Brightest Cluster Galaxies and their Relation to the Cluster Environment

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In collaboration with
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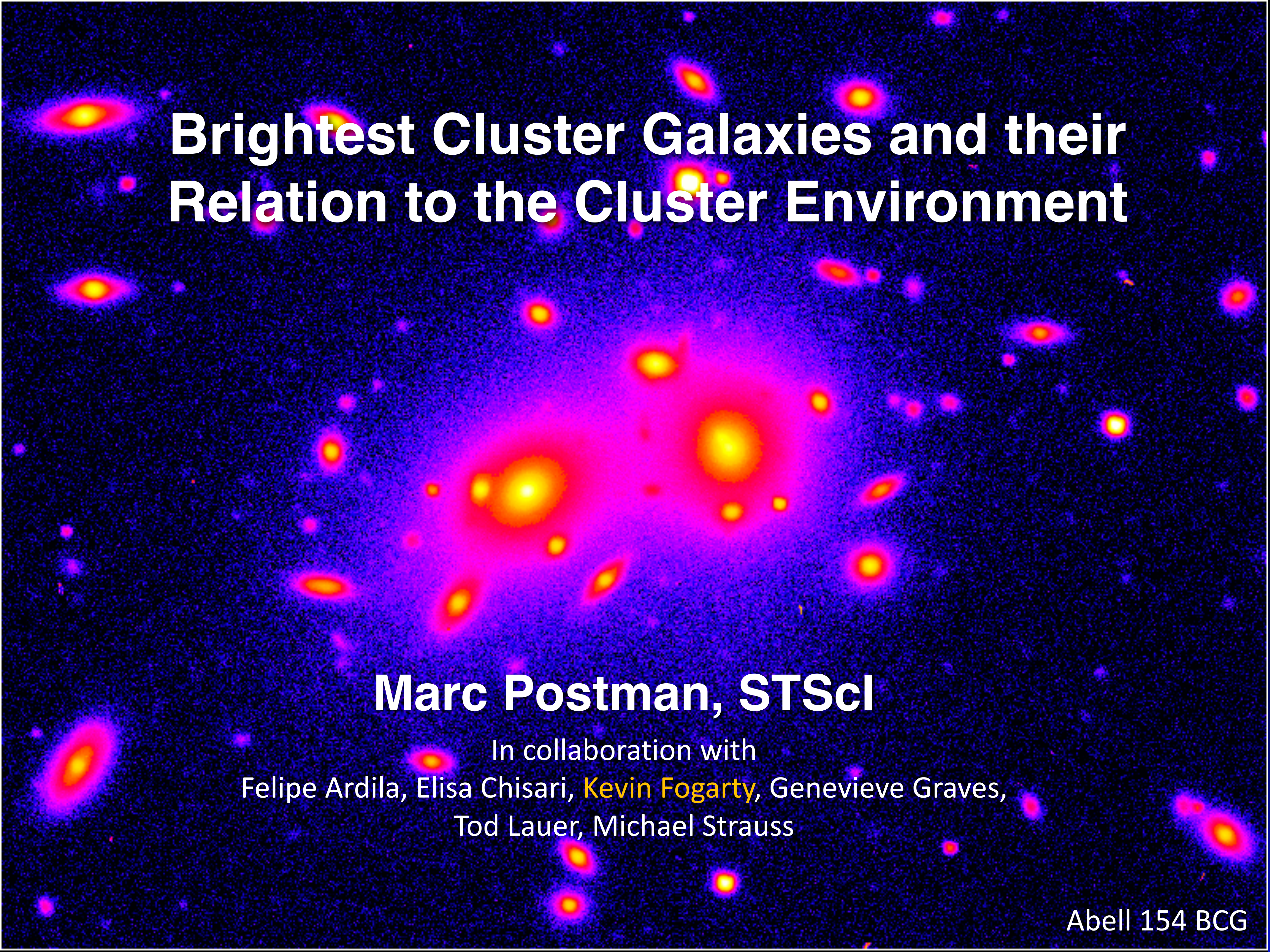

Abell 154 BCG

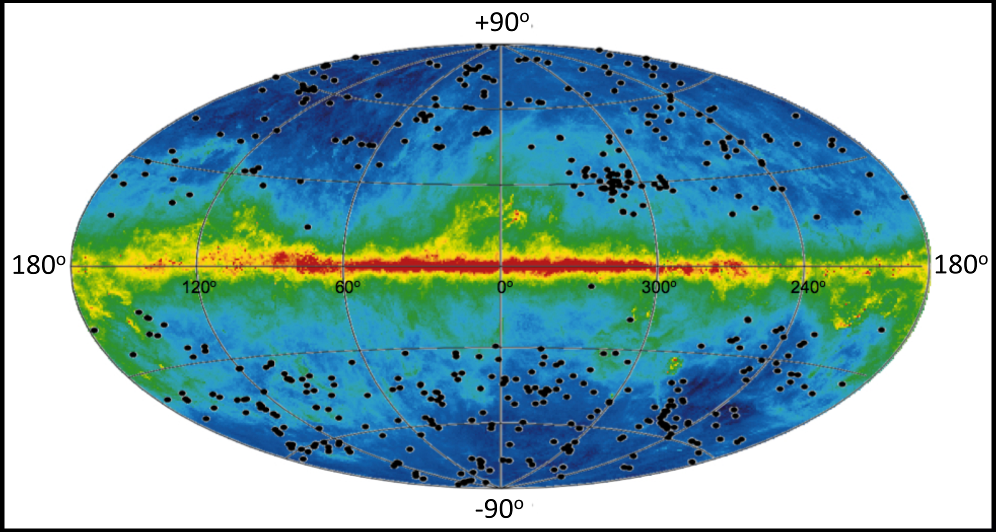
BCG Primer

- The most massive ($M_* > 10^{11.5}\ M_\odot$) galaxies in the local Universe.
- Often (but not always) the central “anchor” of clusters of galaxies.
- Often associated with strong X-ray halos.
- Harbor the most massive BHs: $M_\bullet > 10^{10}\ M_\odot$
- The most luminous galaxies may be “special” because their formation and evolution are tied to physical mechanisms unique to rich galaxy clusters.
- BCG properties (luminosity, outer profile, SFR) correlate with cluster X-ray luminosity & ICM properties.
- Bright standard candles: $\sigma_{L,bcg} = 0.20$ mag (~13% distance error per BCG).

Key Questions

1) What are the properties of BCGs?
2) Where do BGCs reside in their clusters?
3) How are the properties of BCGs related to their hosting clusters?
4) How do BCG properties evolve with time?

BCG Samples Used in This Work



- All Abell clusters $z \leq 0.08$ (433 BCGs with |b|>15º)
- Select BCG by metric luminosity only. (Must be an elliptical galaxy.

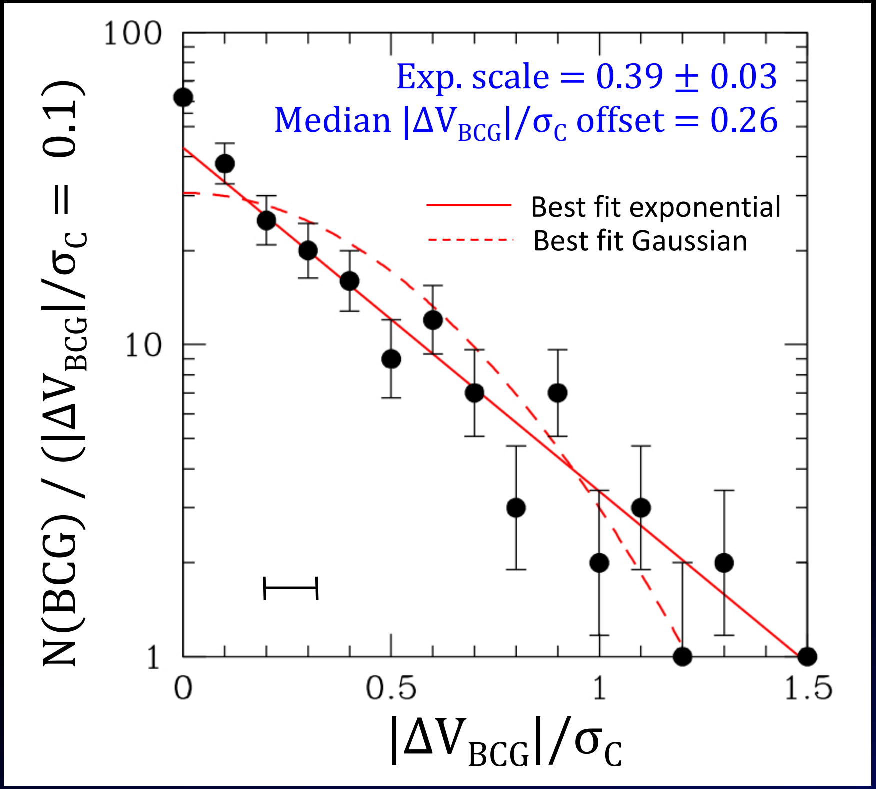
- CLASH Program
- 20 X-ray Selected Clusters
- HST imaging in 16 bands from 200 nm – 1600 nm.

RELICS HST Data

Position of Current Epoch BCGs in Their Clusters

Lauer, Postman, Strauss et al. 2014

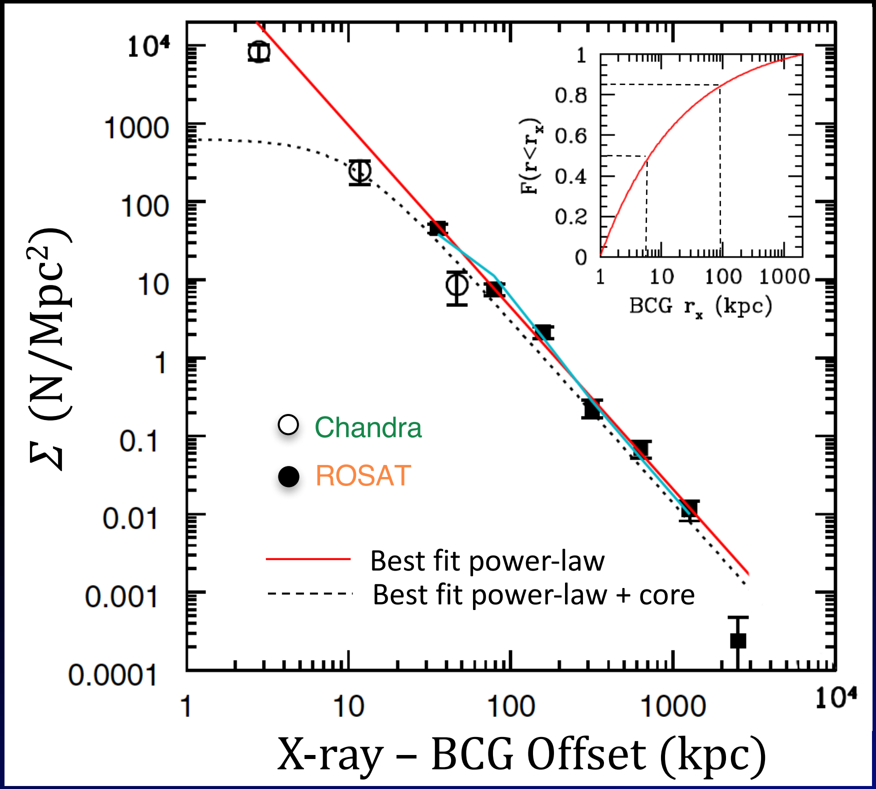
Normalized Velocity Offset



$$N\sim e^{-2.5\pm0.2\,|\Delta v_{\mathrm{BCG}}|/\sigma_c}$$

Gaussian dist'n rejected: $P_{AD} < 6 \times 10^{-5}$

Projected Radial Offset from X-ray Center

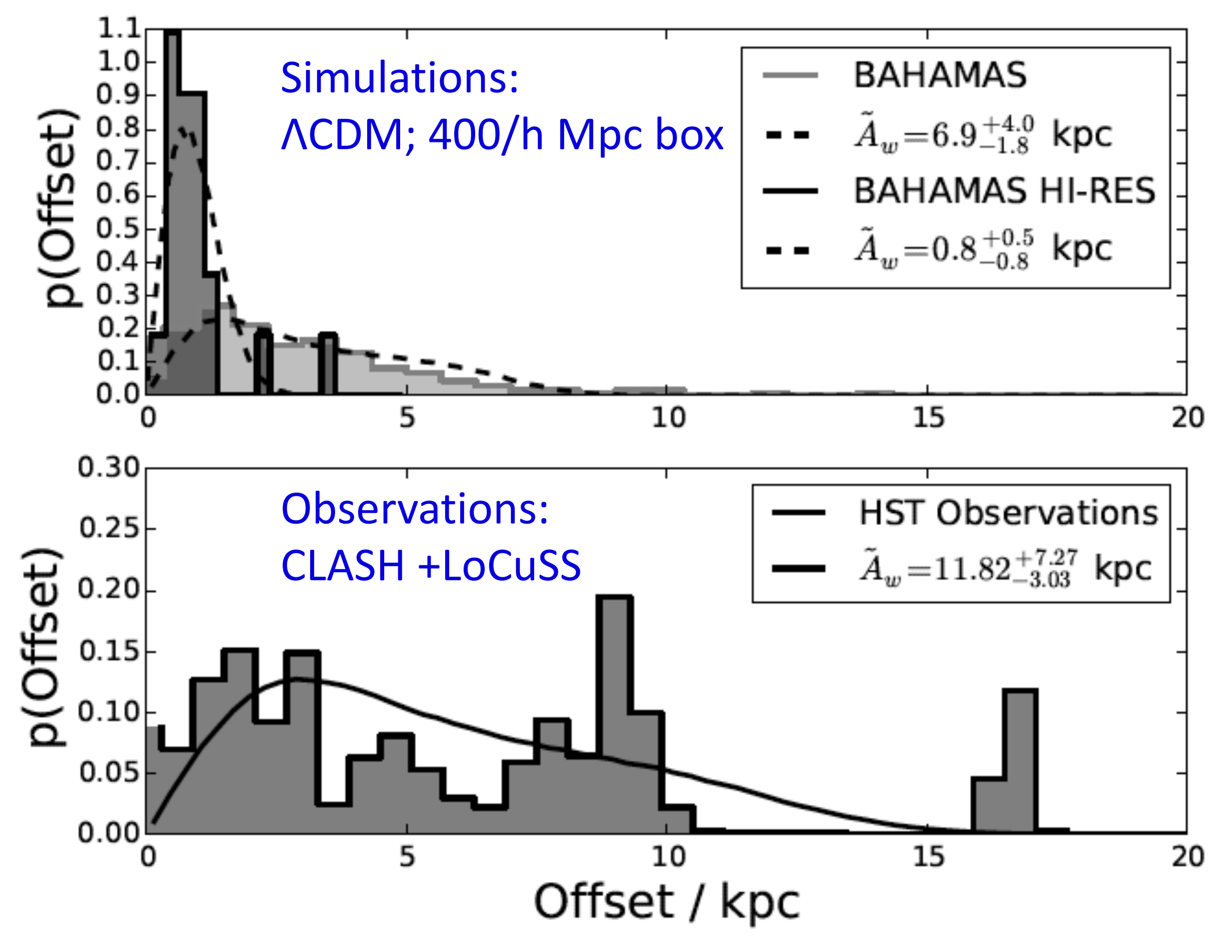


$$\Sigma \sim {r_x}^{-2.3\,\pm0.1}$$

15% of BCGs have $r_x > 100$ kpc

Power law out to $r_x \sim 1$ Mpc

BCG Wobble Also Seen Relative to Dark Matter Distribution

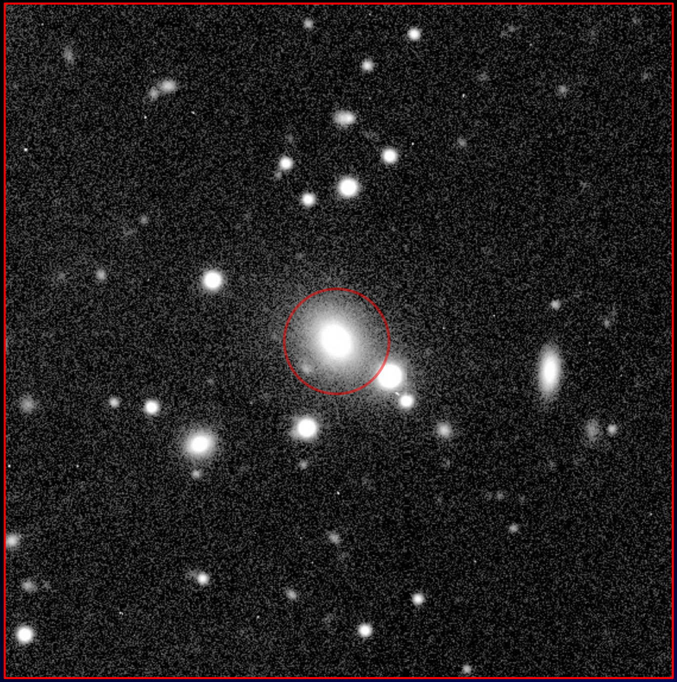


Harvey et al. 2017: "A detection of wobbling BCGs within massive galaxy clusters"

The alpha Parameter

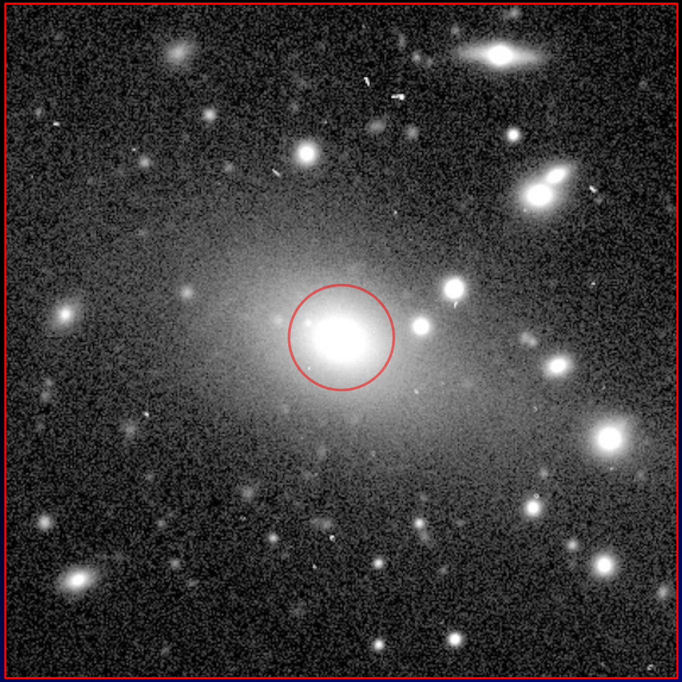
$$\alpha = \left.\frac{d\log L(r)}{d\log r}\right|_{r = R_m}$$

R_m = 14.3 kpc (h=0.7)
“Metric Radius”



α = 0.28

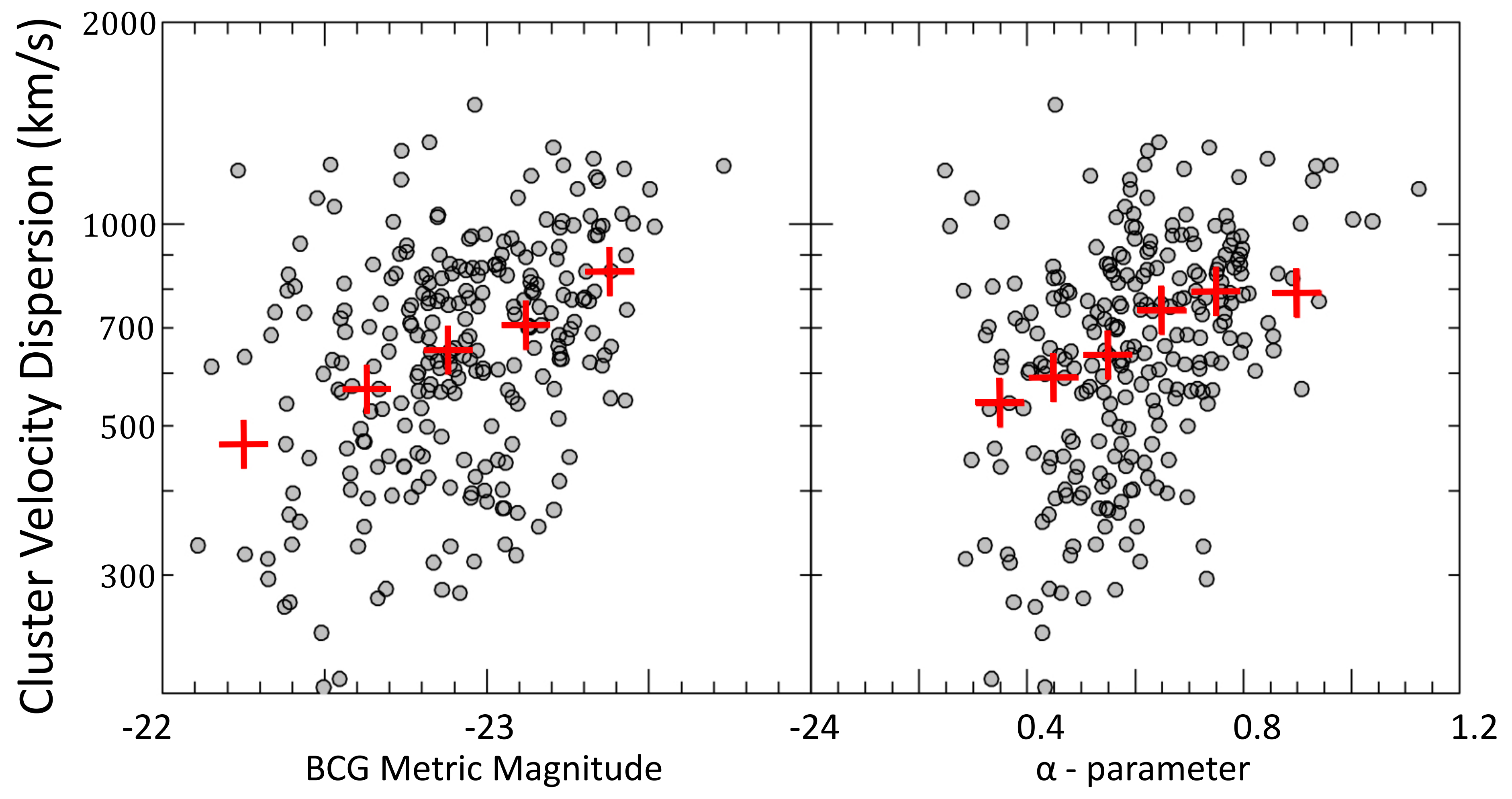
Abell 602 @ z = 0.061



α = 0.86

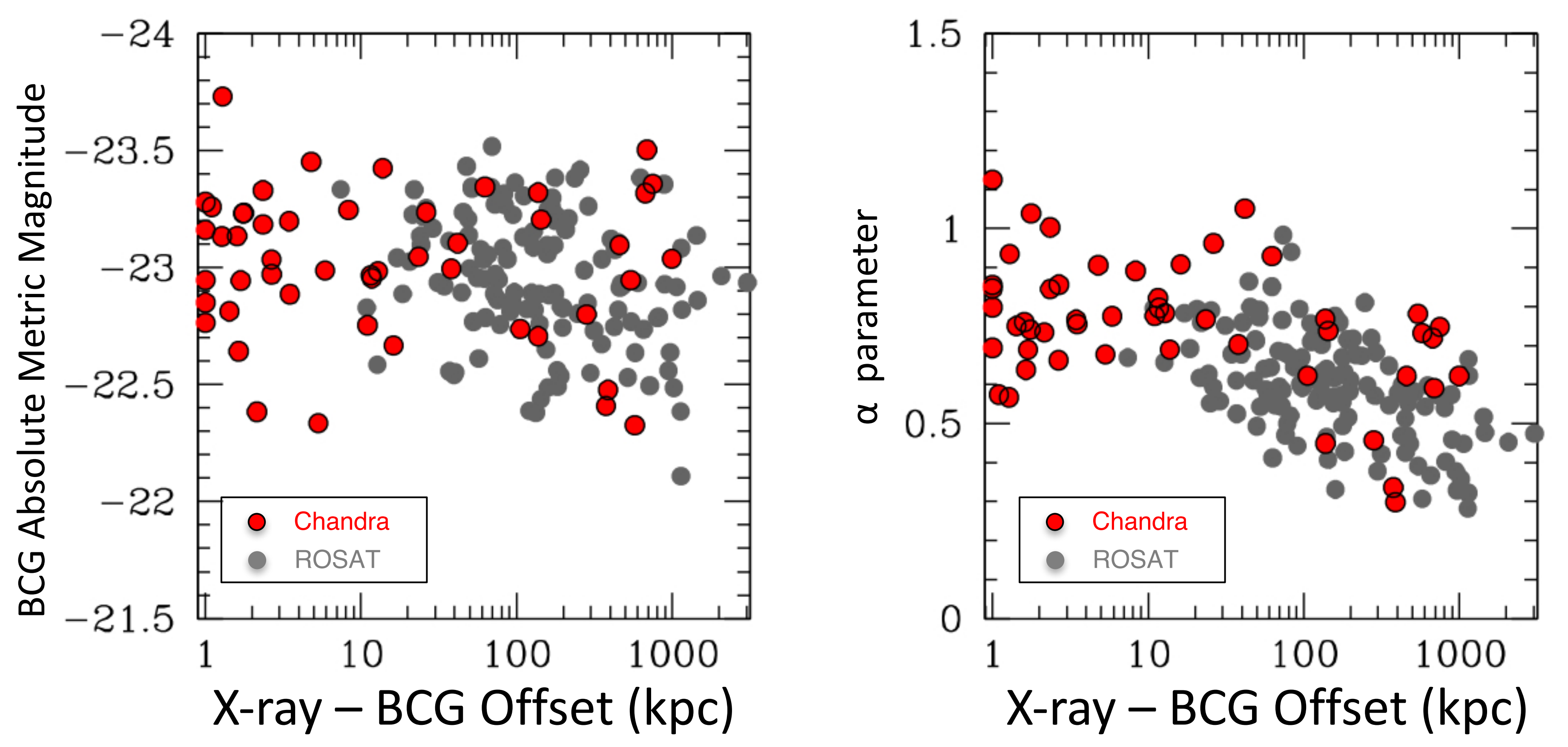
Abell 2734 @ z = 0.062

Bigger, more luminous BGCs are in more massive clusters



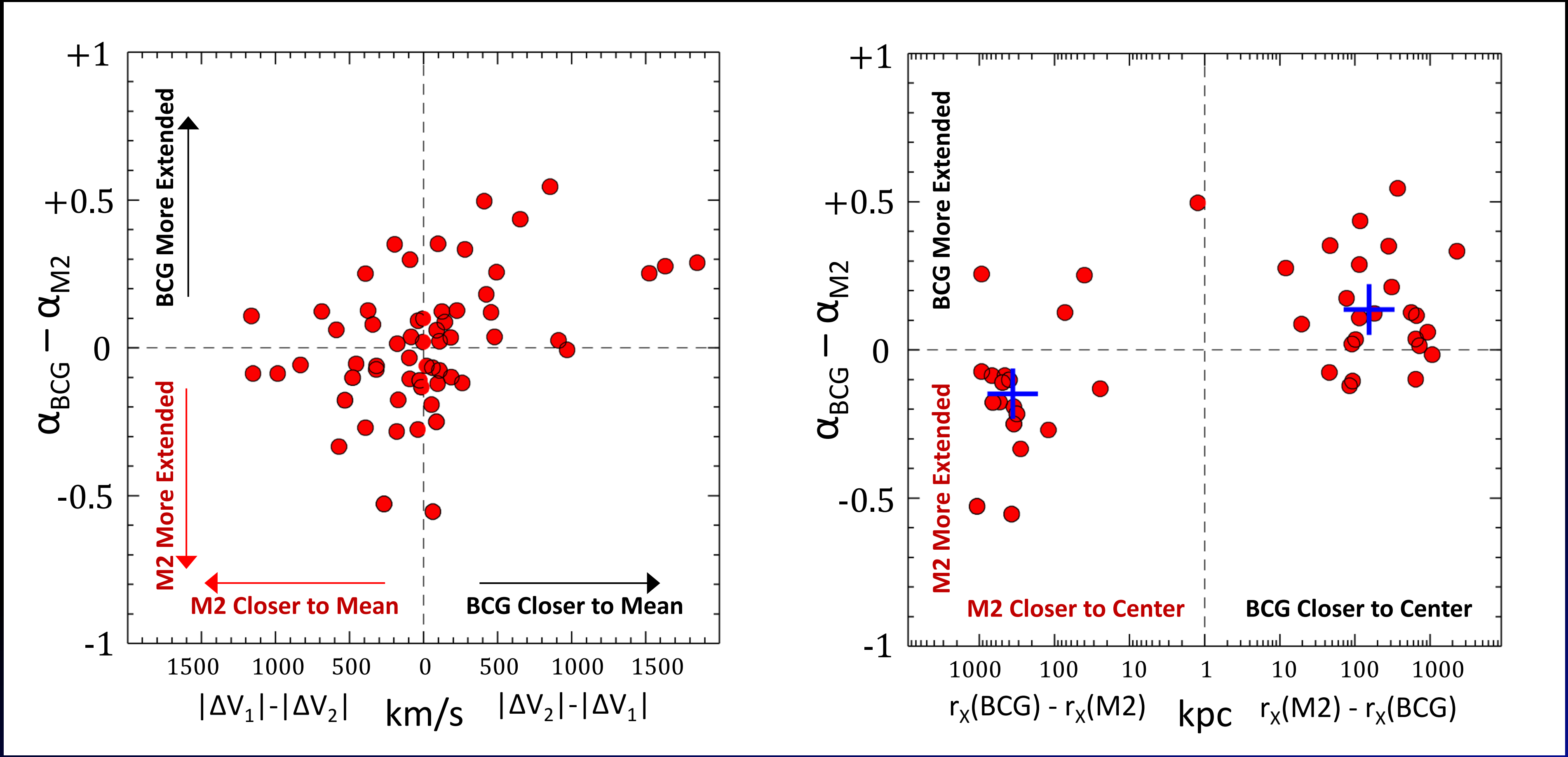
Lauer, Postman, Strauss et al. 2014

BGCs closer to the cluster center are more extended, but not more luminous



Lauer, Postman, Strauss et al. 2014

BCG vs. "rival" M2 – The galaxy closest to the cluster center is more extended

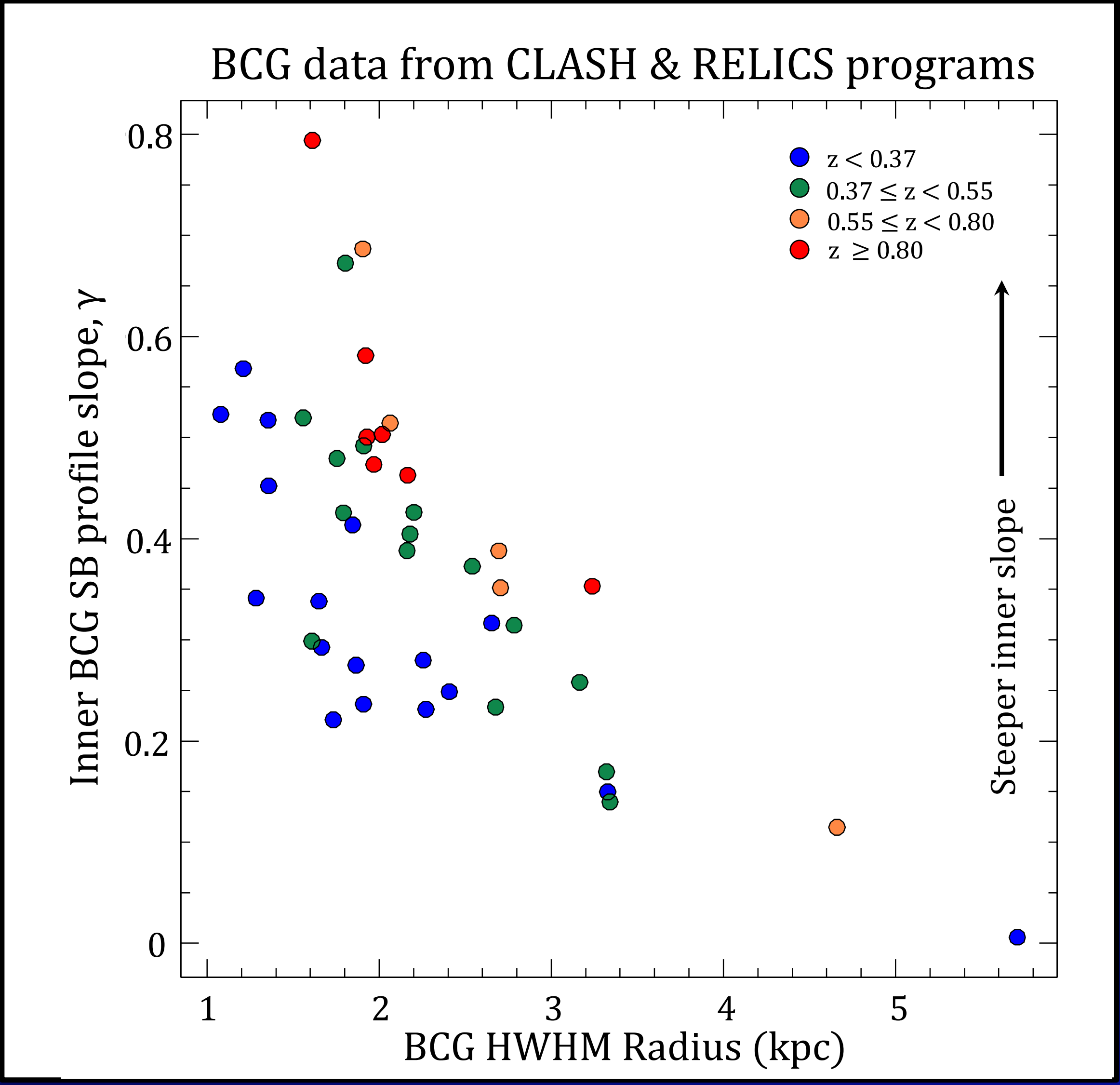


BCG vs. M2 : Velocity Offset

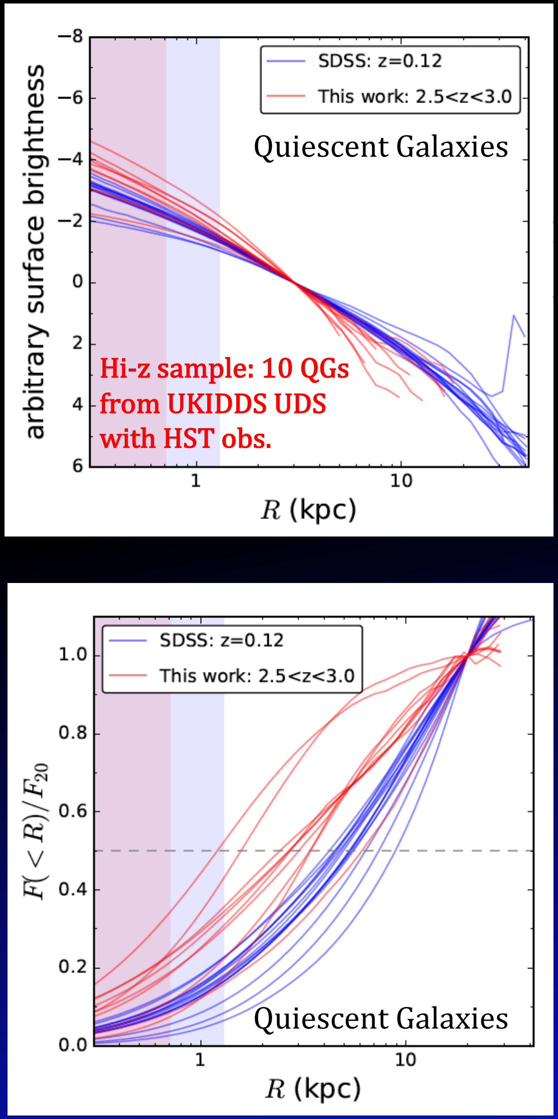
BGC vs. M2: X-ray Offset

Lauer, Postman, Strauss et al. 2014

Central BCG SB profile flattens over time; Larger BCGs tend to have flatter central profiles


BCG data from CLASH & RELICS programs

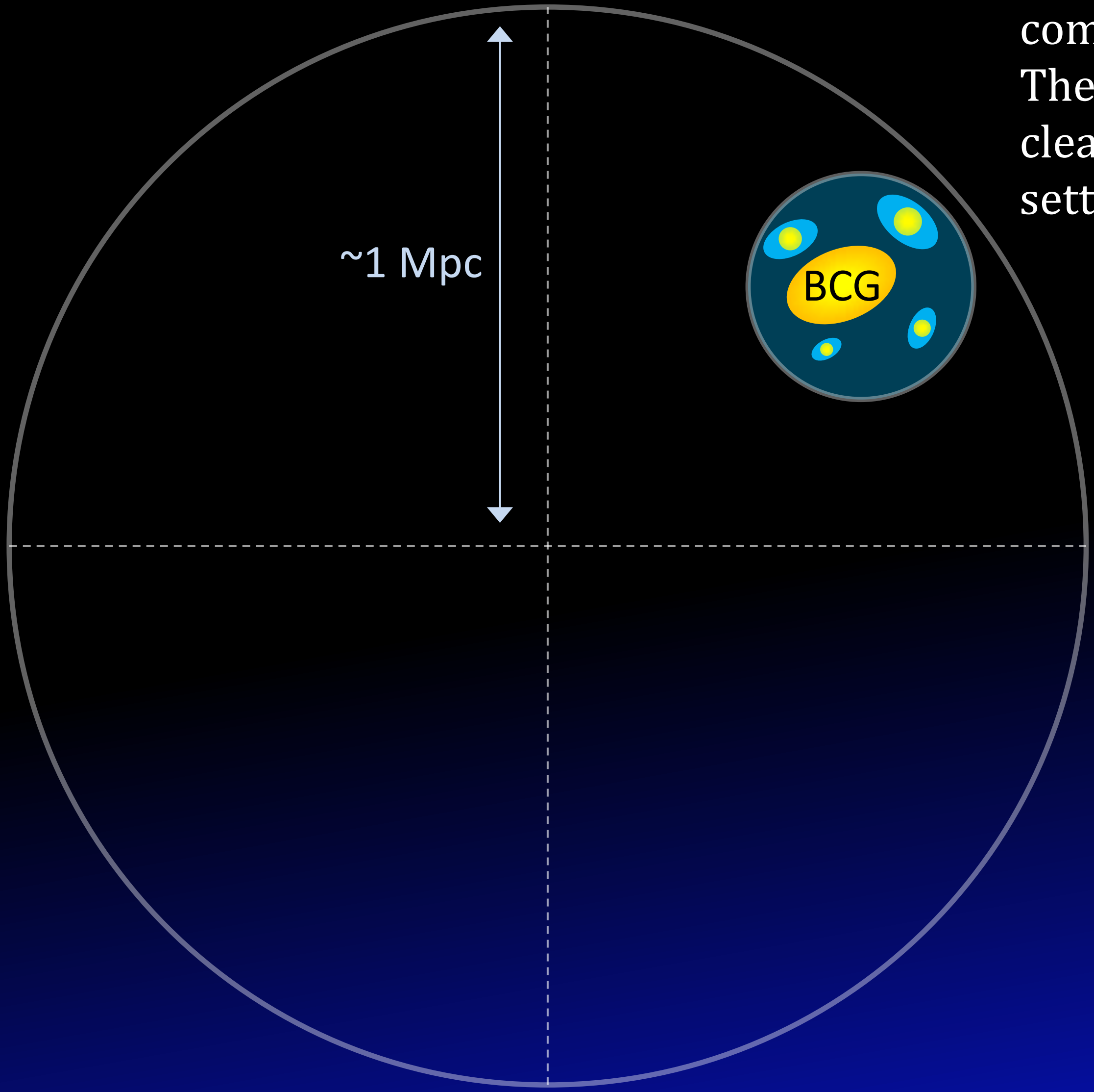
Postman et al. 2018 (in prep)



Hi-z sample: 10 QGs from UKIDDS UDS with HST obs.

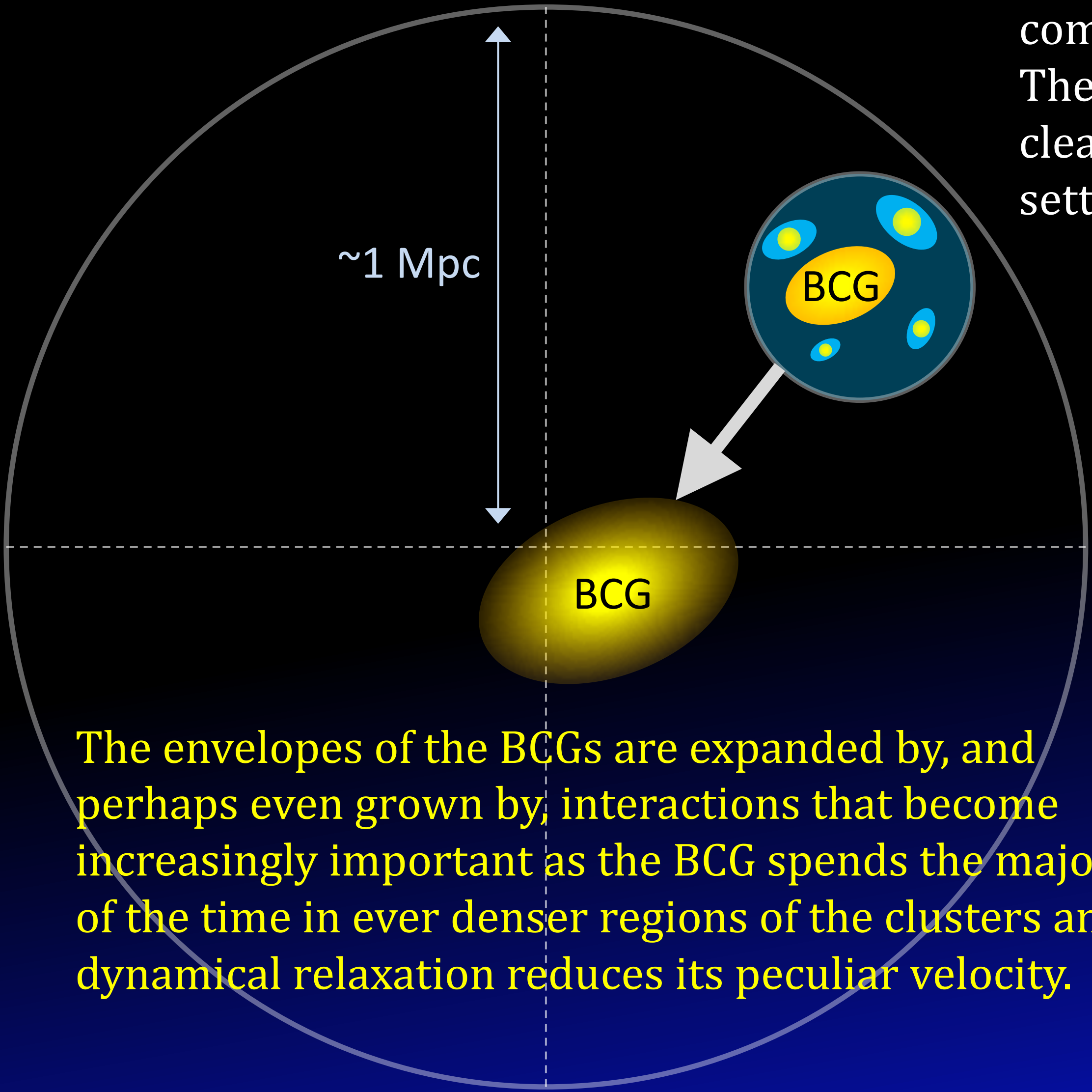
Patel et al. 2017

Implications for BCG Formation & Evolution



BCGs at large velocity and/or x-ray center offsets have luminosities comparable to those near the center. The bulk of their stellar assembly has clearly already occurred before they settle in the center.

Implications for BCG Formation & Evolution



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The envelopes of the BCGs are expanded by, and perhaps even grown by, interactions that become increasingly important as the BCG spends the majority of the time in ever denser regions of the clusters and dynamical relaxation reduces its peculiar velocity.

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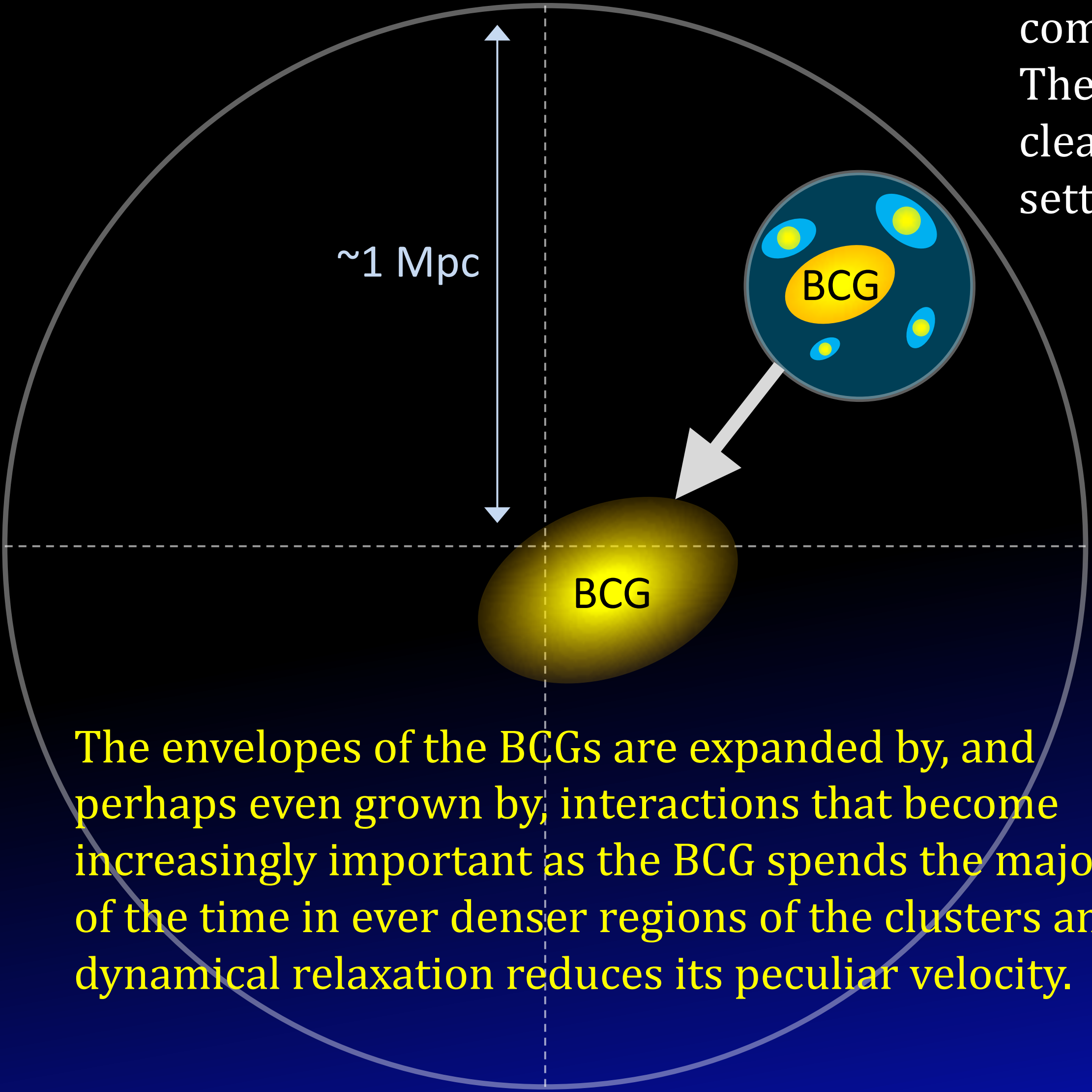

The fact that metric luminosity does not vary with spatial or velocity offset from the center of the cluster argues that the denser central body of the BCG, however, is less affected by the same processes.

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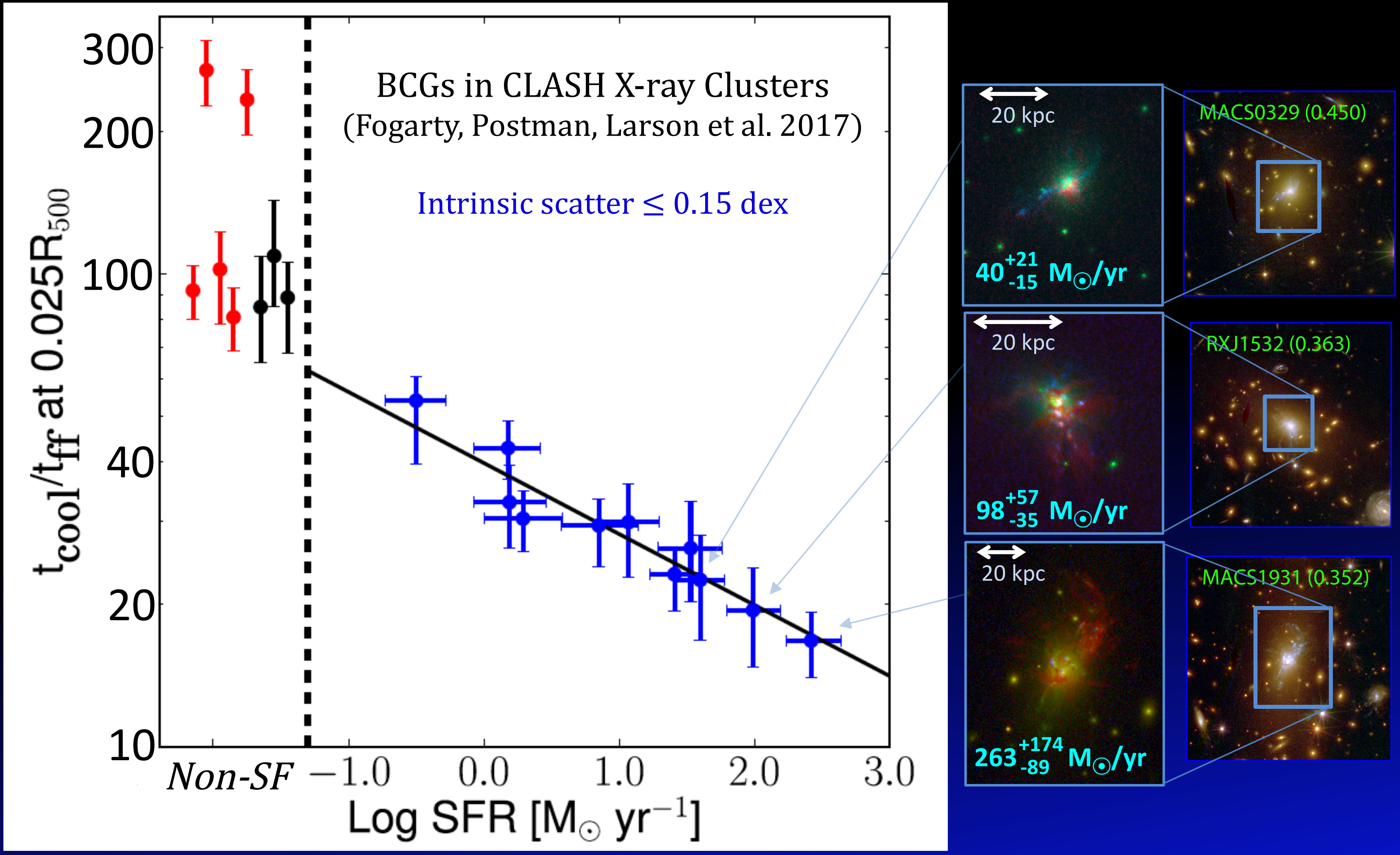
BCGs have higher SFRs in Cool-core clusters with smaller Cooling time-to-free fall time Ratios



Summary

- The $|\Delta V|/\sigma$ distribution of BCGs in clusters is **exponential**. The exponential scale length is 0.39 ± 0.03.
- The BCG x-ray center offset distribution is a **power-law** with index -2.3. The data are well-described by this power-law to offsets up to ~1 Mpc.
- *BCGs with $r_X >$ 100 kpc or $|\Delta V_{BCG}|/\sigma_C >$ 0. 5 are seen in 15% - 20% of local Abell clusters. These outlying BCGs follow the same metric plane as do those closer to the center of their host clusters.*
- *We can now see how BGCs vary with location within the cluster.* The structure of the BCGs varies with ΔV and r_X. More extended BCGs are closer to the cluster center.
- BGCs are more extended and more luminous in more massive clusters.
- BCG cores flatten over time.
- *BCGs are formed outside the centers of rich clusters, but are modified as they settle into their centers.*
- Star-formation rates in BCGs in cool-core clusters correlate tightly with the cluster cooling time-to-free fall time ratio (and with cooling time).
- ***Lots to test with simulations.***