Importance of Mergers to Mass Build-up of Brightest Cluster Galaxies (BCGs)

Danièl Groenewald
SAAO/NWU
Collaborators: D. Gilbank, R. Skelton, S. Loubser
9 February 2015, Sydney
Mergers in BCG formation:

• Hierarchical formation scenario:
  – Mergers very IMPORTANT!

• BCG mass build-up due to mergers still unclear.
  – Close pair statistics (e.g. Edwards & Patton 2012).
  – Morphological distorted pairs (e.g. McIntosh + 2008, Liu + 2009).
Mass build-up of BCGs since $z \sim 1$:

- **Models:**
  - Laporte + 2013: Factor of $2.9 \pm 0.6$.

- **Observations:**
  - Lum evolution: Factor of $\leq 1.8$ (e.g. Lidman + 2012, Lin + 2013).
    - * Collins + 2009 & Stott + 2010 - no growth.
  - Mergers: Factor of $\leq 1.8$ (e.g Liu + 2009, Burke & Collins 2013).
redMaPPer cluster catalog:

• > 25 000 clusters.
• $z = (0.08, 0.55)$.
• Optically selected – SDSS.
  ▪ Identify red-sequence.
• Identify most probable CG candidate.
• Photometry and spectroscopy ($\sim 11\%$).
• Total mag: $i$-band cModelMag.
Testing SDSS magnitudes:

• Large aperture photometry – isolated BCGs:
  – High $z$: Excellent agreement.
  – Low $z$: Disagree with $\geq10\%$ - background subtraction.

• SExtractor:
  – MAG_AUT0 => ideal for crowded fields.
  – Disagreement at faint SDSS mag.
Identifying merger candidates:

• Cluster members: – red galaxies.

• BCG – CG candidate
Identifying merger candidates:

- Cluster members:
  - red galaxies.

- BCG – CG candidate
- 50 kpc
Identifying merger candidates:

- BCG – CG candidate
- 50 kpc
- Photometric companion

- Cluster members: – red galaxies.

- 8277 close pairs
Identifying merger candidates:

- BCG – CG candidate
- 50 kpc
- Photometric companion
  - Bound - $\Delta v \leq 500$ km/s

- Cluster members:  
  - red galaxies.

- 8277 close pairs:  
  - 11% spec pairs  
  - 8% bound.
Search radius

• From field mergers (Patton + 2000):
  – Search radius = 30 or 50 kpc.
  – \( \Delta v \leq 200, 300, 500 \) (e.g Lin + 2013, Keenan + 2014) km/s.

• Simulations (in progress):
  – Mergers in clusters.
  – Applicable search radius and \( \Delta v \).
Final sample:

• BCG – 1st CG candidate.
• $r \leq 50$ kpc.

Companion

$\Delta v \leq 500$ km/s

Final sample: $\Delta m_i \leq 2$ mag
Luminosity ratios:

Major mergers: (1:1) – (1:4)

Minor mergers: (1:4) – (1:6)
Major merger fraction:

Luminosity ratio (≤1:4) and r ≤ 30 kpc

30 kpc
Major merger fraction:

Luminosity ratio \( \leq 1:4 \) and \( r \leq 30 \) kpc

\[
\langle f_{\text{major}} \rangle = \frac{N_{\text{BCGs with } \geq 1 \text{ companion}}}{N_{\text{BCGs}}} \quad \text{with } 0.08 \leq z_i \leq 0.55
\]
Major merger fraction:

Luminosity ratio (≤ 1 : 4) and r ≤ 30 kpc

30 kpc

\[ \langle f_m \rangle = 0.20 \times (1 + z)^{-2.53} \]
Major merger fraction:

Luminosity ratio (≤1:4) and r ≤ 30 kpc

30 kpc

\[ <f_m> = 0.20 \times (1+z)^{-2.53} \]

\[ <f_m> = 0.07 \times (1+z)^{-6.21} \]
Major merger fraction:

Luminosity ratio (≤1:4) and r ≤ 30 kpc

\[ <f_m> = 0.20 \times (1 + z)^{-2.53} \]

\[ <f_m> = 0.14 \times (1 + z)^{-3.24} \]

\[ <f_m> = 0.07 \times (1 + z)^{-6.21} \]
Major merger fraction:

Luminosity ratio ($\leq 1:4$) and $r \leq 30$ kpc

Cluster

30 kpc

Cluster

$\langle f_{\text{major}} \rangle = 0.14 \times (1 + z)^{-3.24}$
Major merger fraction:

Luminosity ratio ($\leq 1:4$) and $r \leq 30$ kpc

$<f_m> = 0.14 \times (1+z)^{-3.24}$

30 kpc
BCG mass increase:

• Assumptions:
  – All companions merge by $z = 0$.
  – 100% mass transfer during mergers.

• $\text{Lum} \rightarrow \text{mass}$ using $M/L$.

• $M_f = N_c(1:1-1:4) + N_c(>1:4)$
BCG mass evolution:

Lum evolution – past growth
BCG mass evolution:

Lum evolution – past growth
Mergers – future growth
BCG mass evolution:

- Lum evolution – past growth
- Mergers – future growth

![Graph showing BCG mass evolution with data points and error bars.](image)
Summary and Future Work:

• $M_{\text{today}} = 1.11 \, M_{\text{star}}$ (due to mergers).
  – $(11.0 \pm 5.0)\%$ mass growth since $z=0.5$. 

Daniël Groenewald  SAAO/NWU
Summary and Future Work:

• $M_{\text{today}} = 1.11 \ M_{\text{star}}$ (due to mergers).
  – $(11.0 \pm 5.0)\%$ mass growth since $z=0.5$.

• Future work:
  – Final spec. incompleteness correction.
  – Correcting photometry.
  – SALT spectroscopy – extend sample at high $z$.
  – Cluster matching across $z$. 
Thank you for your attention.

Questions?