

# Tracing the Dynamical Evolution of Cluster Galaxies in HectoMAP and IllustrisTNG

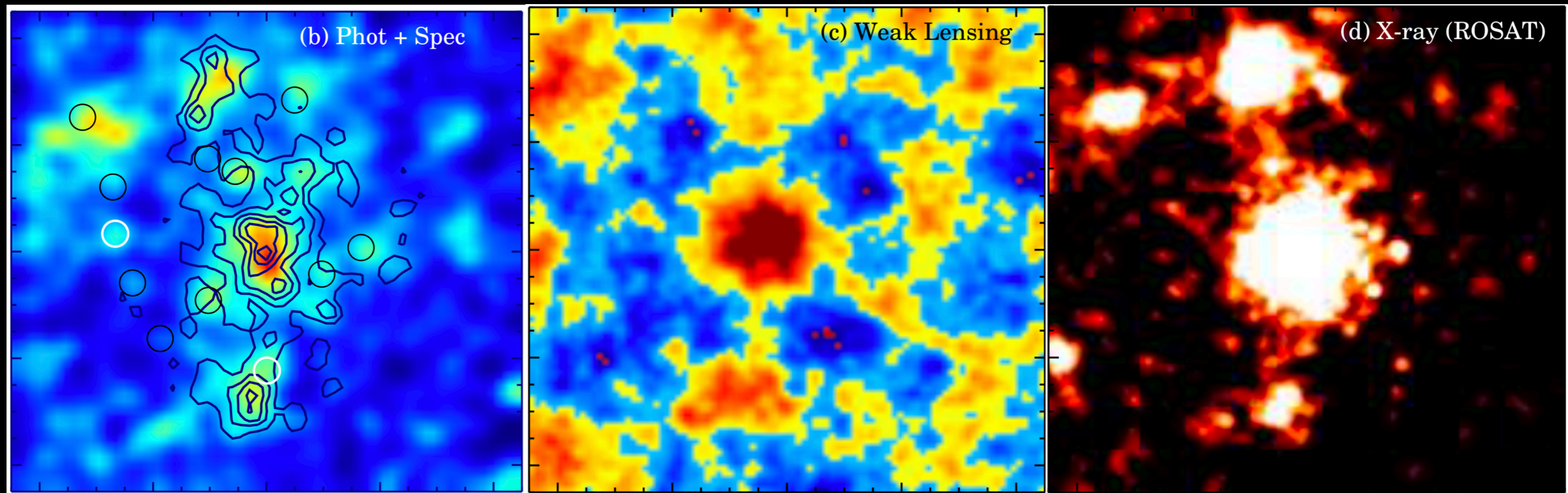
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In collaboration with Margaret Geller (CfA), Mark Vogelsberger (MIT),  
Josh Borrow (MIT), Ho Seong Hwang (SNU)



# Why Galaxy Clusters?

- Galaxy evolution with a large galaxy sample
- A Cosmological tool (e.g., cluster mass functions)



Phot. + Spec.

Weak Lensing

X-ray

Multiwavelength view of a local cluster (A2029)

Sohn et al. 2019a

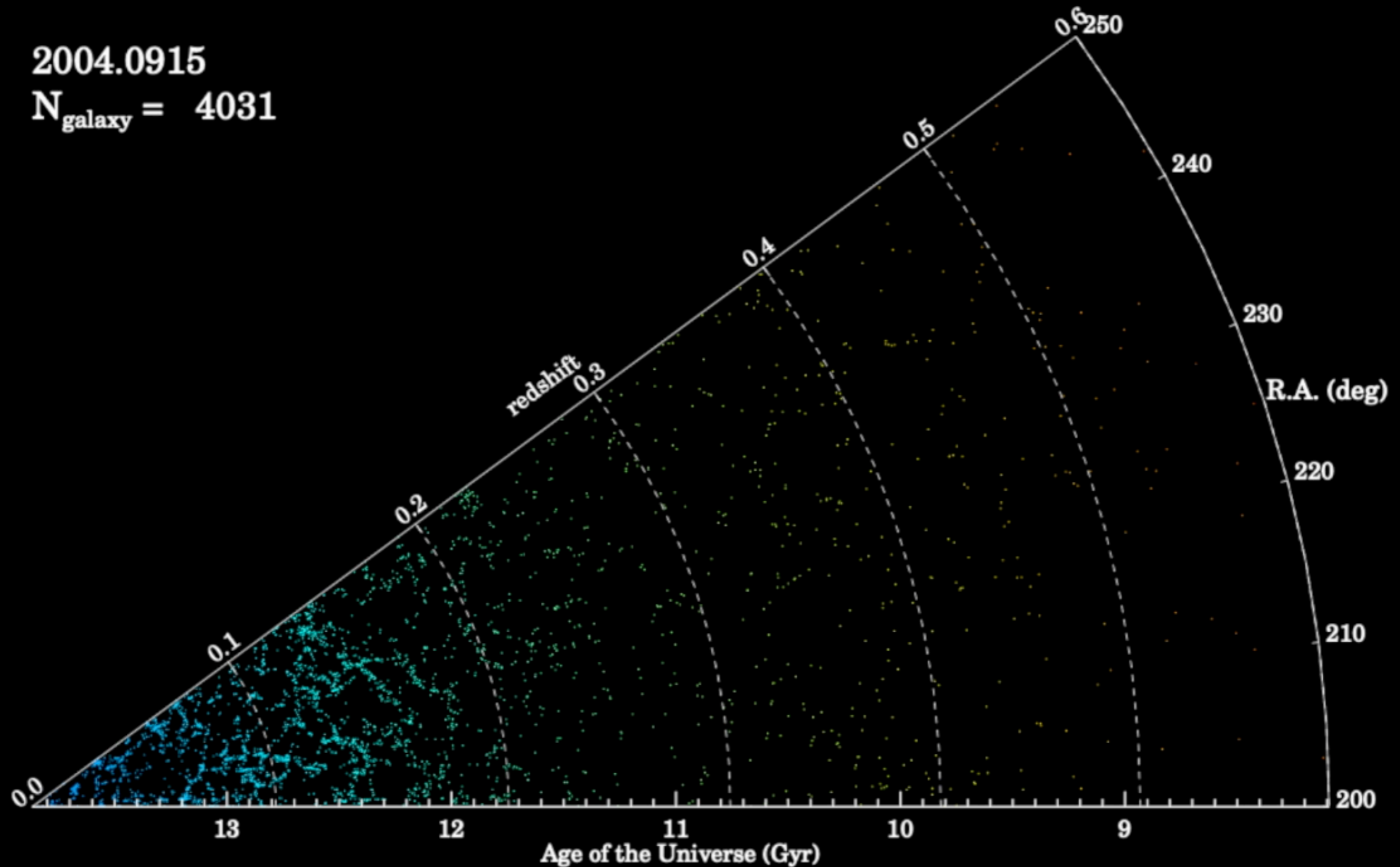
# HectoMAP (Cluster) Surveys

- **HectoMAP** (P.I. Margaret Geller)
  - a dense redshift survey for cluster studies
  - MMT/Hectospec + Subaru/HSC + ROSAT/eROSITA
  - Full data release : [Sohn et al. \(2022\)](#)
- **HectoMAP** cluster surveys
  - Cluster catalogs (Sohn et al. 2018a, b, 2021)
  - Evolution of cluster galaxies
  - Measuring the mass accretion rate of clusters (Pizzardo et al. 2022)
  - Estimating cluster mass with Weak Lensing (Dell'Antonio et al., in prep)

# The HectoMAP Redshift Survey

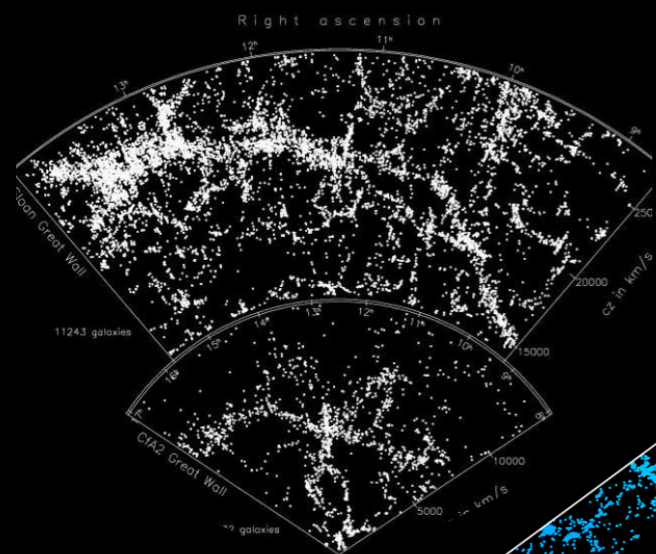
2004.0915

$N_{\text{galaxy}} = 4031$

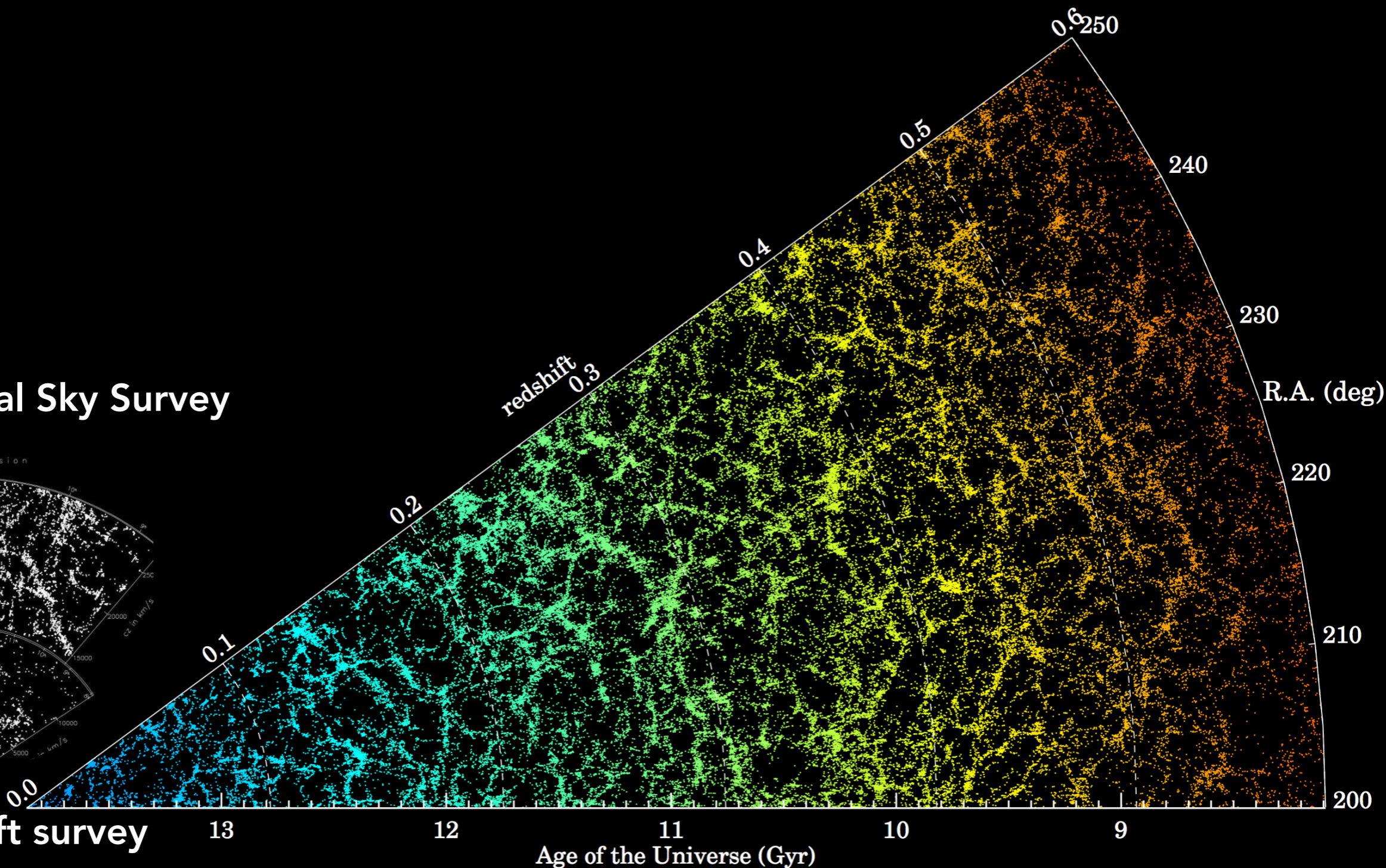


# The HectoMAP Redshift Survey

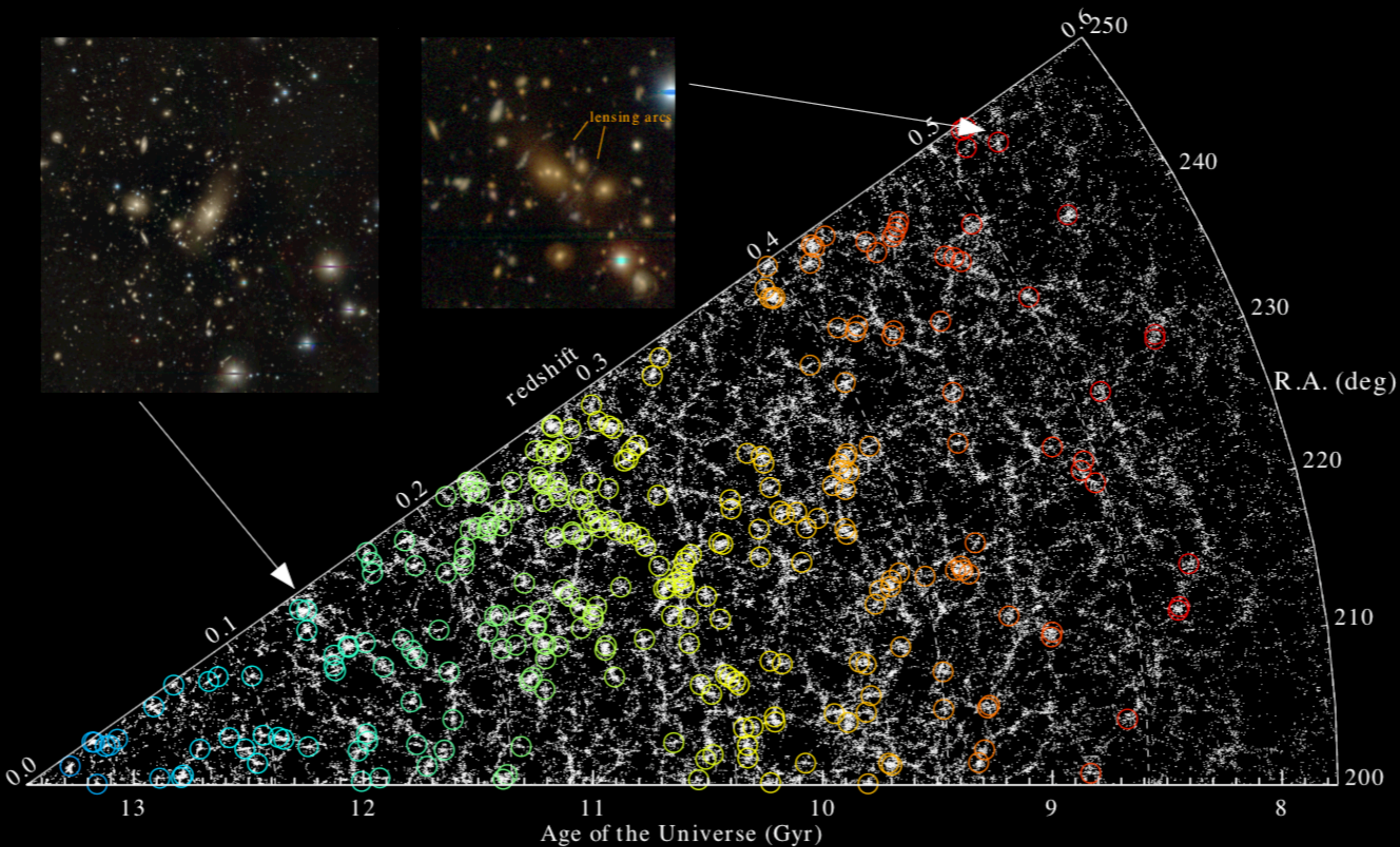
Sloan Digital Sky Survey



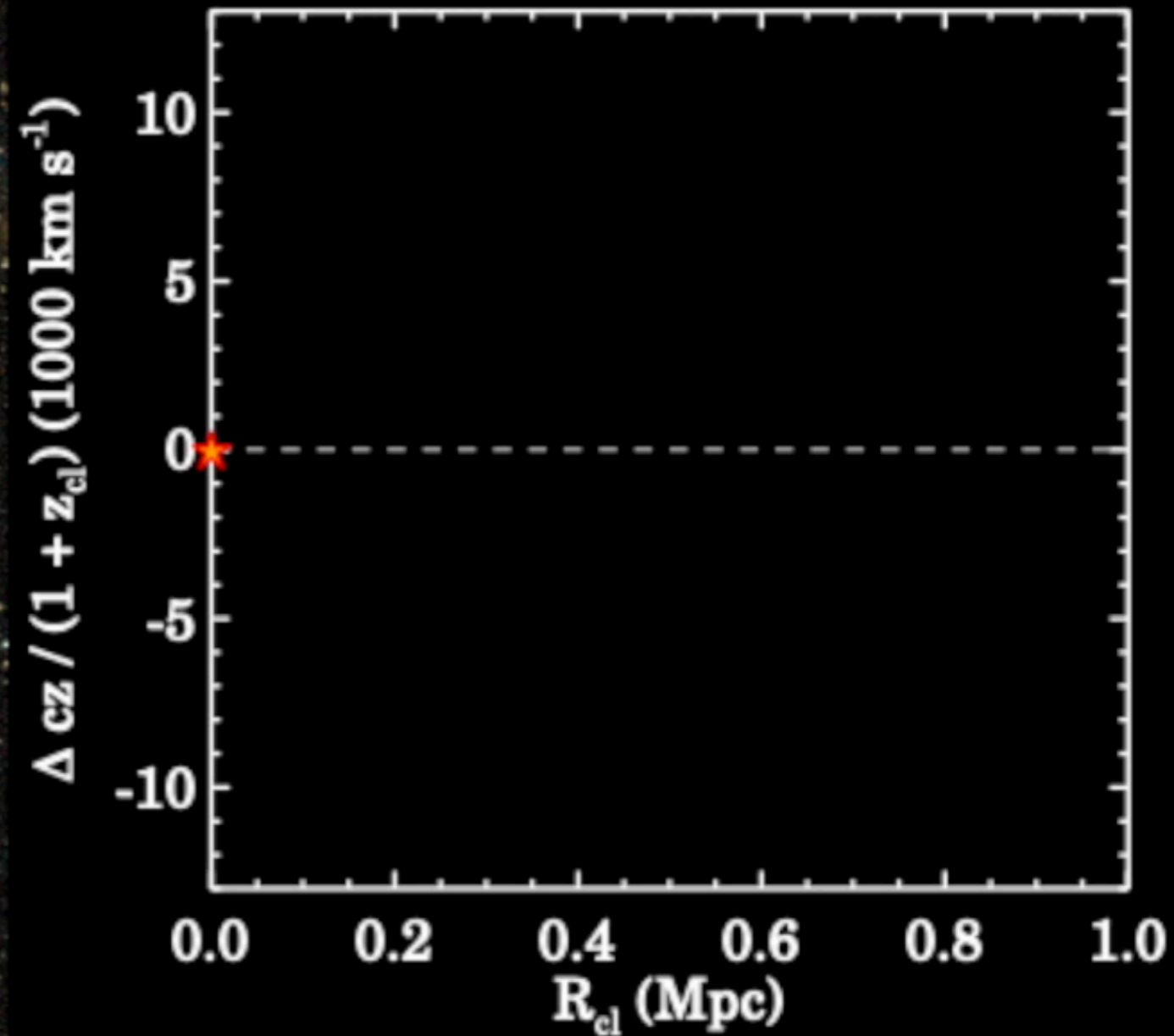
CfA2 redshift survey



Sohn et al. 2018a,b, 2020c, 2023a

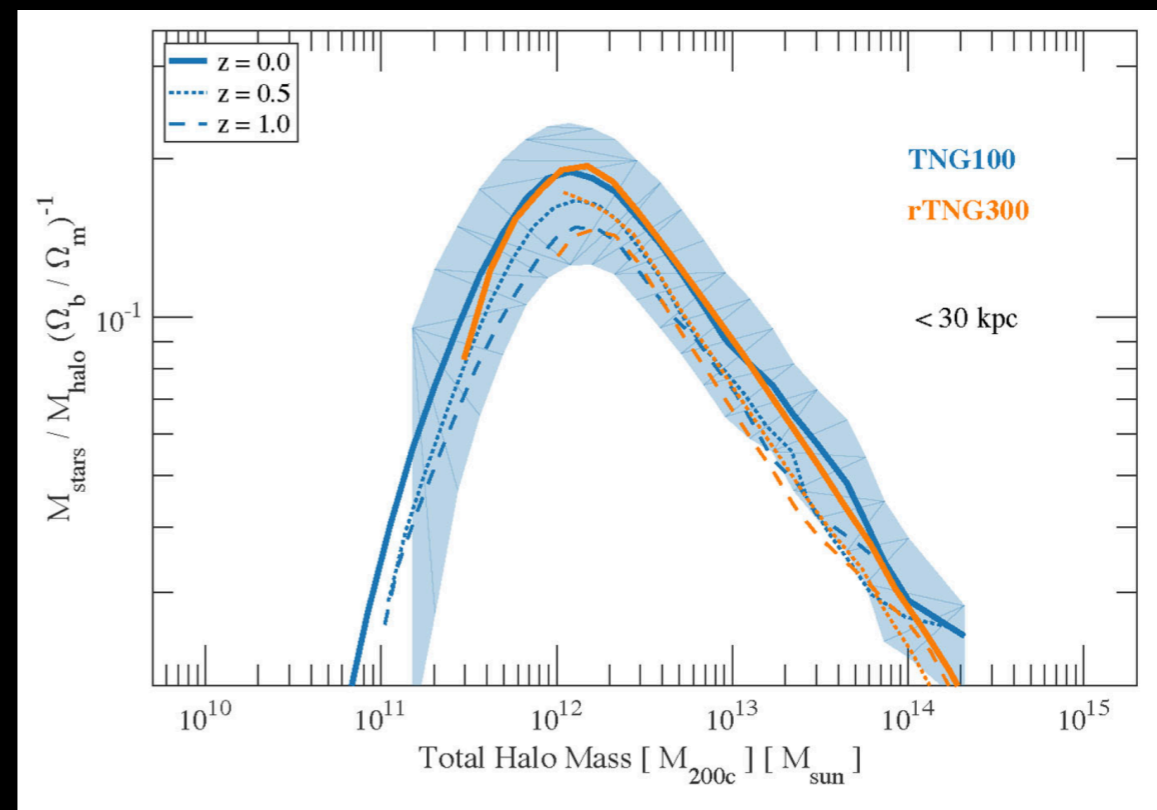
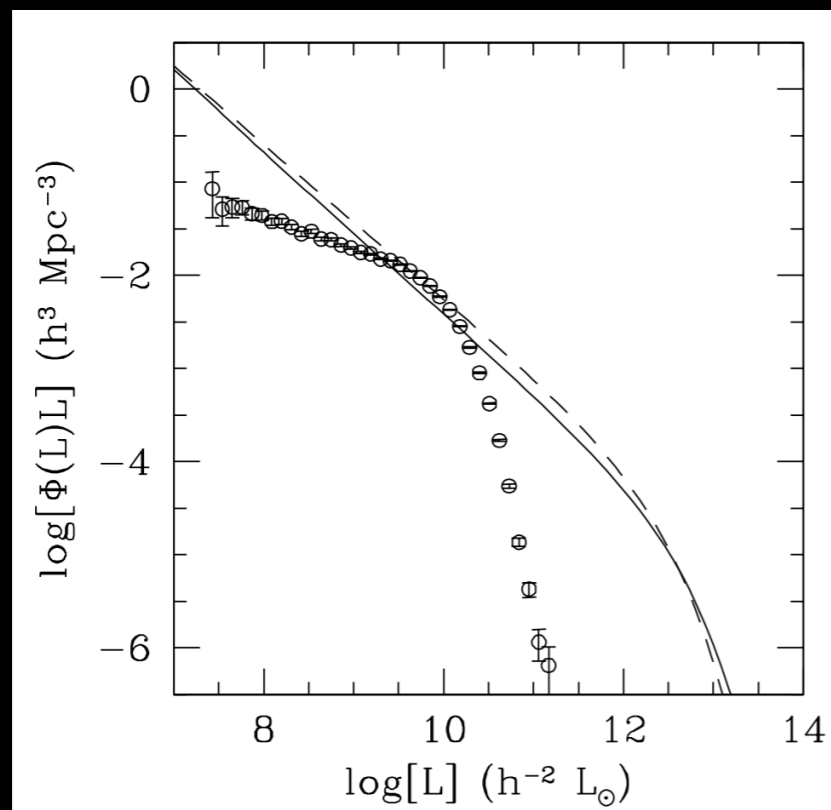


# Spectroscopic Survey of Clusters



# Velocity Dispersions - Power of Spectroscopy

- Direct observable
- Insensitive to complicated baryonic physics
- Baryonic proxies : Luminosity / Stellar mass
- Crowding / Complex baryonic physics / Feedback

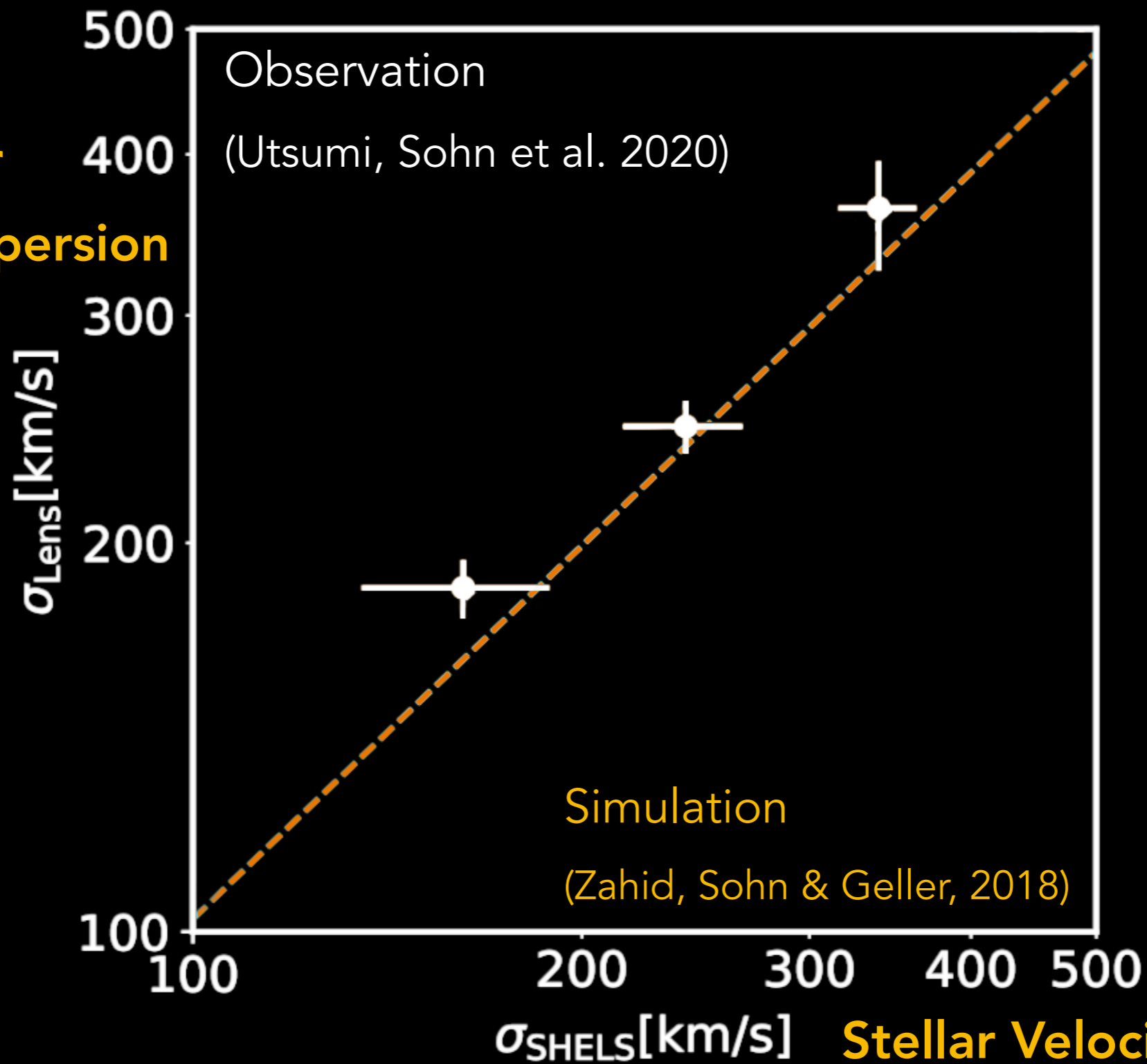




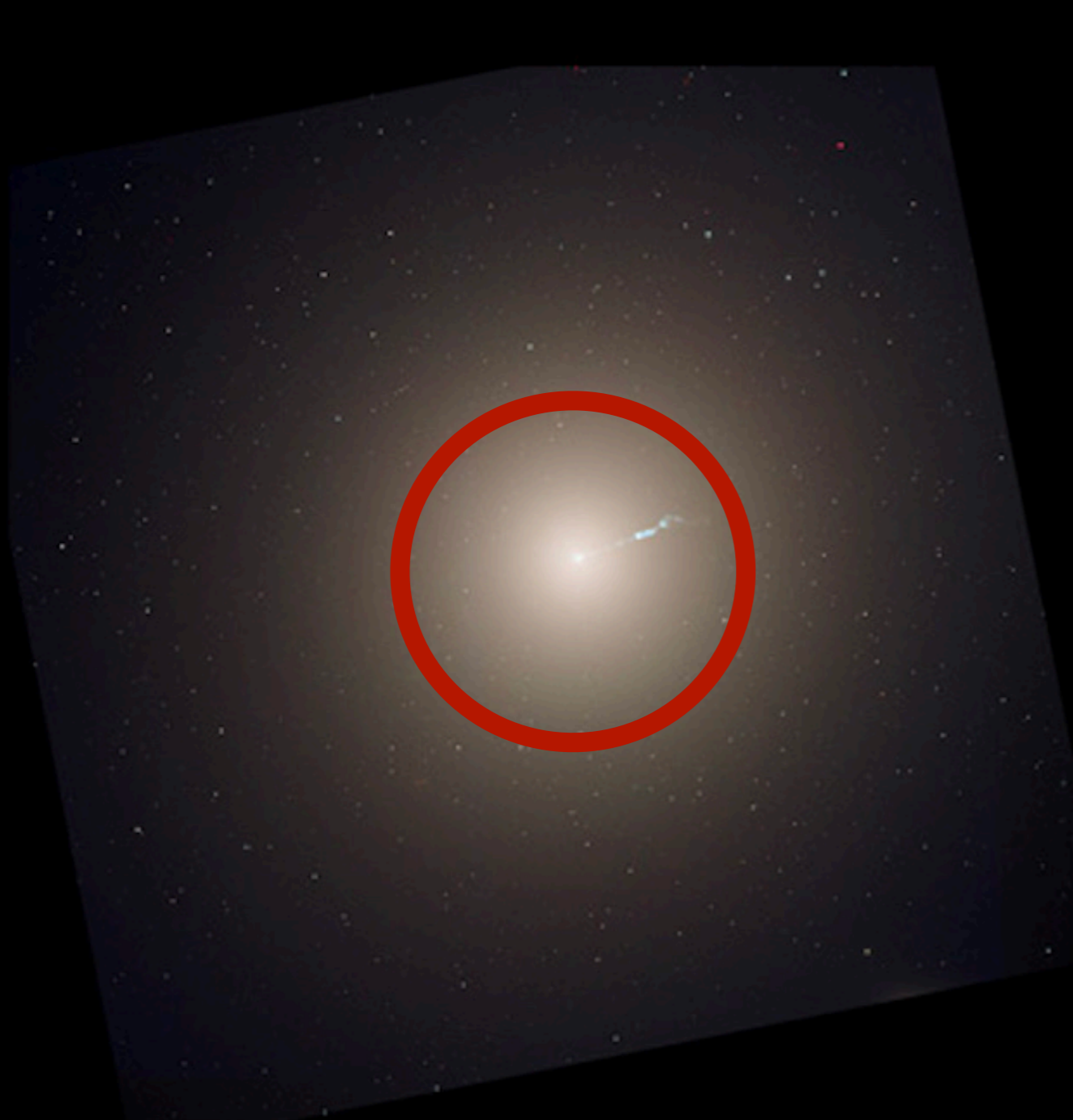
# Velocity Dispersions

**Dark Matter**

**Velocity Dispersion**



# Measuring $\sigma$ in Simulations



HUBBLE PHOTO OF M87

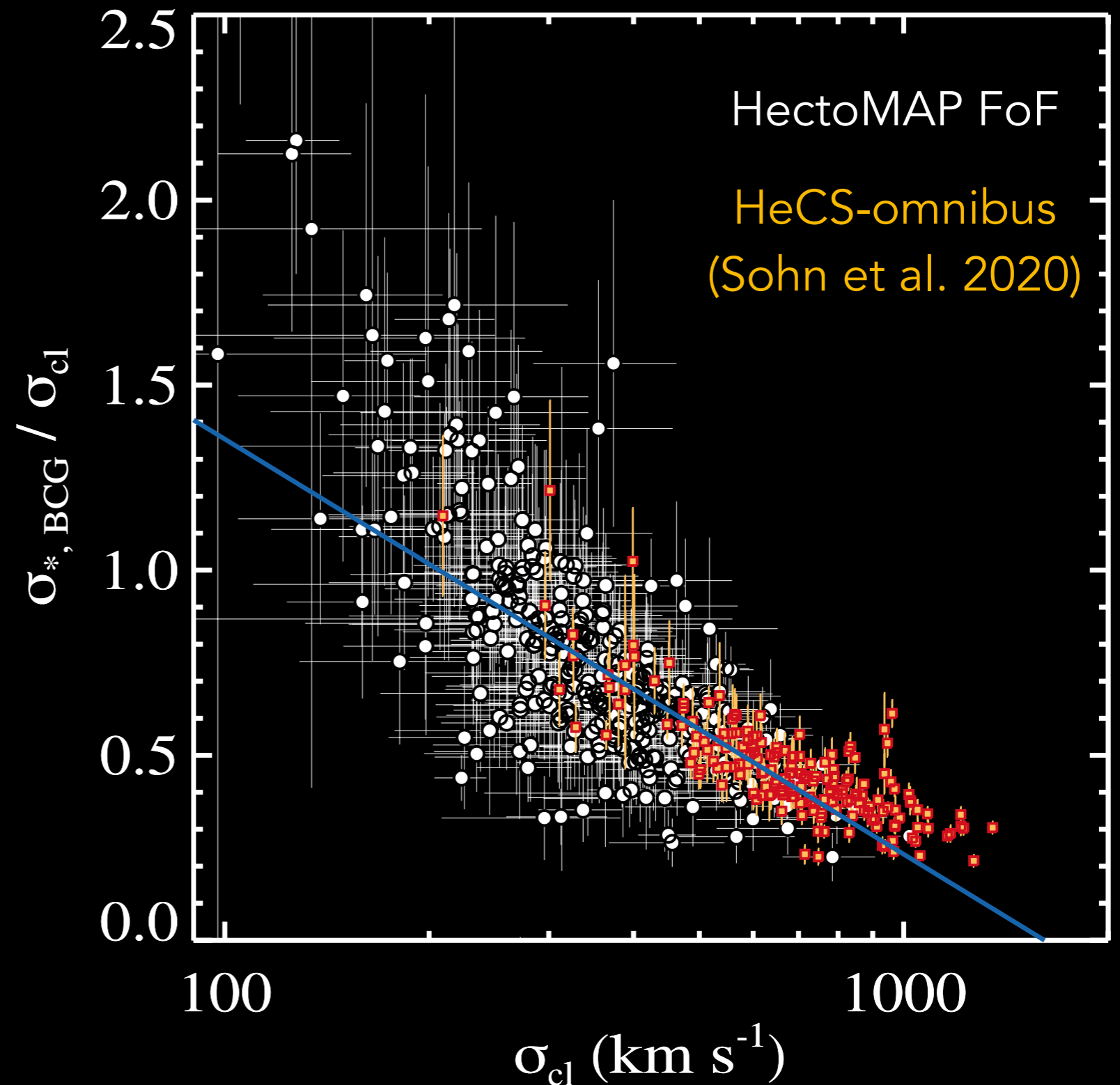


3D ILLUSTRATION OF M87

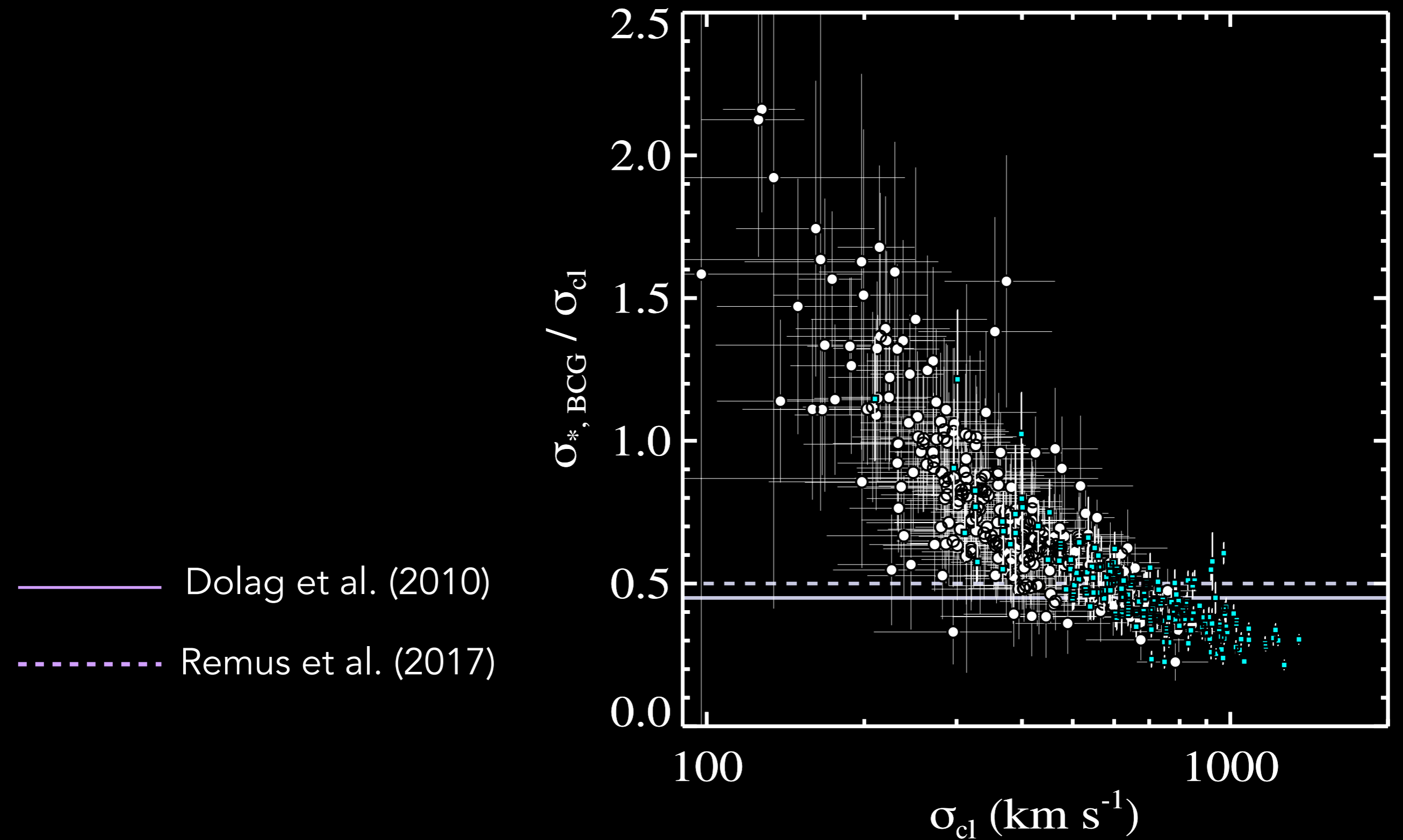
# Co-evolution of clusters and BCGs

- Cluster mass  $\sim \sigma_{cl}$
- BCG mass  $\sim \sigma_{*, BCG}$

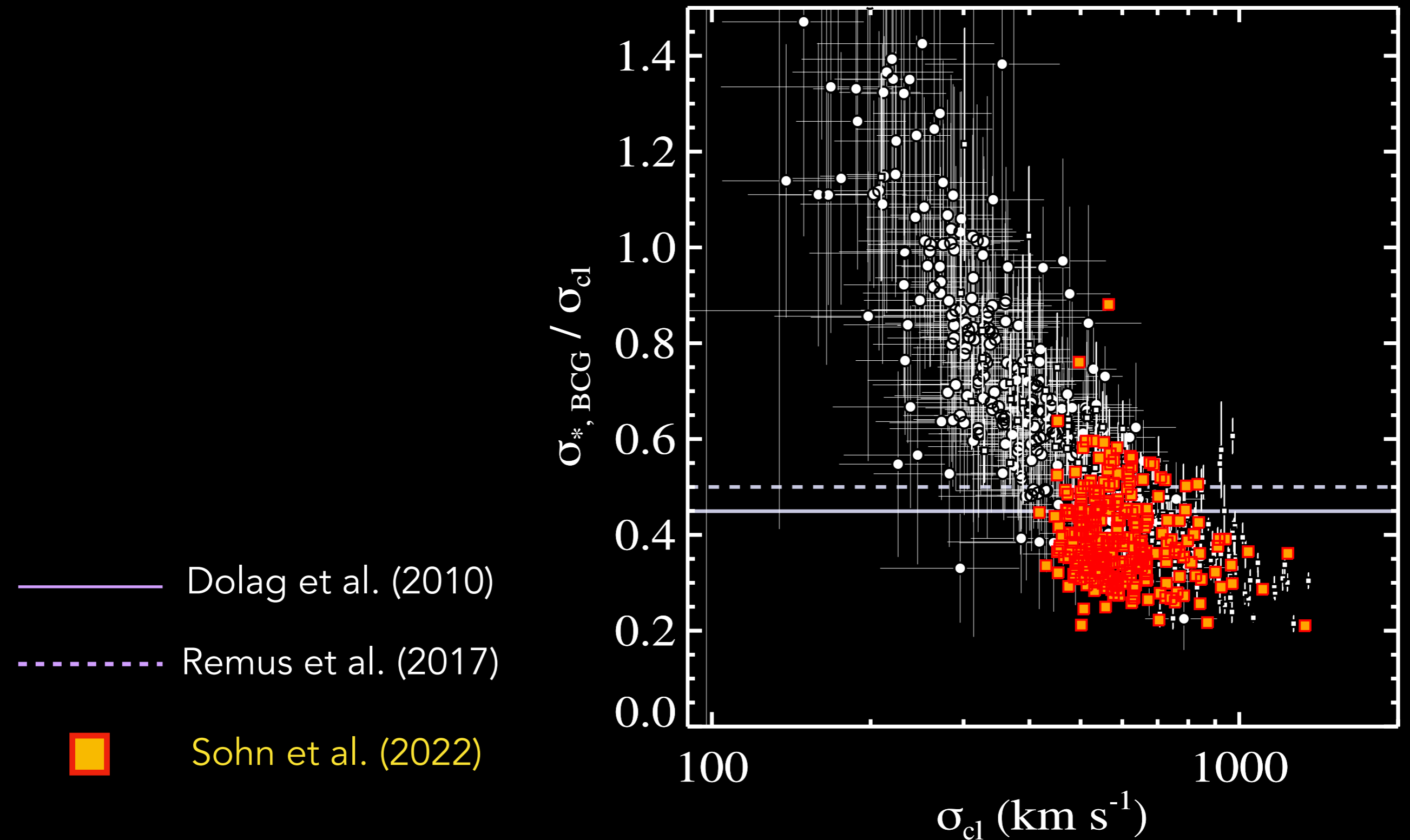
HeCS-omnibus  
(Sohn et al. 2020) :  
spec-surveys of  
227 clusters at  $z < 0.27$

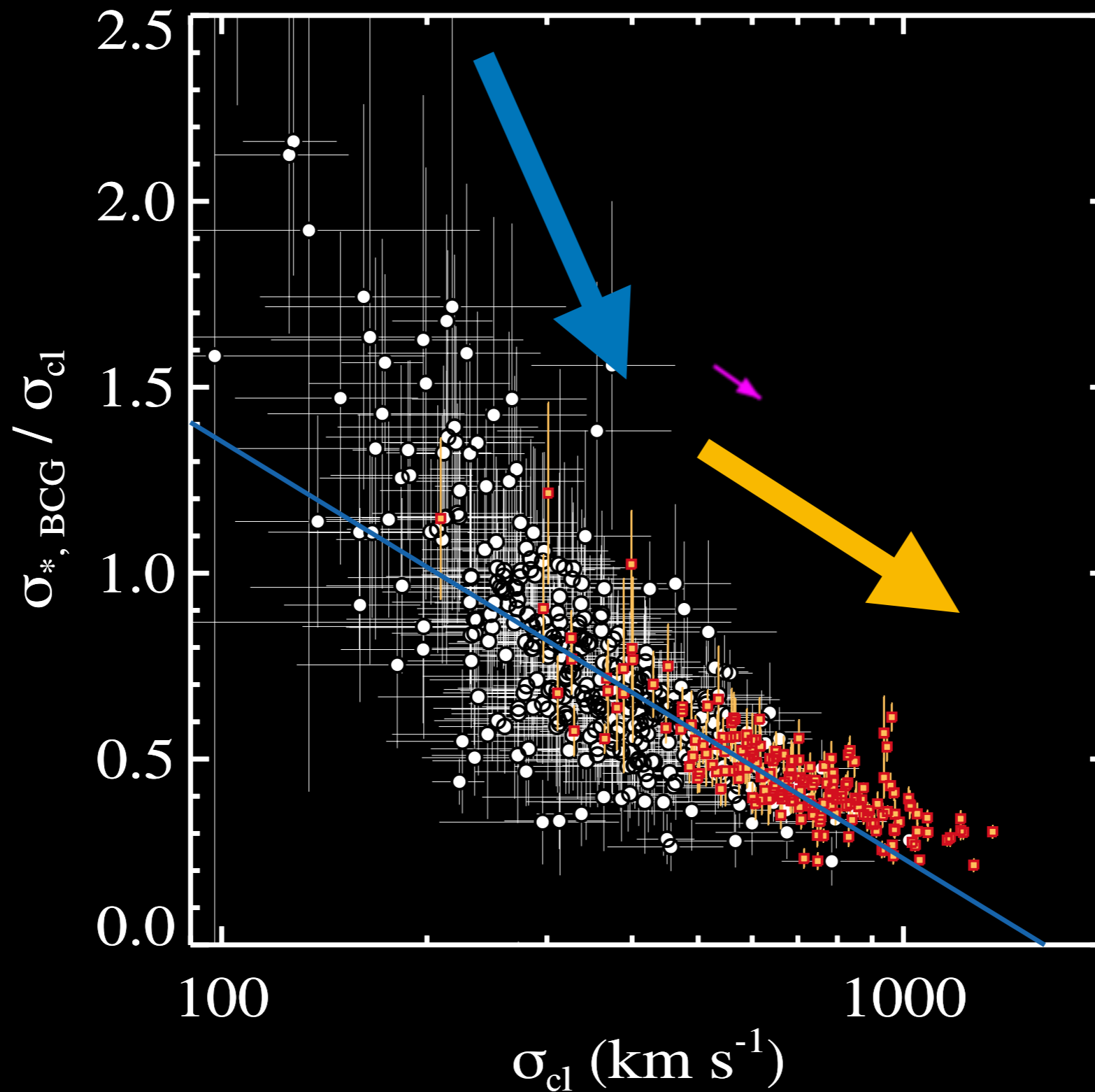


- Comparison with numerical simulations



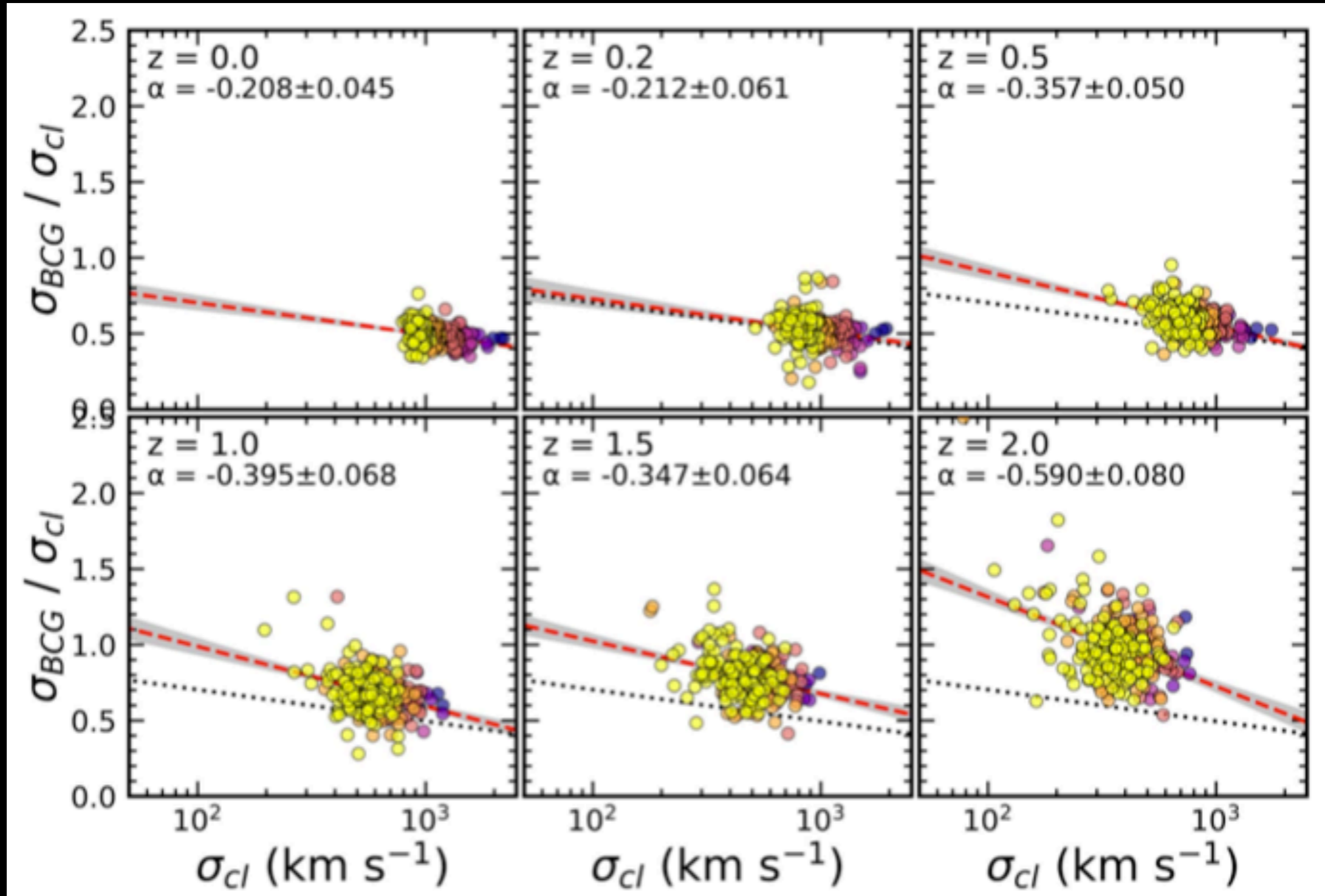
- IllustrisTNG simulation
- 280 simulated clusters with  $M > 10^{14} M_{\odot}$





- **Slow growth of the BCGs at large  $\sigma_{\text{cl}}$ : minor mergers**
- **Fast growth of the BCGs at small  $\sigma_{\text{cl}}$ : major mergers**

- Redshift evolution of the  $(\sigma_{\text{BCG}} / \sigma_{\text{cl}}) - \sigma_{\text{cl}}$  relation

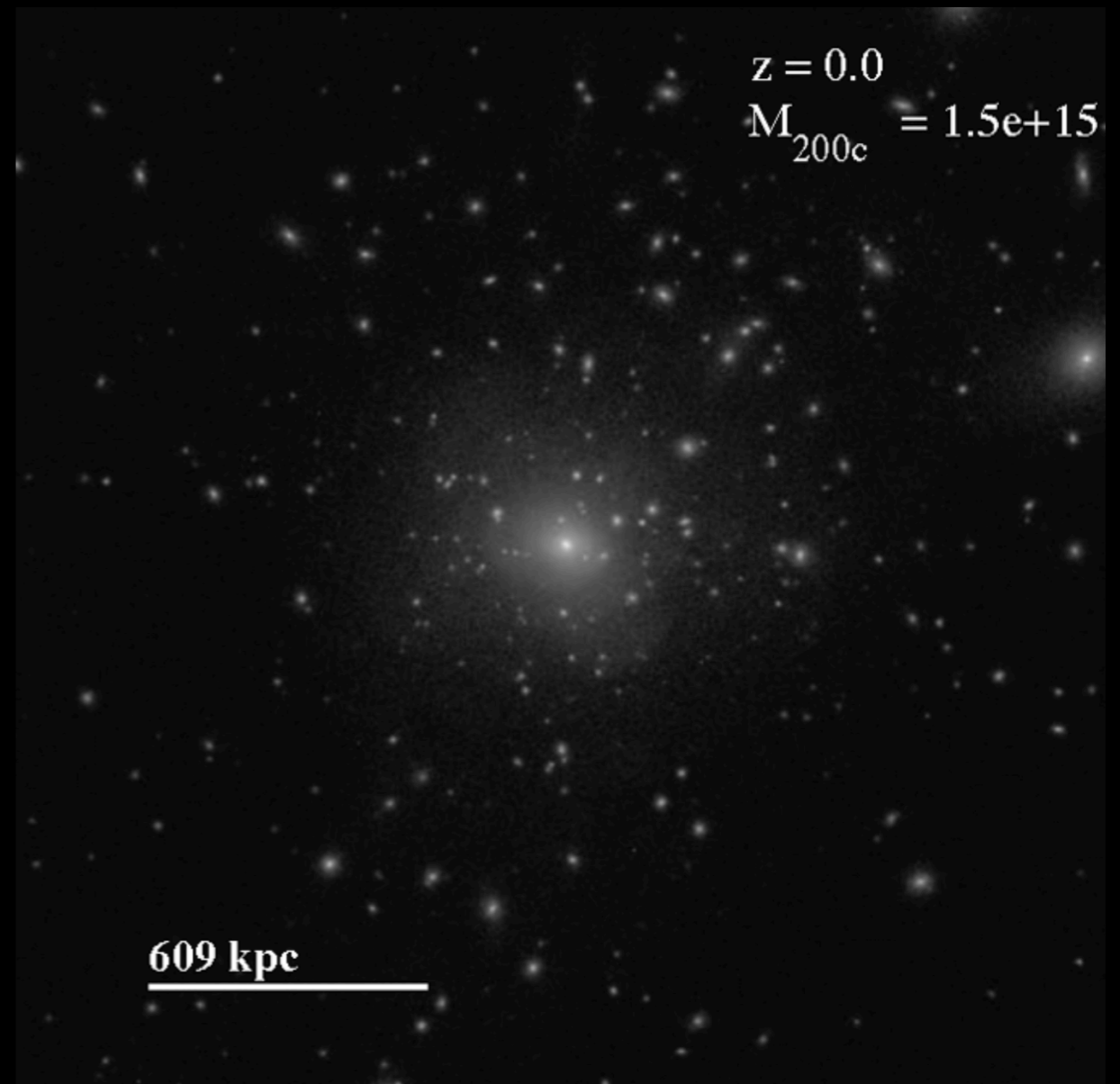


# Tracing DM mass distributions



A2029

Optical imaging



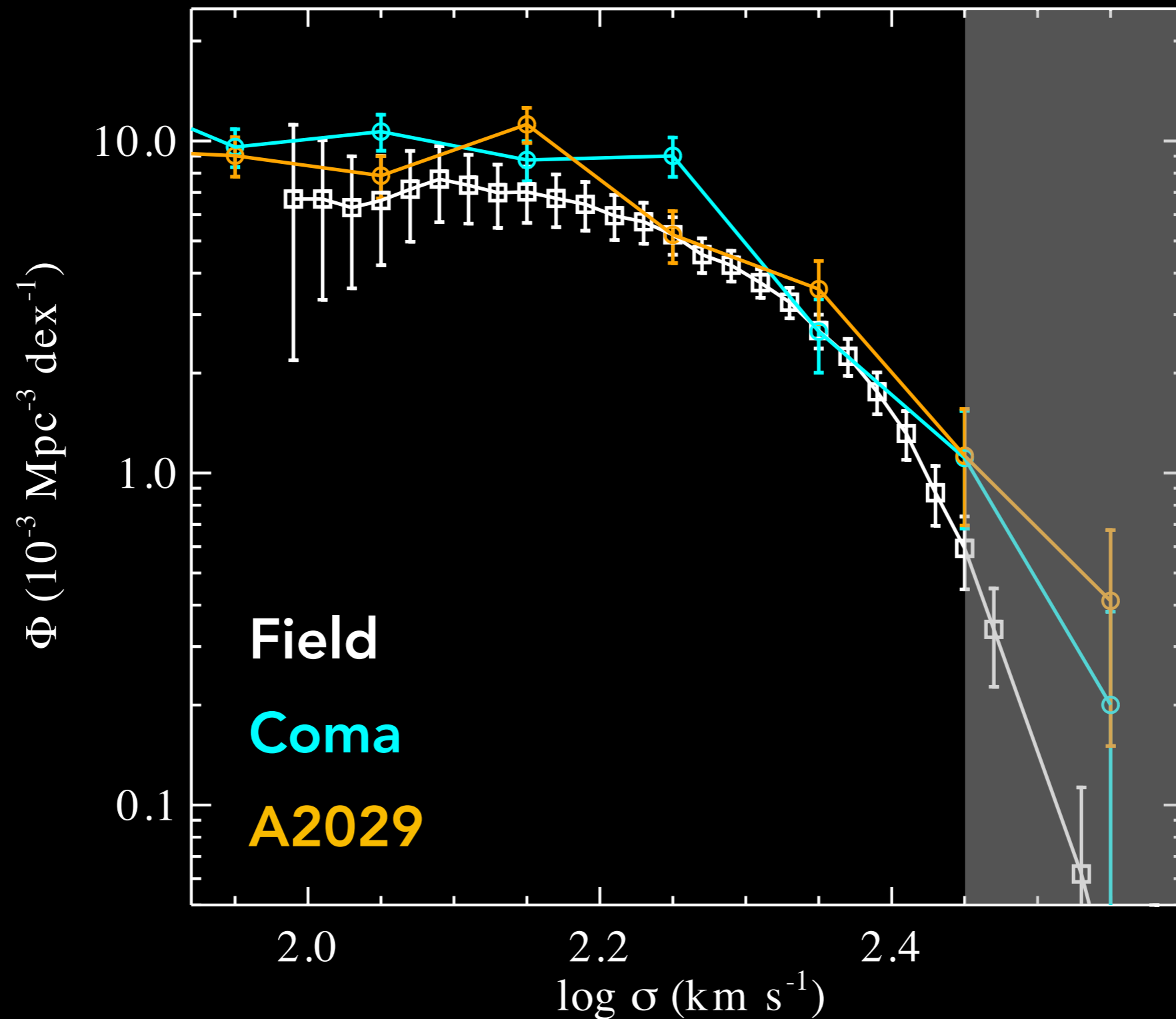
IllustrisTNG

Pillepich et al. 2018

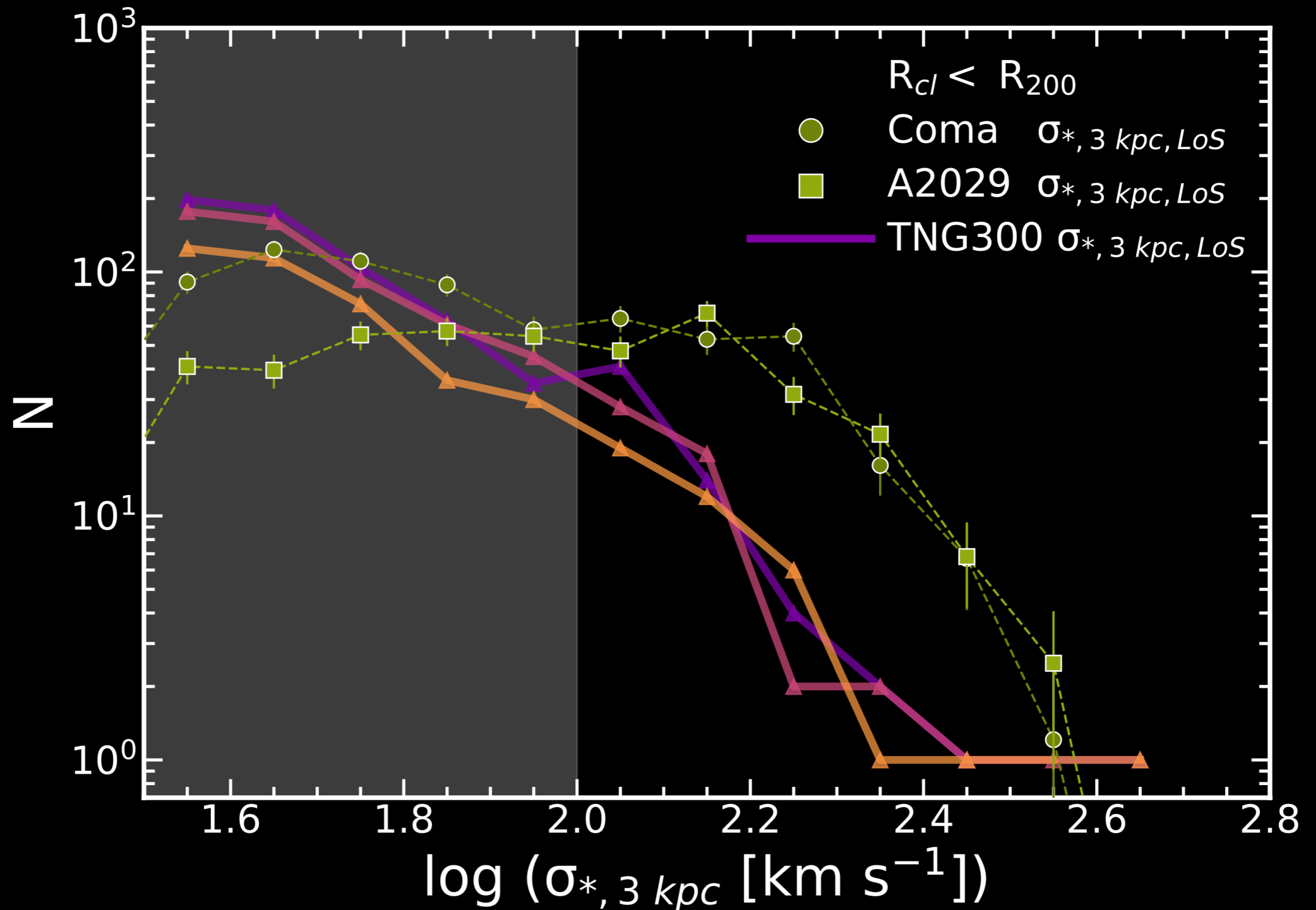


# Velocity Dispersion Functions

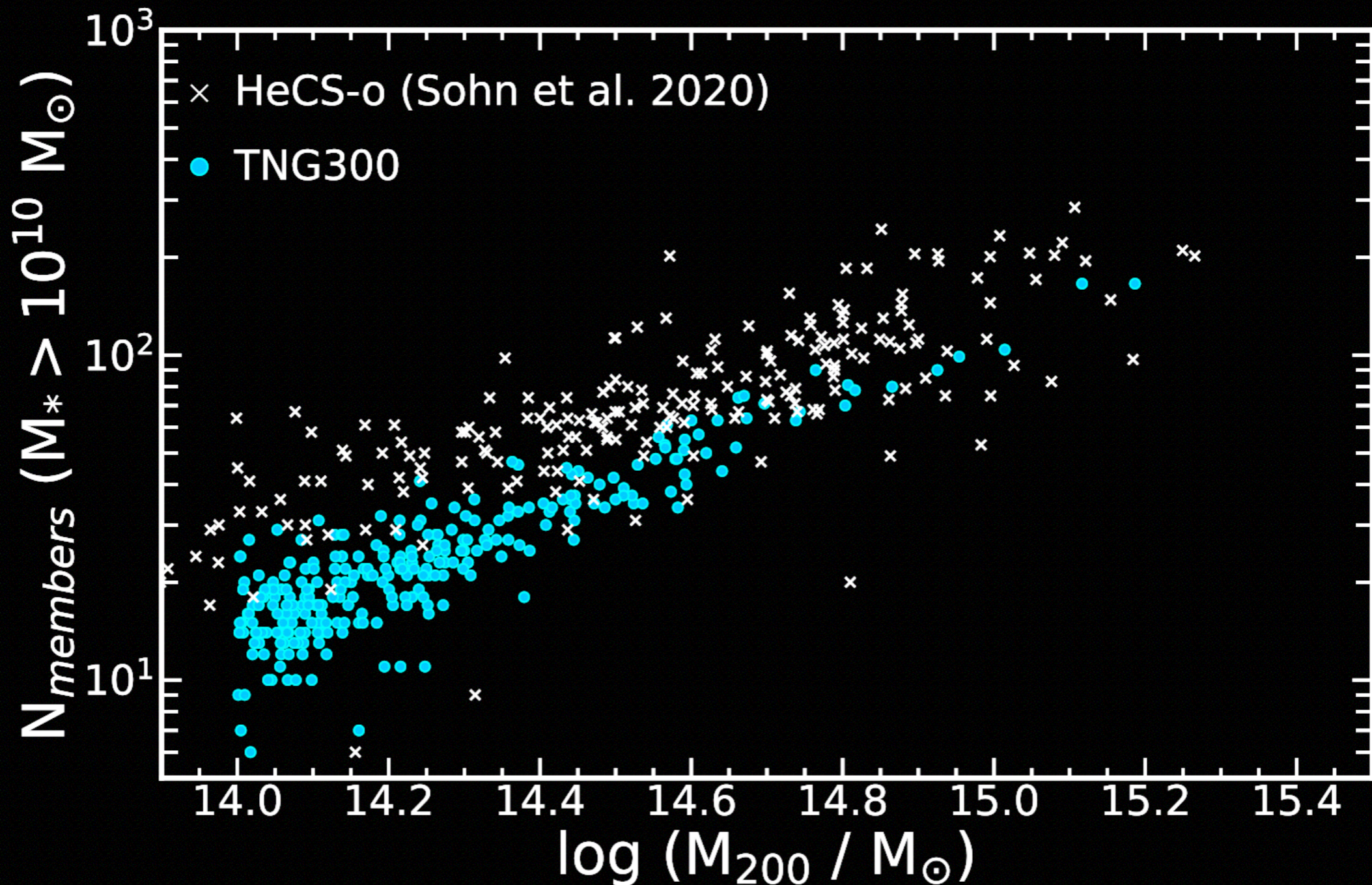
An excess at  $\sigma > 250$  km/s

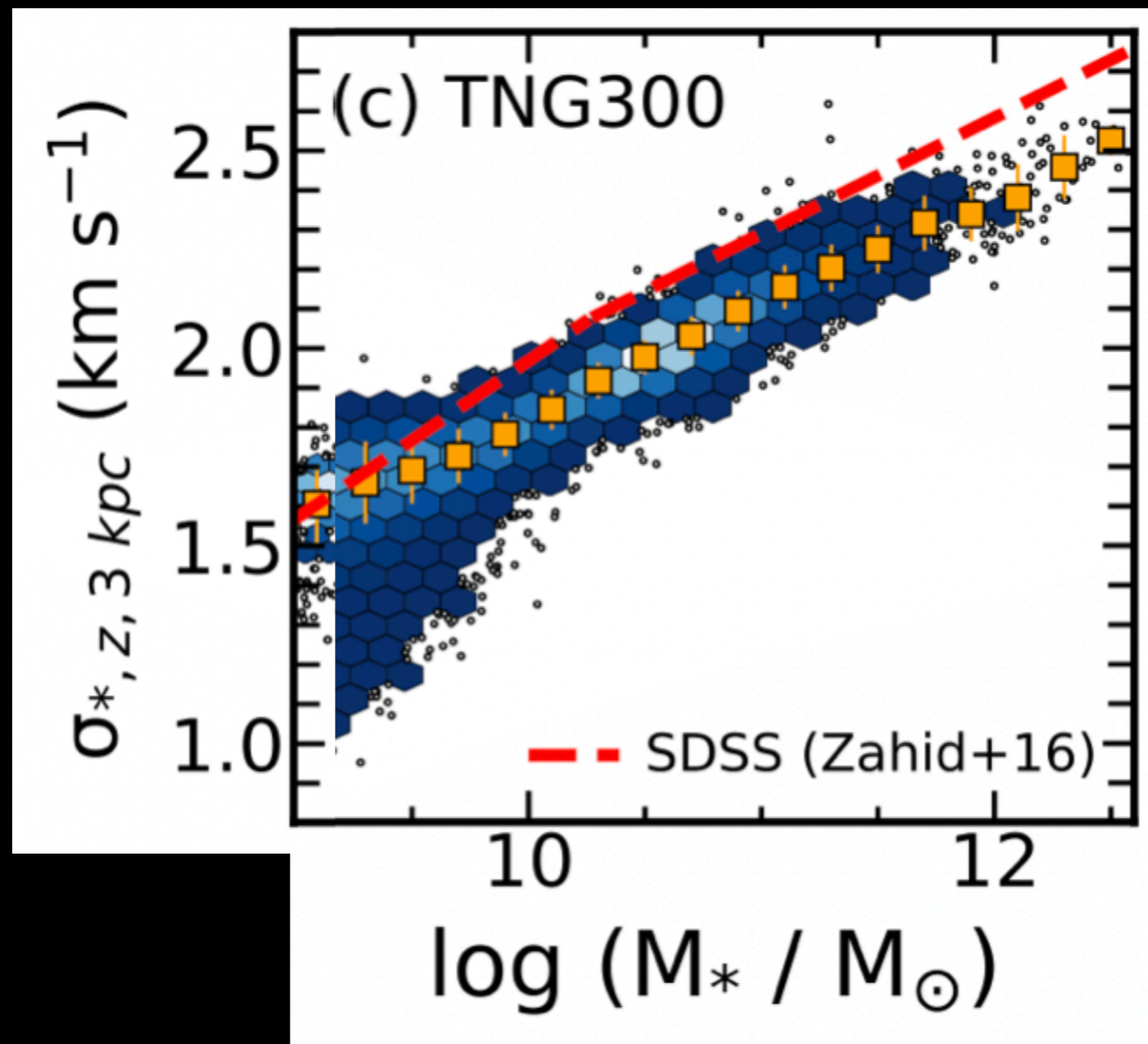


# Velocity Dispersion Functions



- Issue of stellar mass functions (SMFs)?
- Observed SMFs  $\neq$  Simulated SMFs in clusters





- TNG is not fine-tuned to match observed  $\sigma_*$
  - TNG  $\sigma_* \ll$  observed  $\sigma_*$  at given  $M_*$
  - No systematic change with different resolution, aperture, member particle identification ...
- Independent test for TNG simulations (e.g. feedback?)

# Summary

- Tracing clusters and cluster galaxies with  $\sigma_*$ s
- Future large spectroscopic surveys
- Theoretical guidance & calibration required

