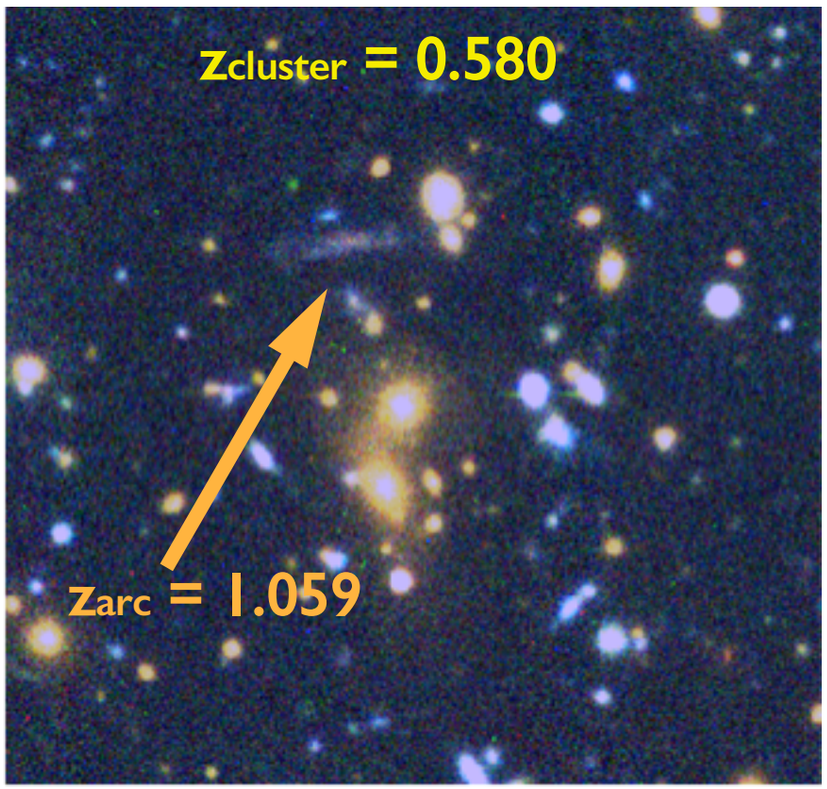
Bayliss et al. (2016)

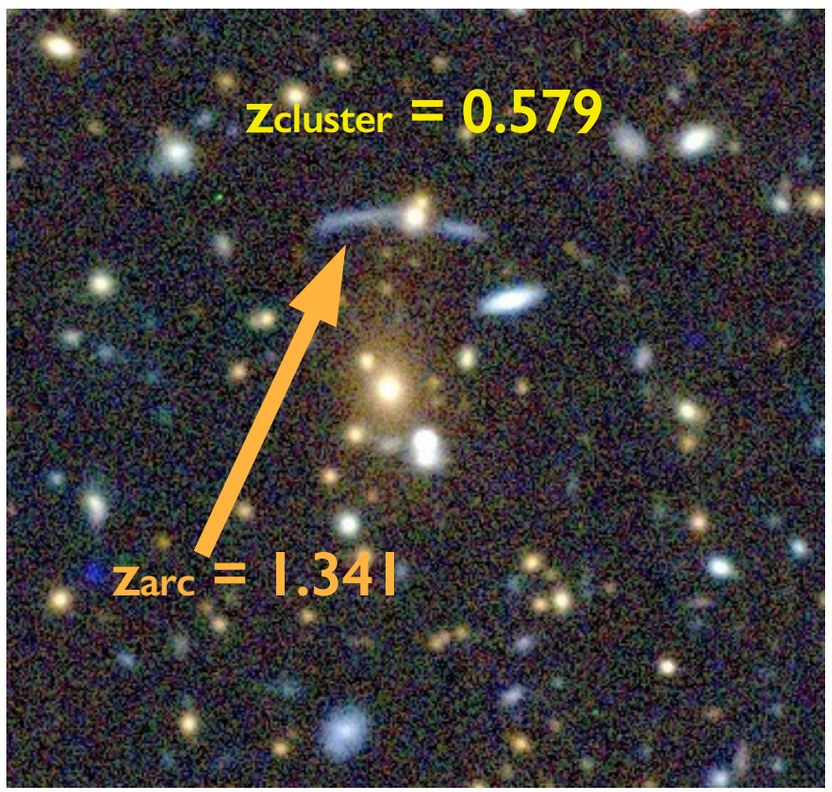
Not Just Cluster Members: For Free Get Some Cool Things Like Strongly Lensed Galaxies





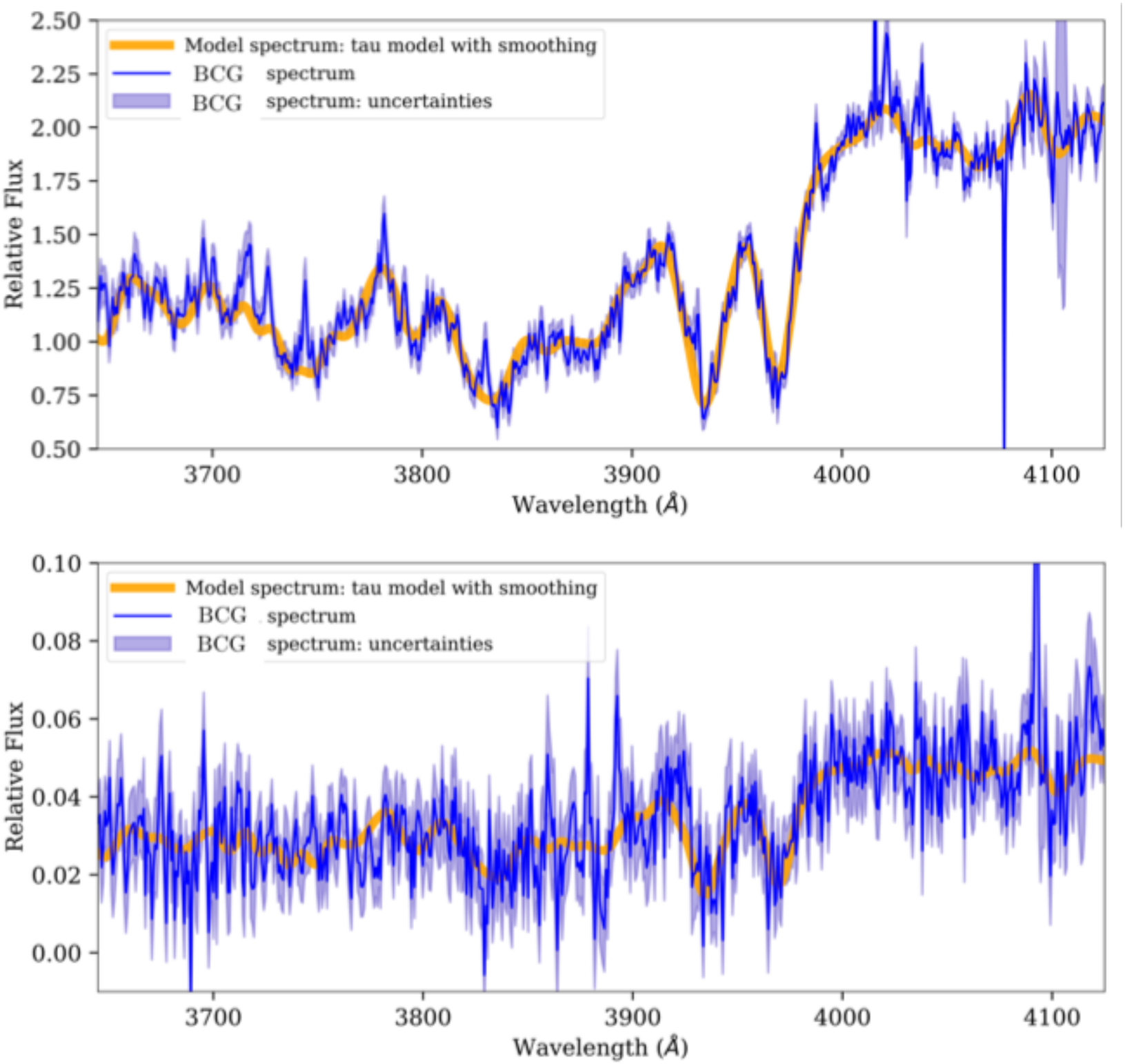






Nine giant arc redshifts measured from SPT-GMOS spectra, and redshift constraints (i.e. redshift desert limits) inferred for five more arcs.

Extracting Detailed Information from Stellar Population Fits to Brightest Cluster Galaxies



$\log(Z / Z_{\odot}) = 0.18$

$\tau_{age} = 7.6$ Gyr

$\sigma_{\star} = 380$ km s^{-1}

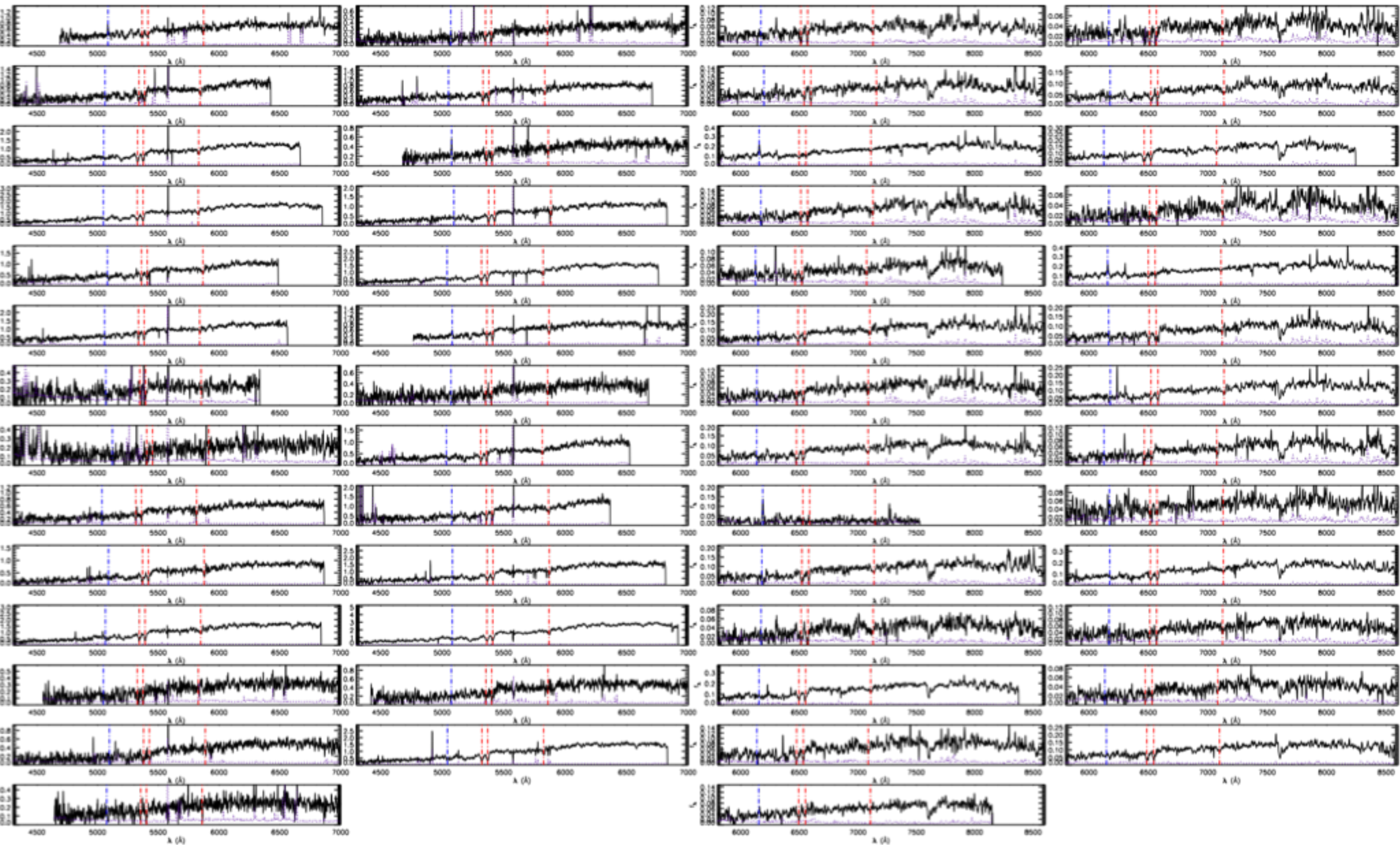
$\log(Z / Z_{\odot}) = 0.32$

$\tau_{age} = 8.3$ Gyr

$\sigma_{\star} = 290$ km s^{-1}

Khullar et al., in prep (see also Khullar et al. 2018)

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



Bayliss et al. (2016)

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SPT-CL J2245-6206 N=04
SPT-CL J2258-4044 N=27
SPT-CL J2301-4023 N=20
SPT-CL J2306-6505 N=43
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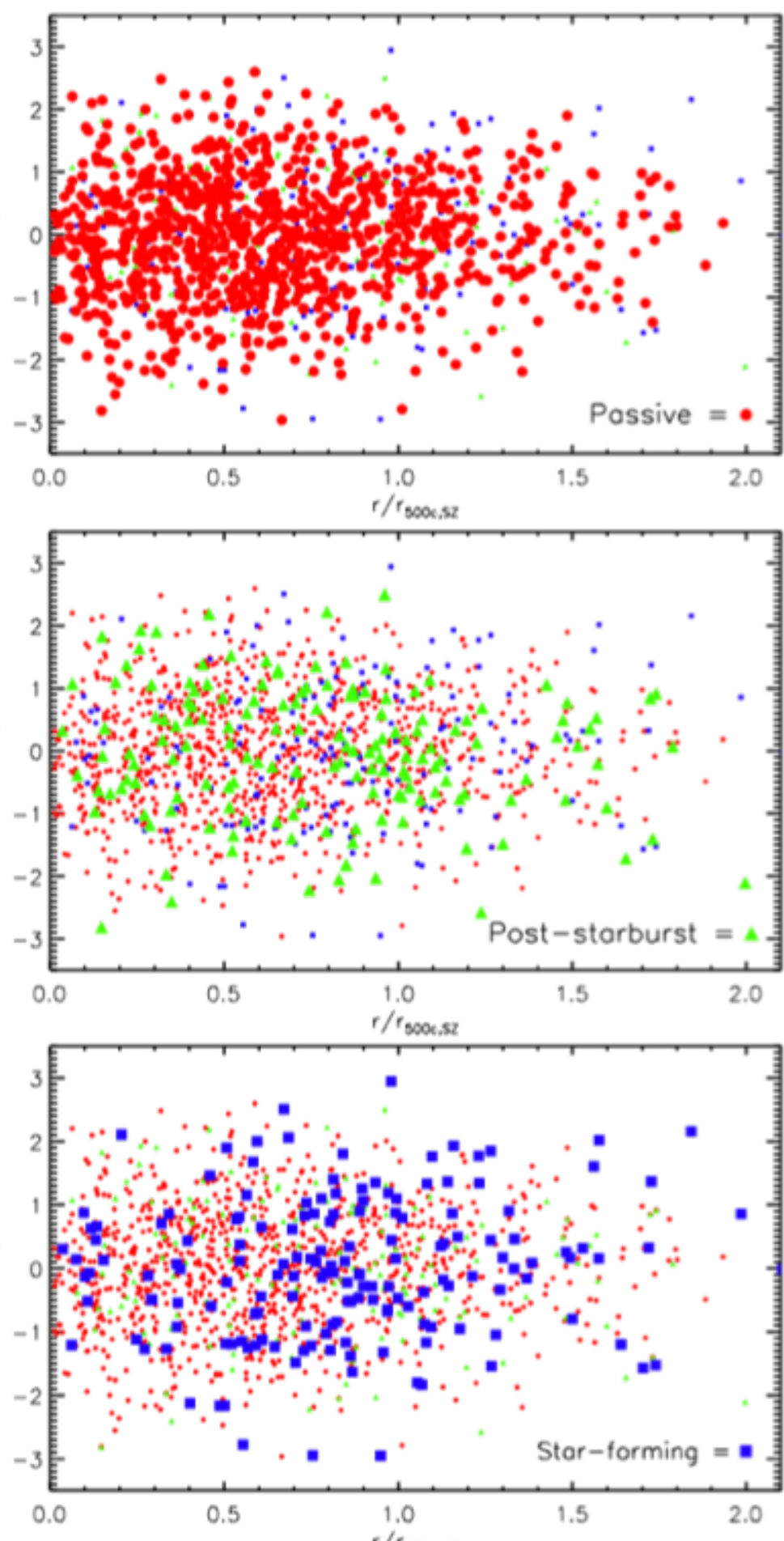
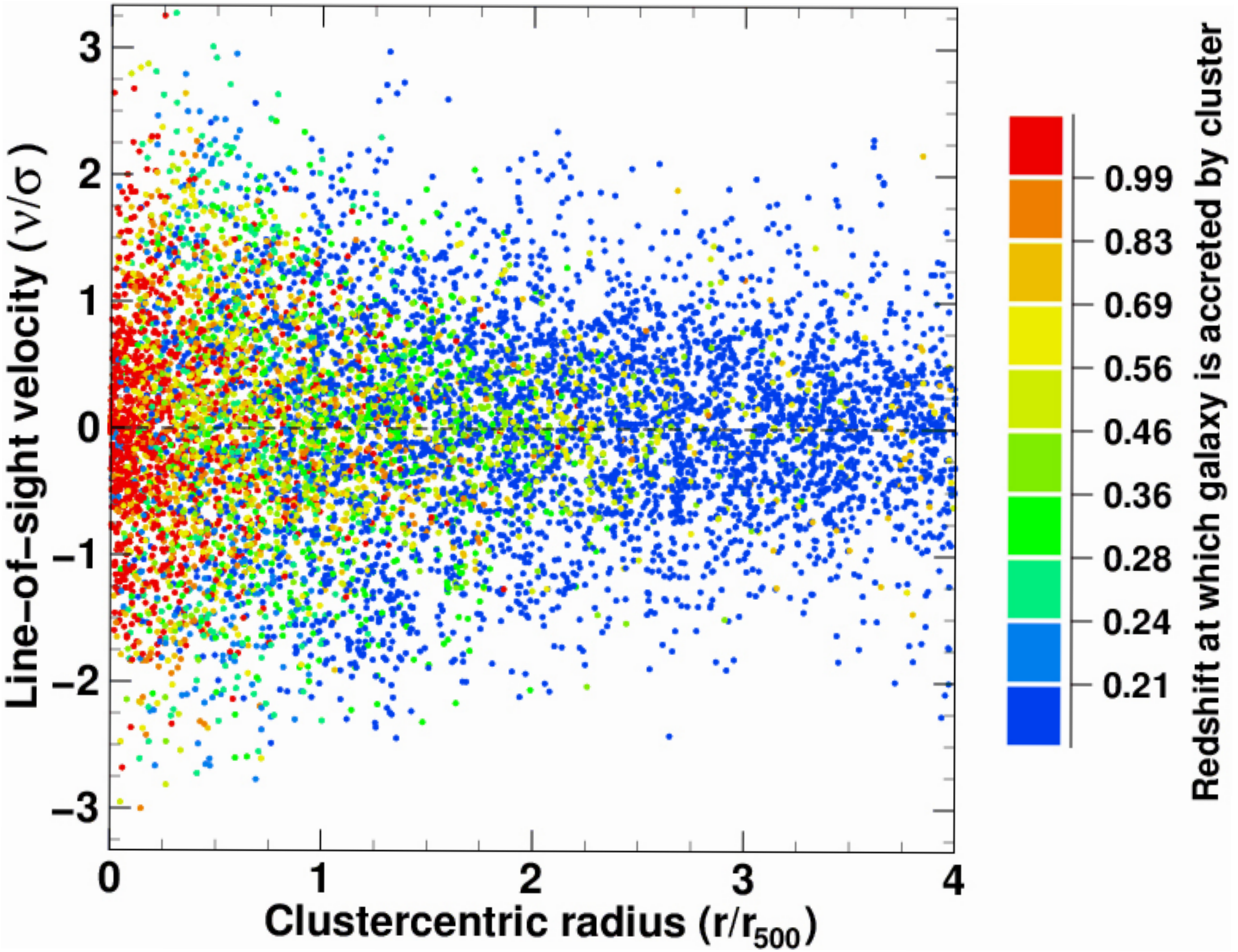
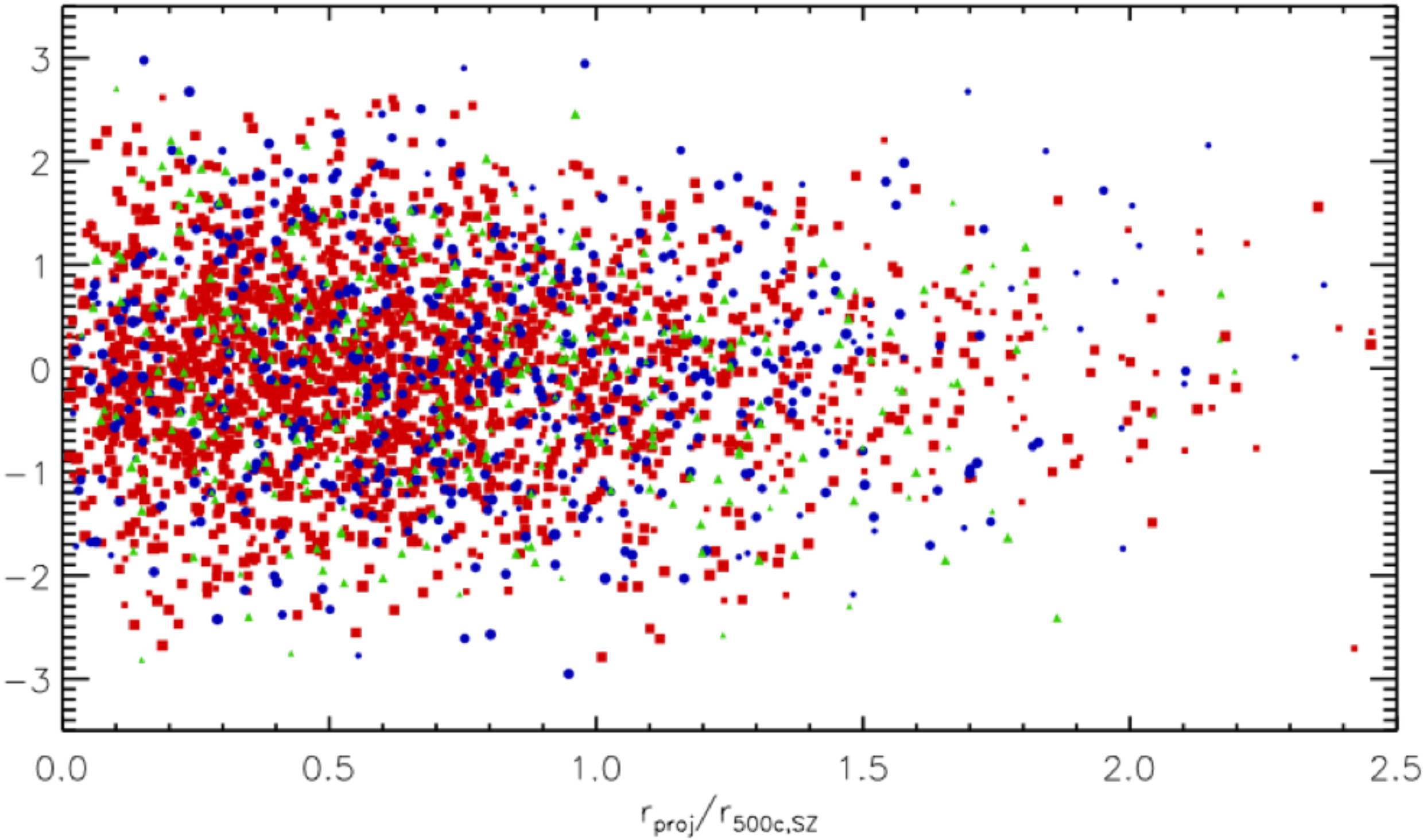
SPT-CL J2335-4544 N=35
SPT-CL J2344-4243 N=32
v (km/s)





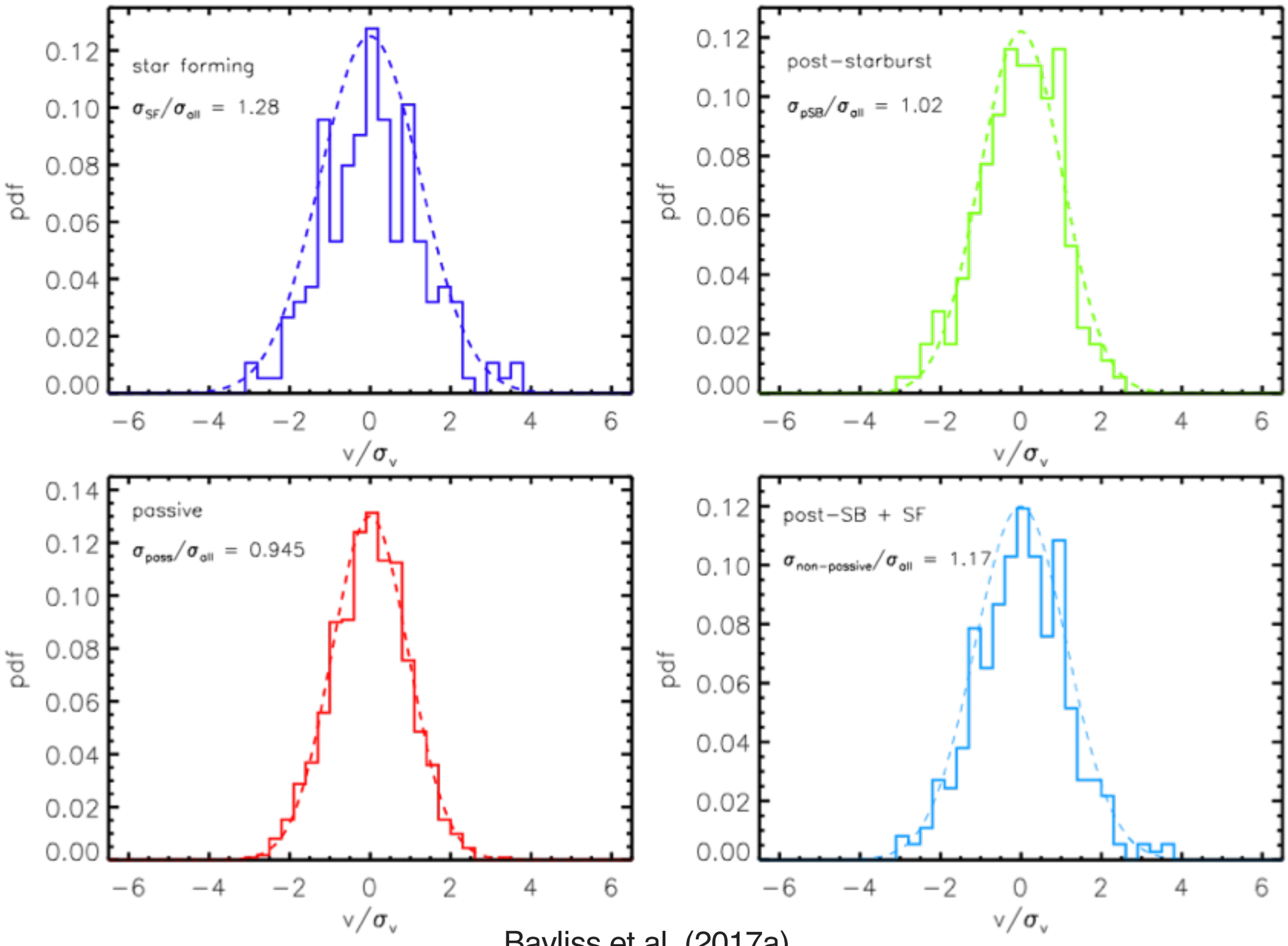
Haines et al. (2012) simulations [LoCuSS Collaboration]

Ensemble Analyses: Global Phase Space Properties of Cluster Members



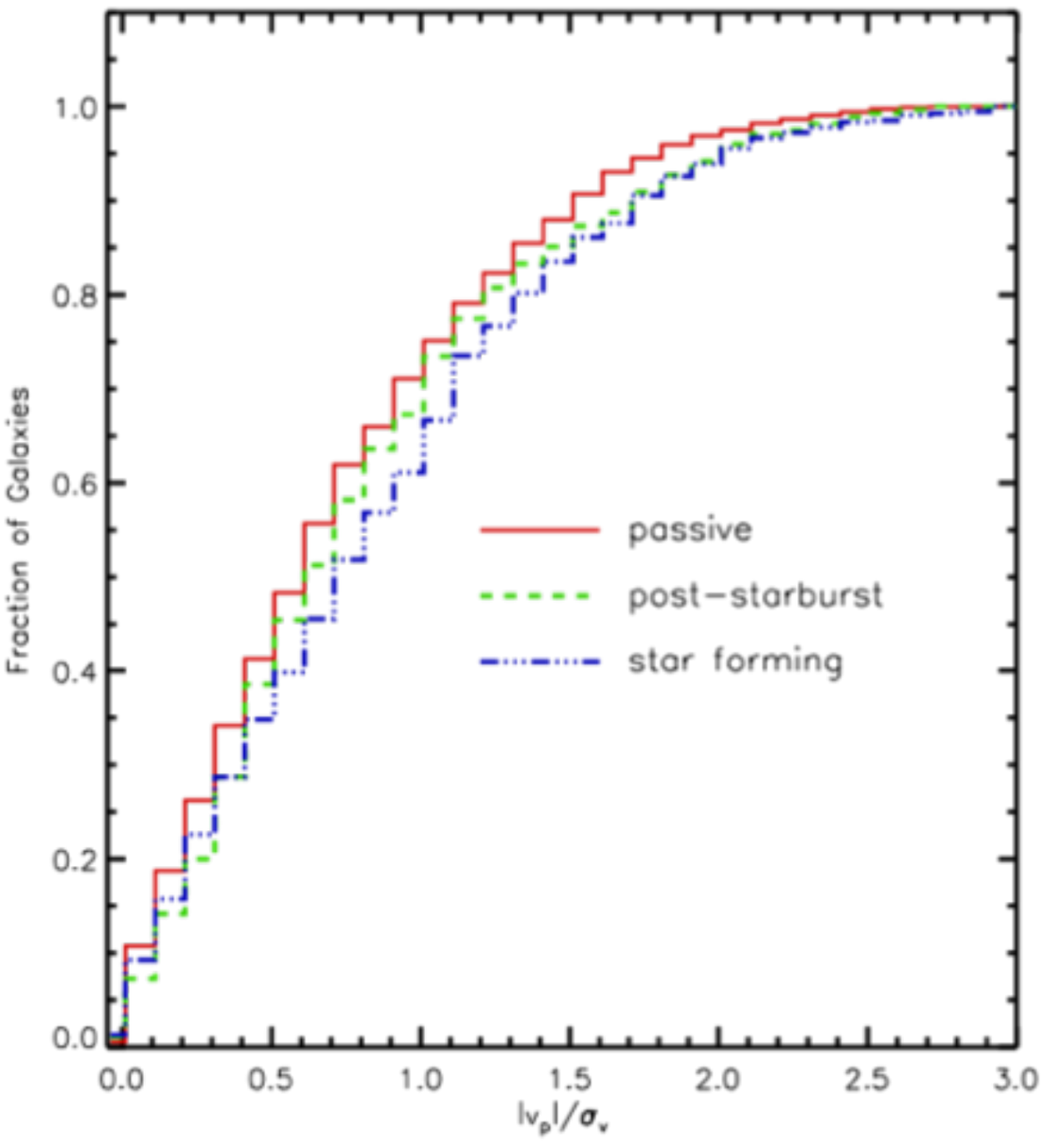
Bayliss et al. (2017a)

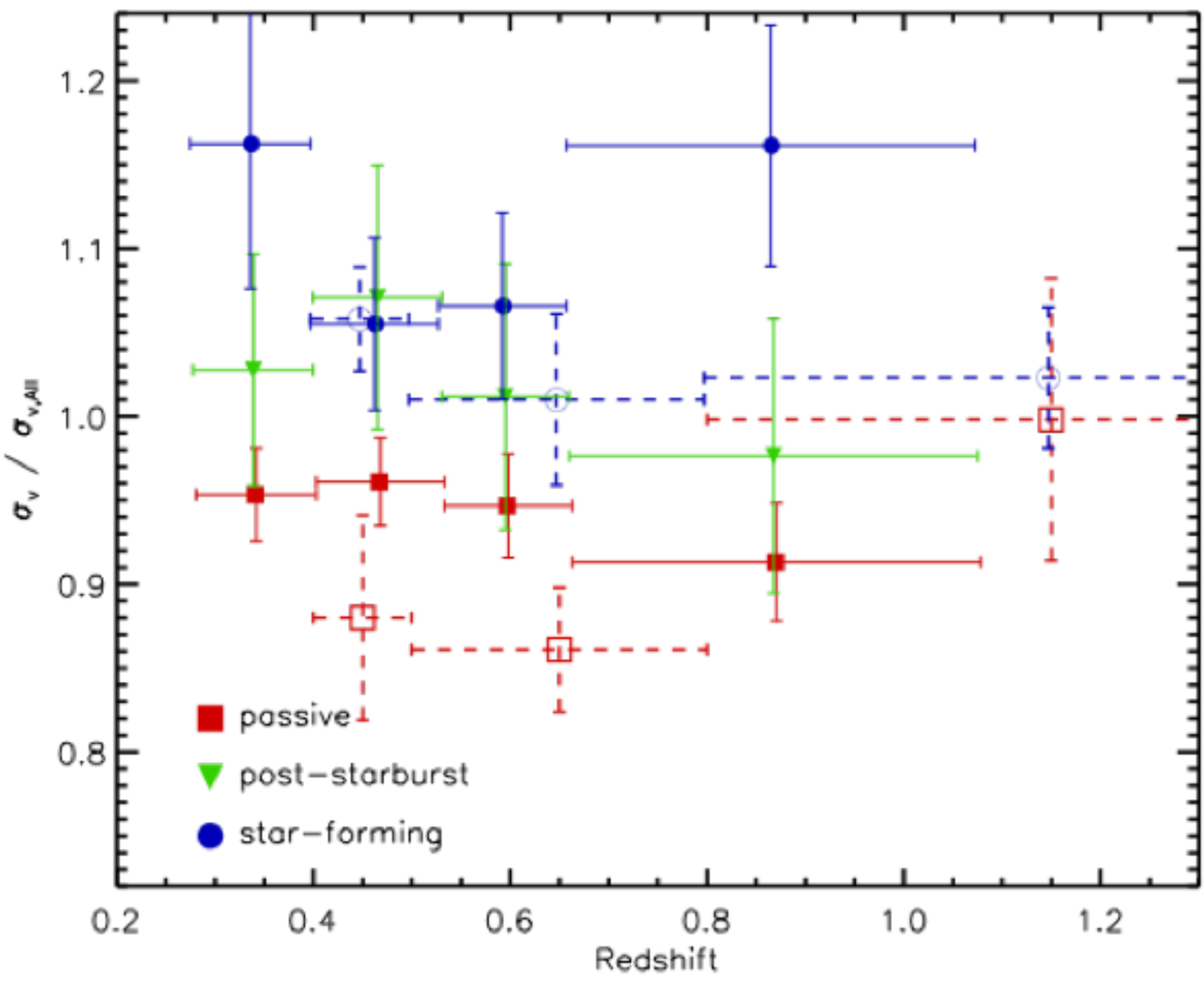
Ensemble Analyses: Global Phase Space Properties of Cluster Members



Bayliss et al. (2017a)

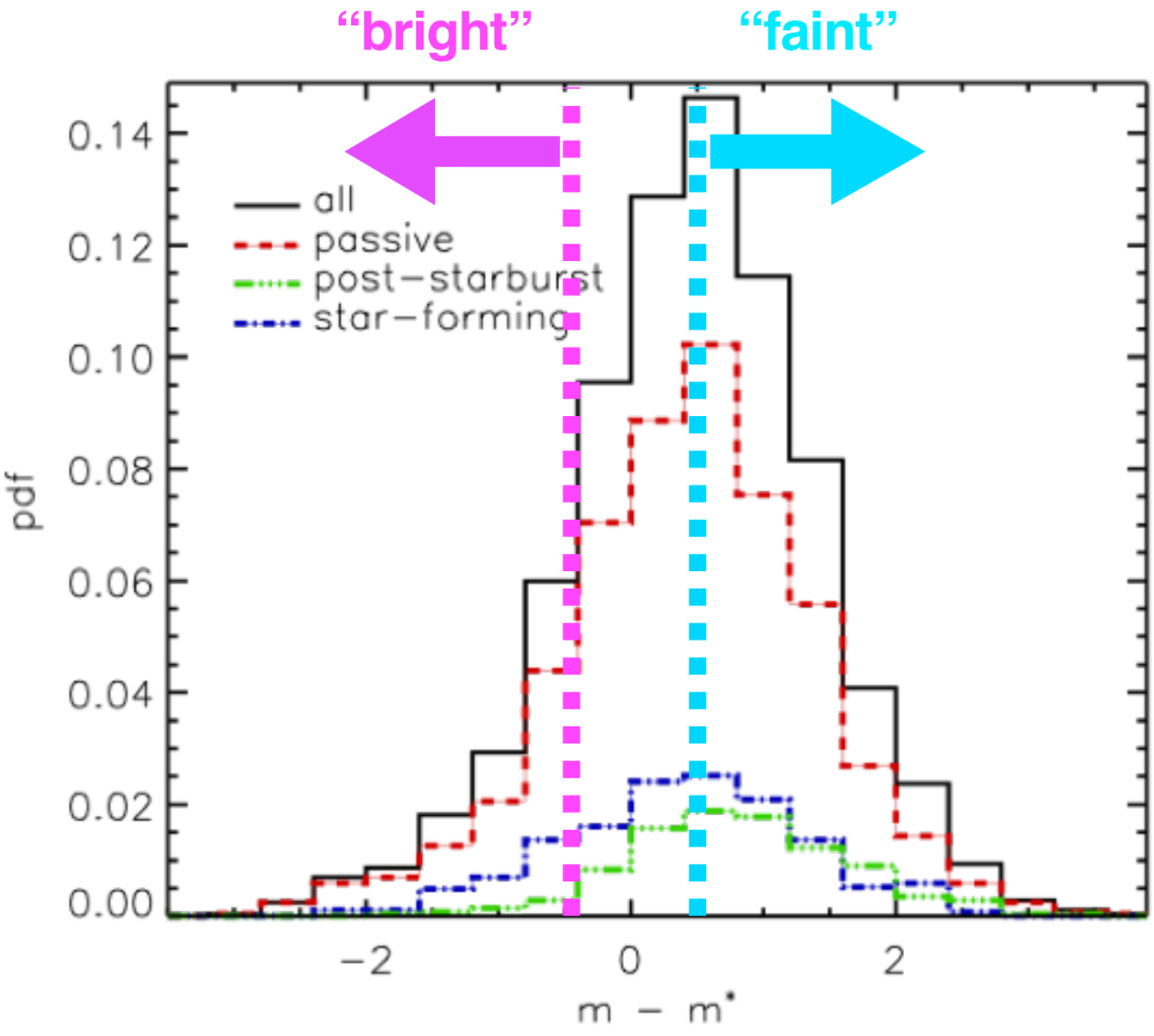
Different (Spectral) Types of Cluster Member Galaxies Have Different Velocity Distributions

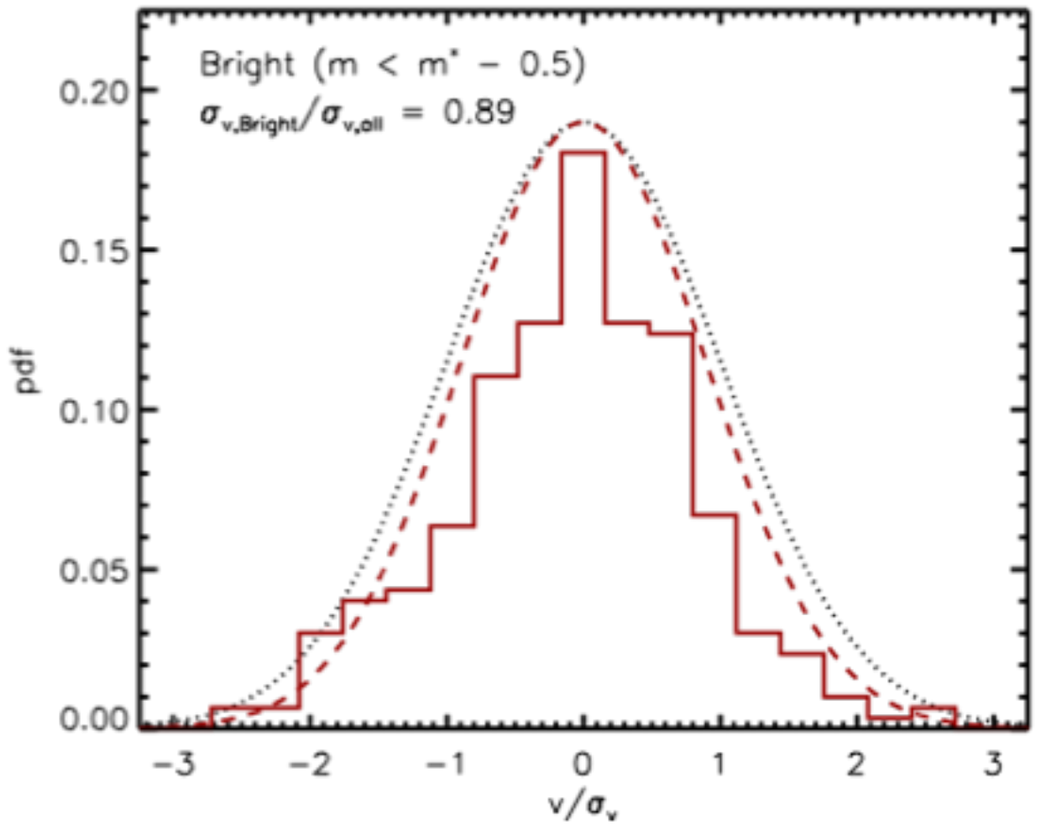


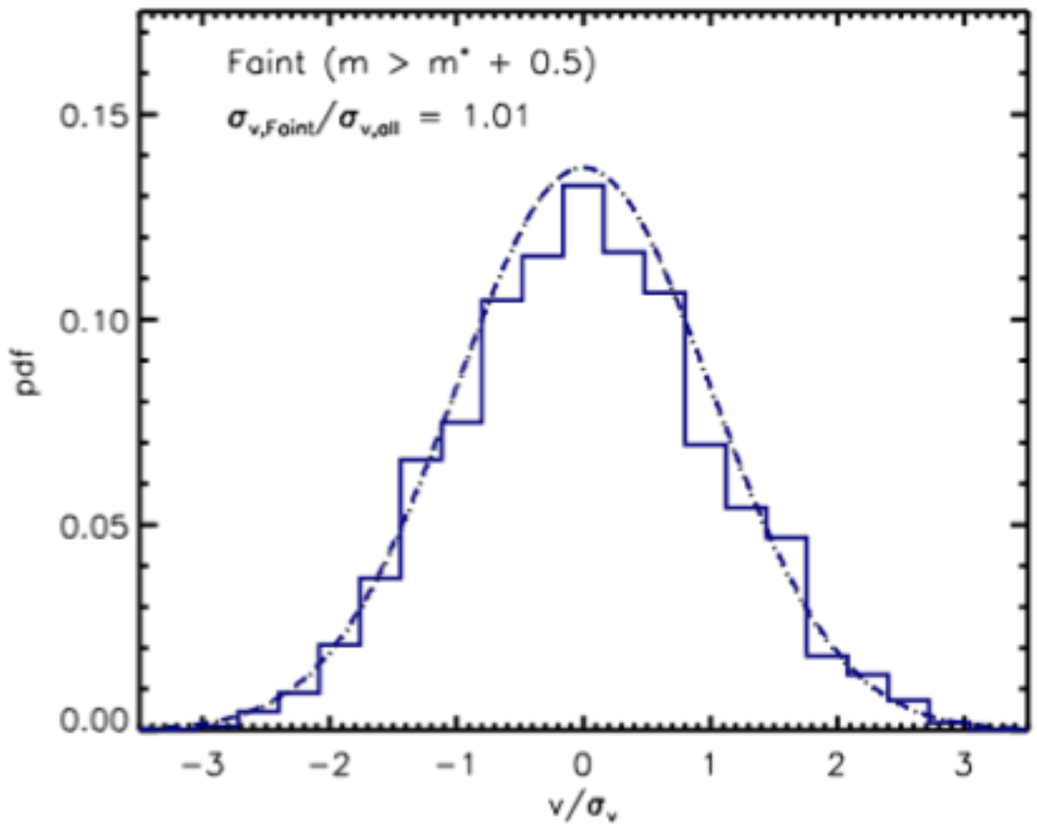


Bayliss et al. (2017a)

Velocity Segregation With Galaxy Luminosity

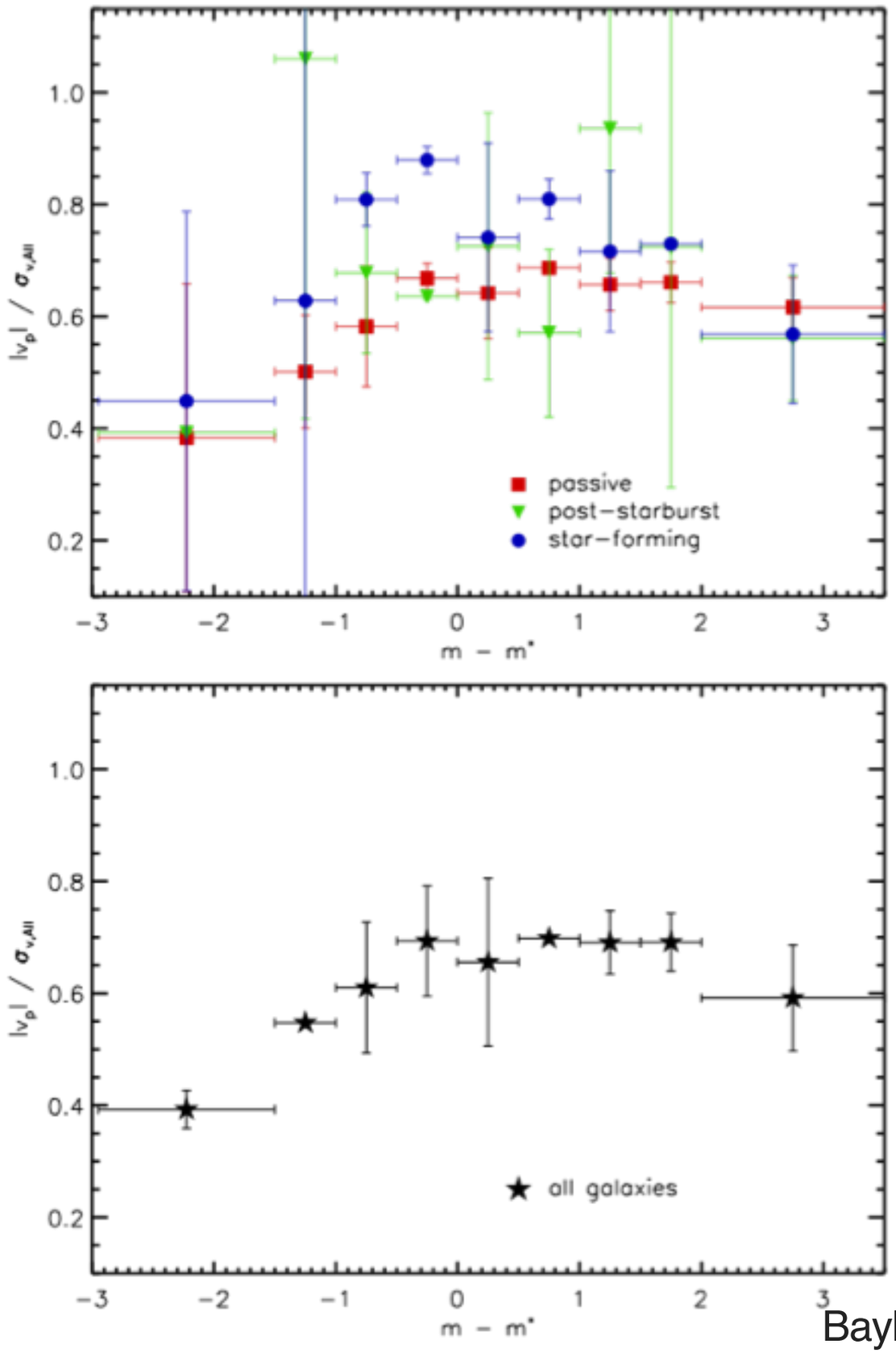


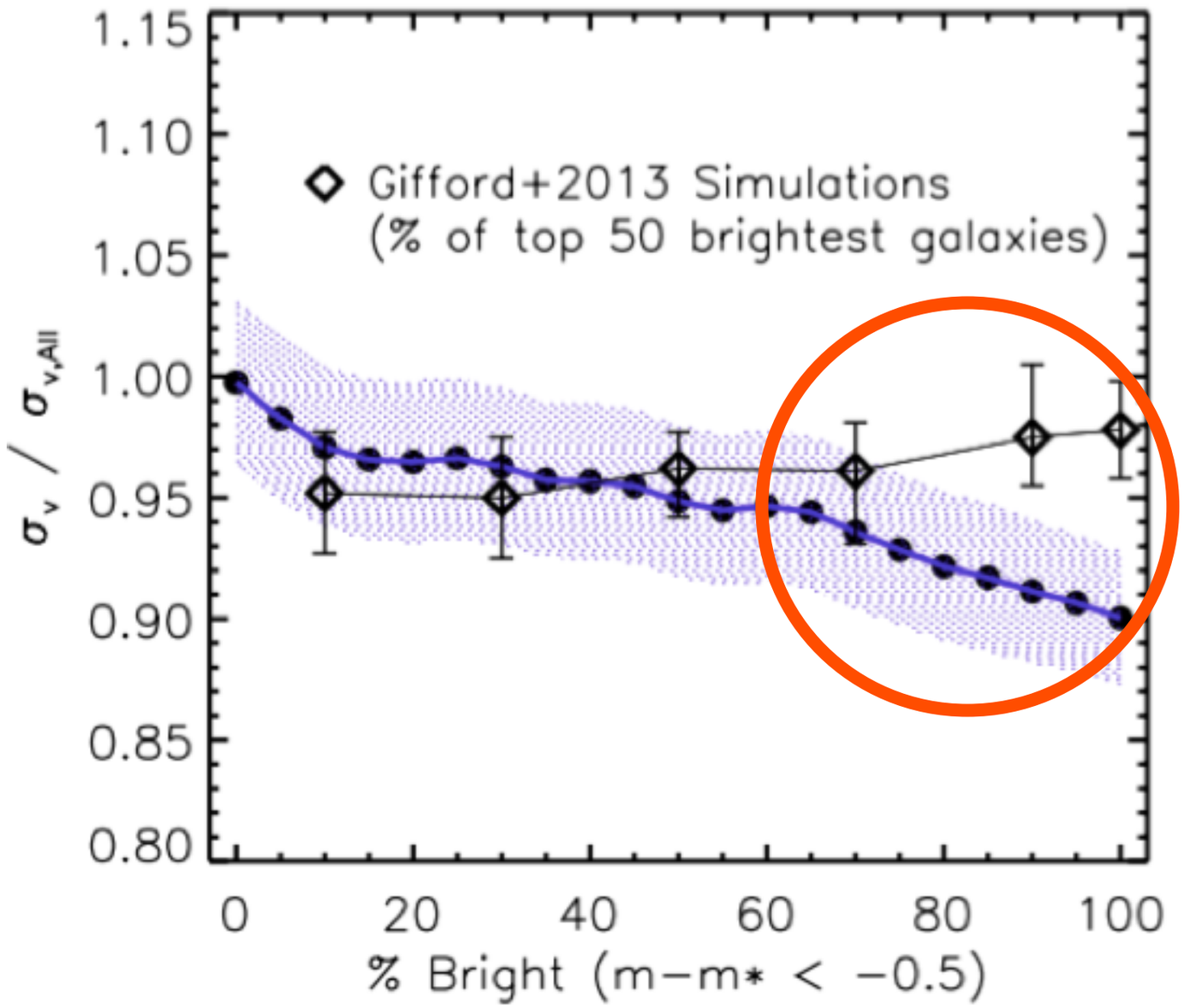




Bayliss et al. (2017a)

Velocity Segregation With Galaxy Luminosity





What's going on here?

Bayliss et al. (2017a)

Summary So Far

- We have a wealth of spectroscopic data, including velocity dispersion measurements for a substantial fraction (~20-25%) of the SPT-SZ cluster sample, which overlaps w/ other multi-wavelength (SZ, X-ray, WL, HST) data.

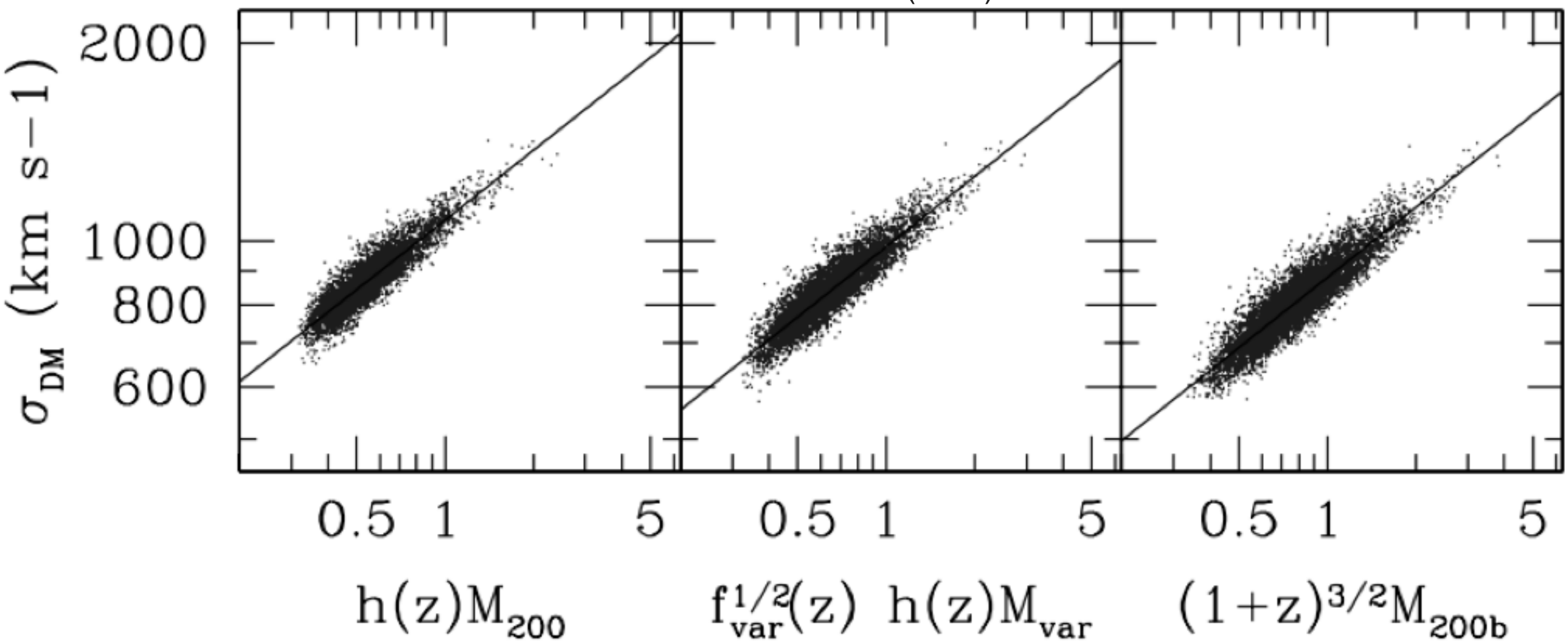
- The spectra provide detailed information about the thousands of individual galaxies in our clusters.

- The survey has fed numerous publications:
  - Papers w/ SPT-GMOS spectroscopy as the primary data product:
    - Ruel et al. (2014) — First results and velocity dispersion measurements.
    - Bocquet et al. (2015) — SPT cluster cosmology w/ joint X-ray+velocity dispersion masses.
    - Bayliss et al. (2016) — Full survey and data product release.
    - Bayliss et al. (2017a) — Velocity segregation in SPT clusters.
    - Capasso et al. (2018) — SPT cluster mass calibration with caustic fitting.

  - Also 23 (and counting) SPT papers using SPT-GMOS spectroscopy alongside and in support of other data.

Calibrating Velocity Dispersion Measurements Between Data and Sims

Evrard et al. (2008)



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

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

But when working with real data, what we actually need to know is:

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

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 challenge is to measure this quantity for your data *and* the same simulation. This is 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

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

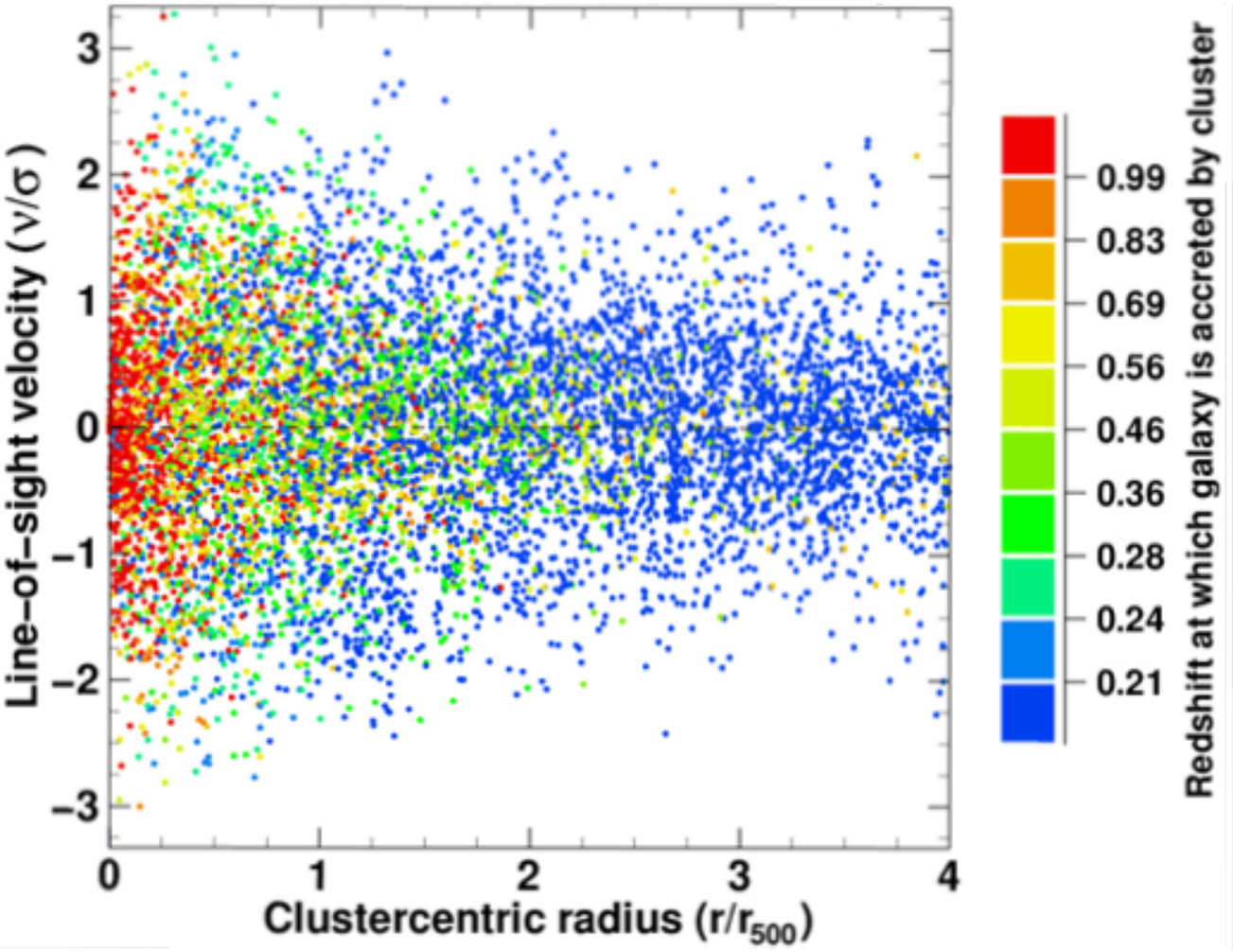
$$b_{v,obs} = \frac{\sigma_{gal,obs}}{\sigma_{DM}} = \frac{\sigma_{gal,obs}}{\sigma_{gal,sims}} \times \frac{\sigma_{gal,sims}}{\sigma_{DM}}$$

The dispersion we measure is subject to numerous sources of bias, including but not limited too:

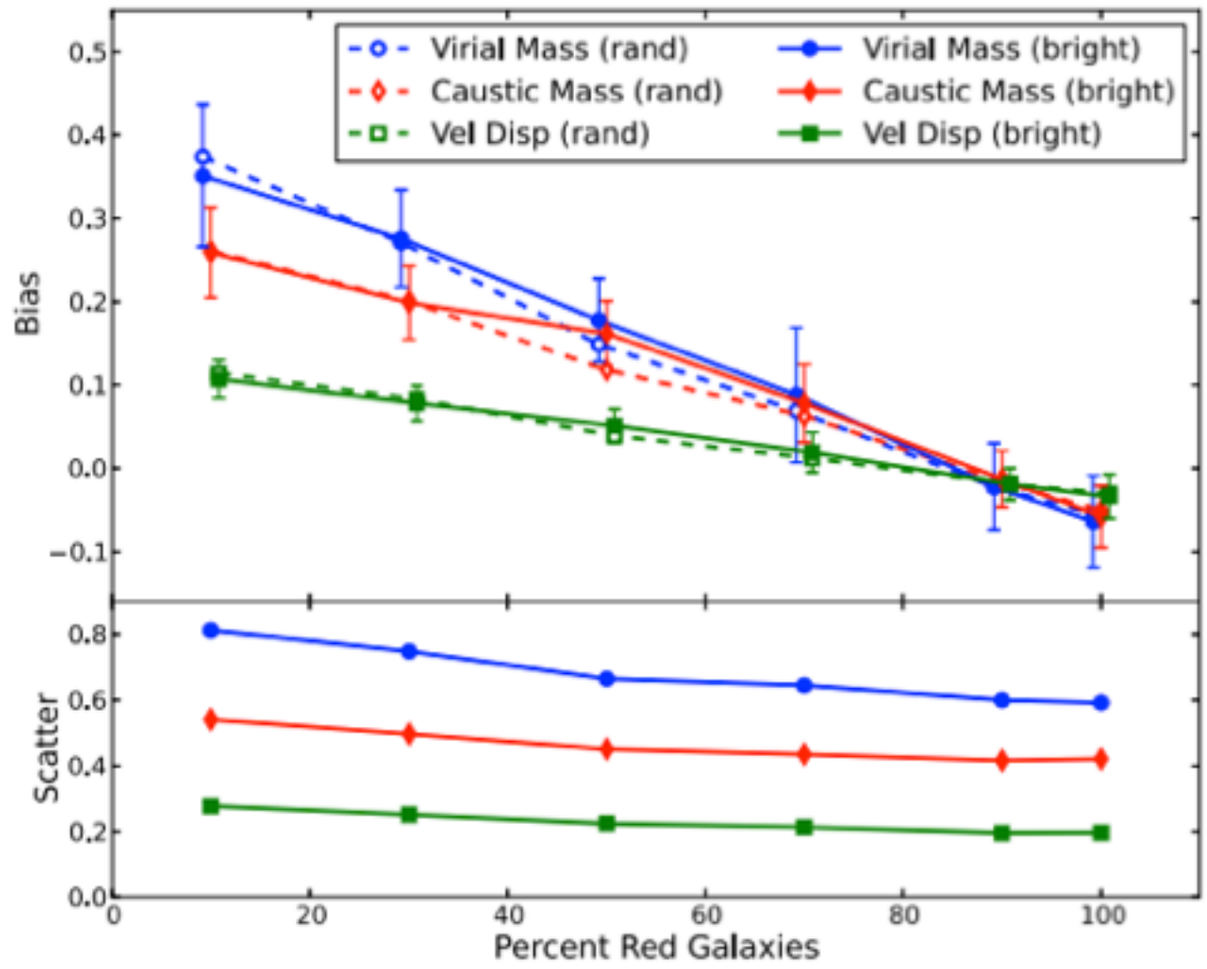
interlopers
radial sampling
target selection

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



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

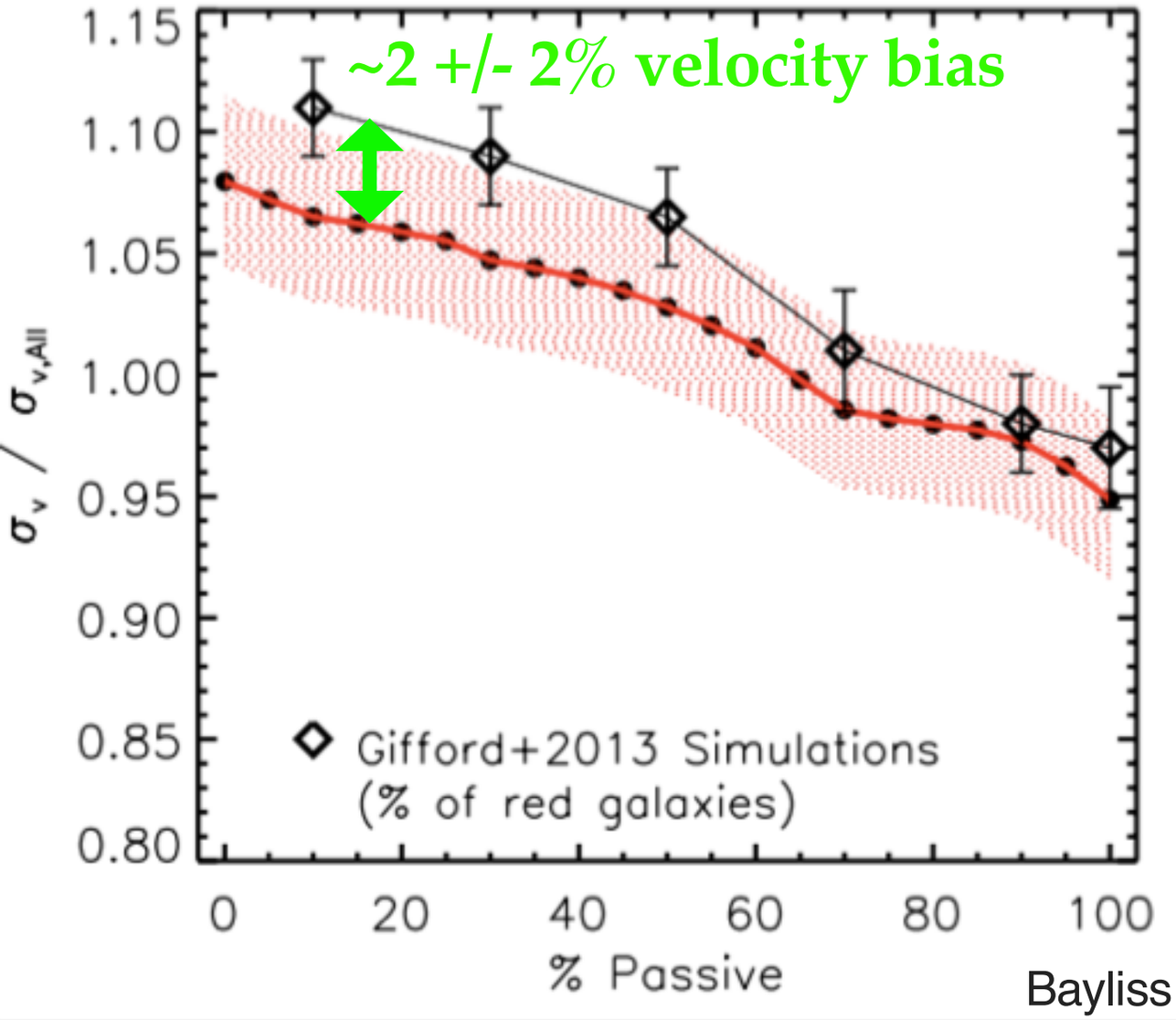


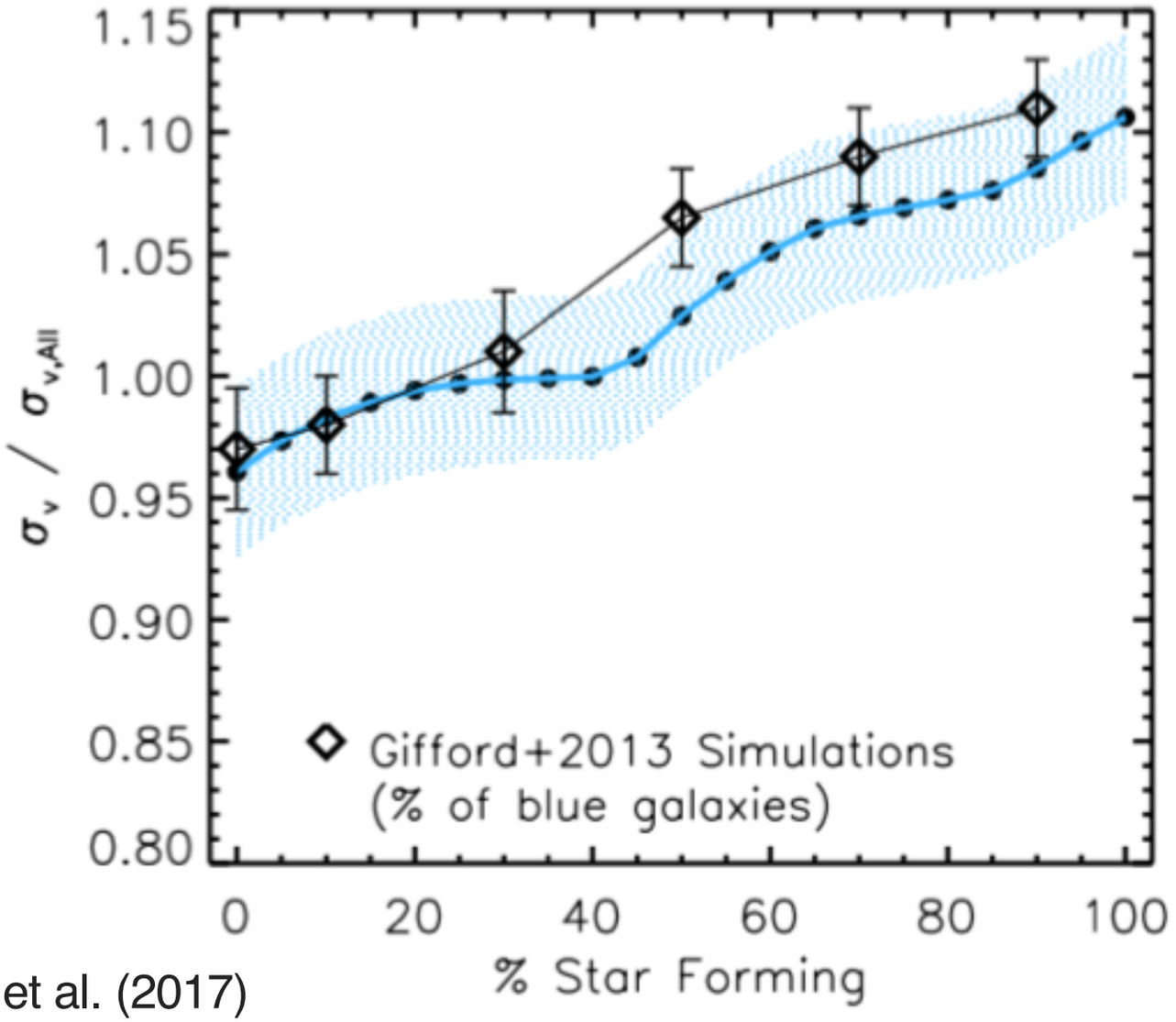
Gifford, Miller & Kern (2013) simulations

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

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

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





Bayliss et al. (2017)

The phase space properties by galaxy type represent an additional observational test that we can use to try to solve this problem?

Thank you to the conference organizers!

End

Other Results/Tangents — Some Other Interesting Projects