Relationship between Morphology and Structure of Brightest Cluster Galaxies and their Environment

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Motivation

- Brightest cluster galaxies (BCGs): the most massive and luminous galaxies in the universe
- Most BCGs are either giant ellipticals or cD galaxies
  - Do structural properties link with morphologies of BCGs?
  - Automatic selection of cD galaxies
  - Do structural properties of BCGs link with intrinsic properties or environments?
  - Do cDs have a distinct evolutionary history?

Abell 370 (HST ACS)  
NGC 3551 (SDSS)
Visual Classification

Sloan Digital Sky Survey (SDSS) DR7 r-band

- 625 BCGs at $0.02 \leq z \leq 0.1$ from von der Linden et al. (2007)
- Three main types: cD (414), elliptical (155), disk (S0 22; spiral 24)
Link between Morphology and Structure of BCGs

Measurements of Structure

- GALAPAGOS (Barden et al. 2012) and GALFIT (Peng et al. 2002)
- Sky value from GALAPAGOS
  - $\mu_{\text{limit}} \sim 27$ mag/arcsec$^2$
- Fitting model
  - single Sérsic profile

Peng et al. (2010)
Evaluate the Fittings

- Quantify the residual images
  - residual flux fraction (RFF)

\[
RFF = \frac{\sum_{i,j \in A} |I_{i,j} - I_{i,j}^{\text{model}}|}{0.8 \times \sum_{i,j \in A} \sigma_{i,j}^{\text{bkg}}} \\
\text{Reduced } \chi^2 = \frac{1}{N_{\text{dof}}} \sum \frac{(I_{i,j} - I_{i,j}^{\text{model}})^2}{\sigma_{i,j}^2}
\]

- Reduced \( \chi^2 \)

Good fit:
\[
\begin{align*}
\text{RFF} & \sim 0.02 \\
\text{\( \chi^2 \)} & \sim 1.1
\end{align*}
\]

\[
\begin{align*}
\text{RFF} & = 0.015 \\
\text{\( \chi^2 \)} & = 1.052 \\
\text{RFF} & = 0.045 \\
\text{\( \chi^2 \)} & = 1.348 \\
\text{RFF} & = 0.047 \\
\text{\( \chi^2 \)} & = 1.455
\end{align*}
\]
Fitting with Single Sérsic Profile

- cD and elliptical BCGs have similar n
- cD galaxies have larger effective radii
- It is harder to fit cD galaxies very well just by single Sérsic profile (larger RFF and $\chi^2$)
- Clear link between morphology and structure
Best border

- Method from Hoyos et al. (2011)
- Selected cDs have high completeness (75%) and low contamination (20%)
- This method can be applied to future BCG samples
Stellar Mass

- $M^*$ does not correlate with Sérsic index $n$
- $M^*$ correlates with effective radius $R_e$

Stellar masses are from 'The MPA-JHU DR7 release of spectrum measurements'
Density does not correlate with $n$ and $R_e$.
Density correlates with $M_\ast$.

Density is from Tempel et al. (2012) for scale of $1 \, h^{-1}\text{Mpc}$.
DM halo virial mass does not correlate with \( n, R_e \) and \( M_* \) of BCGs.

DM halo virial mass correlates with density.

Cluster velocity dispersion is from von der Linden et al (2007).
cDs Properties Relate with M* and environment

- cDs tend to be more massive and reside in denser clusters
- cDs are larger in factor of 2 and 60% more massive than ellipticals in same density
- cDs may grow through minor mergers
Conclusions

- Visual morphology strongly correlates with the structural parameters of BCGs
  - cDs are larger in size compared to elliptical BCGs
  - cDs are harder to fit with single Sérsic profile than elliptical BCGs--larger residuals

- Automatic selection of cDs

- For BCGs
  - Size correlates with stellar mass
  - Stellar mass correlates with environmental density
  - cDs tend to live in denser environments than elliptical BCGs
  - At a fixed density, cDs are larger and more massive than elliptical BCGs implying that cDs may evolve from elliptical BCGs by forming the outer part through minor mergers