Radial kinematics of brightest cluster galaxies

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Introduction

Brightest cluster galaxies (BCGs) are special. They have extremely high luminosities, diffuse and extended structures (see **Figure 1**), and dominant locations in clusters. Because of their special location in the cluster, they are believed to be sites of very interesting evolutionary phenomena (e.g. dynamical friction, galactic cannibalism, cooling flows). This special class of objects may well require there to have been a special process of formation. Mergers between smaller galaxies, massive star formation in the early stages of the formation of the cluster due to (the now extinguished) cooling flows, or monolithic collapse that may originate from unusually large primordial fluctuations, are all possible formation mechanisms. These processes will leave different imprints in the dynamical properties and in the detailed chemical abundances of the stars.

We have initiated a project devoted to the investigation of a large sample of BCGs, their kinematic and stellar population properties, and the relationships between those and the properties of the cluster. We have obtained high signal-to-noise ratio, long-slit spectra of 49 of these galaxies with the Gemini and WHT telescopes with the primary purpose of investigating their stellar population properties. Here, we present the stellar kinematics results obtained through derivation of velocity and velocity dispersion profiles.

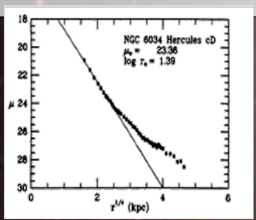


***Fig. 1.** The figure shows the surface brightness profile of NGC 6034 (one of our 10 WHT targets) in the Hercules cluster and illustrates how the profile of a BCG with a stellar halo (called a cD galaxy) deviates from the de Vaucouleurs ($r^{1/4}$) law (Schombert 1986).*

Formation Theories

The formation, characteristics and locations of BCGs in galaxy clusters are well modelled by mergers of galaxies, referred to in the literature as "galactic cannibalism" (e.g. Jordán et al. 2004). Various observations, for example multiple nuclei in central galaxies, favours this theory. It is also possible at higher redshifts to see the progenitors of BCGs as multiple cluster galaxies come together.

Another theory proposes that BCGs are formed by cooling flows in clusters of galaxies. If the central cluster density is high enough, intracluster gas can condense and form stars at the bottom of the potential well. However, this possibility now seems remote in light of *XMM-Newton* observations that show that the X-ray gas does not cool significantly (Jordán et al. 2004). However, several recent studies reported examples of recent or ongoing star formation in BCGs hosted by cooling-flow clusters (Edwards et al. 2007; O'Dea et al. 2008; Bildfell et al. 2008) at a much reduced rate. **Figure 2** shows a summary of the observational tests, involving stellar population gradients, for BCG formation scenarios.

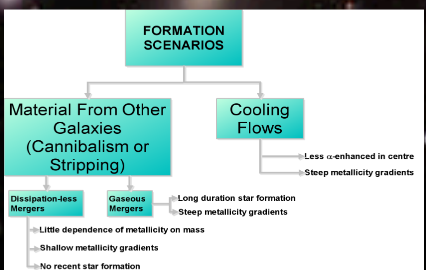
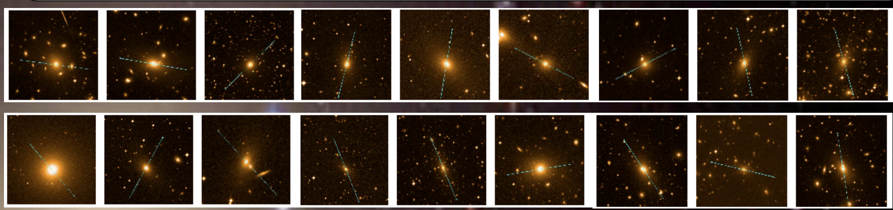


***Fig.2:** Schematic representation of testing the formation theories observationally.*

Galaxy Sample and Observations

We selected and observed a statistically significant sample of nearby BCGs over a 20 month period (2006 - 2008). The selection methods and criteria are described in Loubser et al. (2008). A subset of 10 of the brightest galaxies selected were observed at the 4.2m WHT telescope in June 2006. Further to this, we obtained 41 galaxies with the GEMINI North and South telescopes in the 2006B, 2007A and 2007B observing semesters. Observations of the Lick calibration stars are from the Gemini Science Archive from previous programmes (PI: B. Miller).



Spatially Resolved Kinematics Results

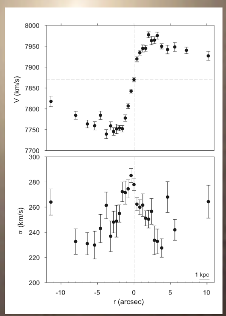


***Fig.3:** NGC7768*

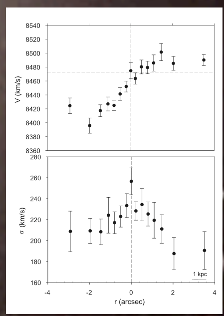


***Fig.4:** ESO346-003*

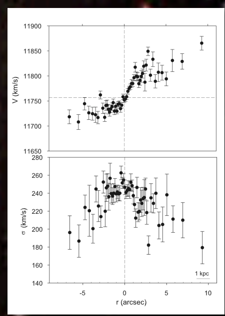


***Fig.5:** ESO488-027*

- A number of BCGs for which we have obtained major axis spectra, show rotation that is > 40 km s^{-1} and more than three times the standard error (**Figure 3 & 4**). However, because of the generally large central velocity dispersions, the BCG data is consistent with the trend for very massive elliptical galaxies to be supported by the random motions of stars and not by rotation.
- At least 15 (out of 49) BCGs show clear velocity substructure in their profiles (**Figure 5, 6 & 7**).
- Six (out of 49) BCGs were found to have a positive velocity dispersion gradient (**Figure 8**).

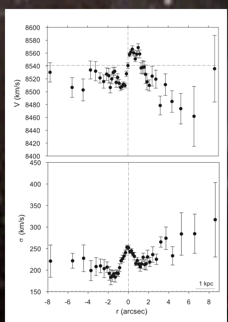


***Fig.6:** IC5358*

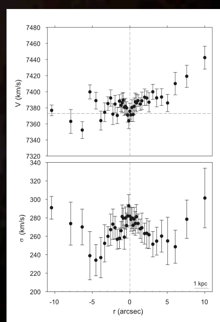


***Fig.7:** NGC4839*

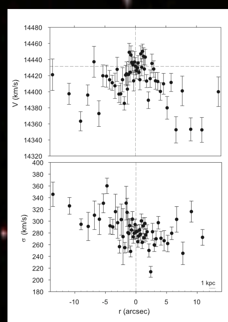


***Fig.8:** ESO349-010*

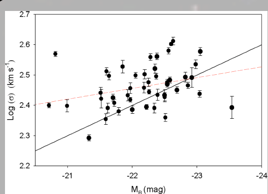


Figure 9 shows the luminosity–velocity dispersion relation fitted with a linear least-squares fit to the BCG data, even though the data exhibit a large amount of scatter. The Faber–Jackson relation for normal ellipticals, corresponding to the slope L ∝ σ^4, is also shown for comparison. The BCGs follow a relation that is significantly different from the Faber–Jackson relation defined by elliptical galaxies (this is also the case when *K*-band magnitudes are used).

***Fig. 9:** The Faber–Jackson relation for normal elliptical galaxies is shown by the black line. Most of the BCGs lie above this relation. The BCG data are fitted with the dashed red line and show a large amount of scatter.*

Conclusions and Further Work

Clear rotation curves were found for a number of galaxies for which major axis spectra were obtained, and in particular, two galaxies were found to have rotational velocities exceeding 100 km s^{-1}. The large rotation is unexpected in the light of numerical simulations, which predict that the bombardment of small satellites without gas is very effective at heating the disc and creating a spheroid supported by velocity anisotropies. However, in general the BCG data are consistent with the known trend for very massive elliptical galaxies to be supported by velocity anisotropy on the anisotropy-luminosity diagram. At least 31 per cent of the BCGs show very clear velocity substructure. Despite the undeniably special nature of BCGs due to their extreme morphological properties and locations, the kinematic properties investigated here seem normal when compared with their ordinary giant elliptical counterparts. However, there are exceptions: 1) BCGs lie above the Faber–Jackson relation, which is naturally explained if the galaxies formed through dissipationless mergers of elliptical galaxies on radial orbits; and 2) the rising velocity dispersion profiles found for a small number of BCGs, which are generally not found in ordinary ellipticals, and might imply a rising M/L ratio. For the stellar population analysis of this sample of BCGs, see poster by Loubser et al. (this meeting).

References

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Observations presented here were obtained with the WHT and Gemini North and South telescopes.