Kinematically Decoupled Cores in Brightest Cluster Galaxies: Early Results

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Background image: from the HBO TV series ‘Game of Thrones’
How BCGs have formed?

Classical scenarios of BCG formation:
1. Galactic cannibalism (e.g. Ostriker & Tremaine 1975)
2. Primordial origin (e.g. Merritt 1984)
3. Accretion of cooling flow (e.g. Fabian & Nulsen 1977).

However, the observed properties of BCGs are so complicated and various that any single scenario can not fully explain every aspect of BCGs (e.g. Loubser & Sánchez-Blázquez 2012: various radial gradients of several quantities).
Until now, observational studies have not reached consensus on the mass growth of BCGs yet:

- Some studies concluded that there is little growth in the stellar mass of BCGs since $z = 1$ (e.g. Brough et al. 2007; Whiley et al. 2008; Stott et al. 2010, De Propris et al. 2013).

- On the other hand, some other studies reported significant mass growth of BCGs at $z < 1$ (e.g. Lidman et al. 2012; Lin et al. 2013; Bai et al. 2014, Wen et al. 2015).
Kinematically Decoupled Cores (KDCs) may be direct evidence about the way of galaxy mass growth.

Davies+01
In a pioneering integral field unit (IFU) study of the SAURON project, McDermid et al. (2006) reported:

- 14 of 28 (50%) early-type galaxies (ETGs) have KDCs.
- KDCs are divided into 2 different kinds:
  1. kpc-scale KDCs: 0.8 – 3.1 kpc in diameter, hosted by old (> 8 Gyr) and slowly-rotating ETGs
  2. compact KDCs: smaller than 500 pc in diameter, mostly hosted by relatively young (< 5 Gyr) and fast-rotating ETGs.

These 2 kinds of KDCs seem to roughly correspond to 2 different theoretical origins of KDCs, respectively:

1. major dry merger (Kormendy 1984)
2. gas-rich merger or gas accretion (Hernquist et al. 1991)

If BCGs have increased their mass via mergers or galaxy interactions, some kinematic vestige such as KDCs is expected to remain in their centers.
As the expectation, several previous studies detected possible signatures of KDCs in some BCGs (Fisher et al. 1995; Carter et al. 1999; Loubser et al. 2008). Loubser et al. (2008) reported:
- At least 12 of 41 (29%) BCGs show KDC features.
- Most of them correspond to kpc-scale KDCs in their sizes.
- This is a result based on long-slit spectroscopy, in which the detection of a KDC significantly depends on slit orientation and thus many KDCs may be missed.

Question: Why do some BCGs host KDCs, while some other BCGs do not? Any environmental influence?
If KDCs are really tracers of past major mergers, and if BCGs have grown by merging their bright neighbors, then the existence of KDCs in BCGs may be related with some properties of BCGs or their host clusters that indicate their past major merging histories.

For example:

- Color gradient
- Magnitude difference between the BCG and the second-rank galaxy ($m_{12}$)
- Local number density ($\rho$)
Pilot Study of KDCs in BCGs

Loubser et al. (2008): Kinematical properties of nearby BCGs, including the existence of KDCs

Tempel et al. (2014): Cluster/group catalogs using SDSS DR10 + more redshift catalogs
Results

No significant difference in:
- absolute magnitude
- color
- light concentration

Very marginal difference in color gradient?
- KDC-BCGs seem to be slightly more concentrated in the bluer band.
- Uncertainty is too large!
Unlike the initial expectation, the BCGs hosting KDCs do not prefer larger $m_{12}$.

There is no significant dependence on the global properties of the host clusters, such as velocity dispersion and cluster size.

Then, are KDCs the results of some internal processes of BCGs, not related to their environments?
Results

In the local density plot, a clear division is found between BCGs hosting KDCs and BCGs without KDCs.

- BCGs hosting KDCs seem to prefer higher local density at $1\,h^{-1}\,\text{Mpc}$ scale.
- On the other hand, BCGs hosting KDCs seem to prefer lower local density at $8\,h^{-1}\,\text{Mpc}$ scale.

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BCGs in denser clusters tend to host KDCs?
- However, the sample size is too small!
Summary

1. The existence of KDCs in BCGs does not depend on the absolute magnitude, optical color, and light concentration of BCGs.

2. BCGs hosting KDCs possibly tend to be more concentrated in the bluer band, but such a trend is statistically not significant.

3. KDCs in BCGs are not related to several properties of the host clusters: \( m_{12} \), richness, velocity dispersion, and cluster size at least in our sample.

4. BCGs hosting KDCs tend to prefer higher density at \( 1h^{-1}\) Mpc scale, but prefer lower density at \( 8h^{-1}\) Mpc scale. This may be related with the evolutionary stage of the host clusters, but the sample size is too small to confirm such a scenario.
Future Work

We are trying to secure a larger sample of BCGs with their central kinematics... with

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Brightest Cluster Galaxy Spectroscopic Survey to Understand the Coevolution of BCGs and Clusters