Brightest Cluster Galaxies

Simple or composite stellar populations?

D.N. Viljoen   S.I. Loubser   North-West University, Centre for Space Research

Abstract

The aim of this project is to study the stellar populations, and thereby the evolution and star formation histories of brightest cluster galaxies (BCGs). In particular, I will determine if a Single Stellar Populations (SSP) or Composite Stellar Populations (CSP) provides the best fit for the BCGs using high signal-to-noise ratio (S/N), long-slit spectra, obtained on the Gemini and WHT telescopes. By using the *ULySS* software (*Koleva et al*., 2009) package, the data will be fitted against the Pegase.HR and Vazdekis/MILES stellar population models to simultaneously derive the SSP equivalent ages and metallicities of the BCGs. Furthermore, the stellar populations will be decomposed into two or more components, and the chi square (χ^2) value for each component will used to determine whether a SSP or CSP represents the BCGs most accurately.

Introduction

Traditionally, the term BCGs applied to the brightest member of the cluster (for example *Fabian,* 1994), however recent literature refers to BCGs as the dominant galaxy in the cluster potential well (see eg. *Loubser*, 2009). *Loubser* (2009) gives a more involved definition which describes these BCGs as the central, dominant galaxy in cluster with a mass ~ 10^{13} $M_\odot$. Some BCGs are also called cD galaxies, which indicate that they have an extended stellar halo. These galaxies are the most luminous and almost always the brightest galaxies in the clusters.

It was suggested by *Fabian* (1994) that a BCG is located near the centre of the host cluster and well–aligned with the cluster galaxy distribution, which implies that the BCG is located at the bottom of the gravitational potential well. This in turn implies that the origin of the BCGs is closely related to the formation of the cluster in which it is embedded because the general idea suggests that the stars have settled to the bottom of this well. The unique and distinctive formation history of BCGs creates a challenge for astronomers studying galaxy formation.

Method

The high S/N, longslit spectra for a sample of 49 BCGs and 2 elliptical galaxies were observed on the Gemini and WHT telescopes. Out of this sample, 38 galaxies contained no emission lines and 13 galaxies did have emission lines. The spectra of the galaxies with emission lines were analysed with the software package *GANDALF* (Sarzi et al., 2006). *GANDALF* accurately separates the stellar and emission line contributions to the observed spectra. The software *ULySS* was used to analyse the spectra of this sample. *ULySS* has the advantage of using the entire observed spectra of the galaxies when determining the stellar populations and star formation history (SFH).

Studies conducted on stellar population synthesis models concluded that the Pegase.HR, with the Elodie 3.1 stellar library, and Vazdekis-MILES stellar population models are trustworthy and consistent (see eg. *Koleva et al*., 2009 and references there in).

Thus the spectra of each BCG were fitted against the two models, in addition fitting a SSP and CSP for each of these BCGs. The error spectra of each BCG was used instead of the S/N ratio. The χ^2 value was then used to determine if the SSP or CSP provided the best fit for the BCGs for each of the models. A series of 500 Monte-Carlo simulations was then preformed, checking the residual of the fits and assessed the relevance of the solutions

. Next the χ^2 maps were constructed to understand the structure of the parameter space and to verify the best possible stellar population fit.

Results

Table 1. Stellar populations of BCGs determined by the Pegase.HR model.

Components	Gemini No emission	Gemini Emission	WHT No emission	WHT Emission
1 SSP	42%	80%	29%	67%
2 SSP	29%	10%	43%	—
3 SSP	29%	10%	29%	33%

From Table 1 it follows that from the results for the BCGs without emission lines the composite populations provide a better fit as indicated by the higher combined percentages for the two and three components than for the 1 SSP. On the other hand, the results for the BCGs with emission lines provided a better fit for the 1 SSP.

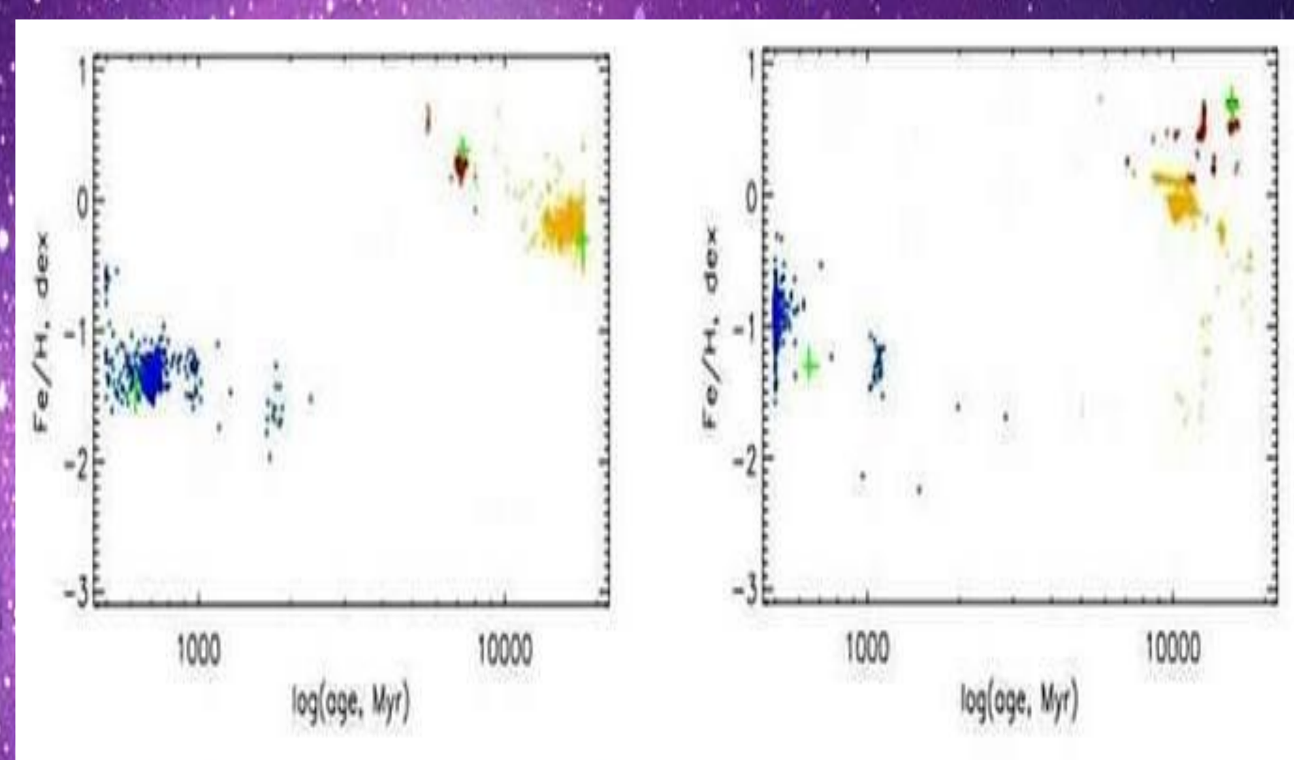

Figure 1. Stellar populations of NGC6160 as determined by the Pegase.HR model. The yellow dots indicate the old component, the red dots the intermediate component while the blue dots indicate the young component. The local minima (best fits) are indicated by the green +.

Figure 2. Stellar populations of NGC6160 as determined by the Vazdekis-MILES model. The yellow dots indicate the old component, the red dots the intermediate component while the blue dots indicate the young component. The local minima (best fits) are indicated by the green +.

Figure 1 show that the CSP fit, determined by the Pegase.HR model is the most accurate representation of the SFH of this BCG because the χ^2-value (indicated by the green cross) of each component converges with the spread of the three components. This is not the case in Figure 2.

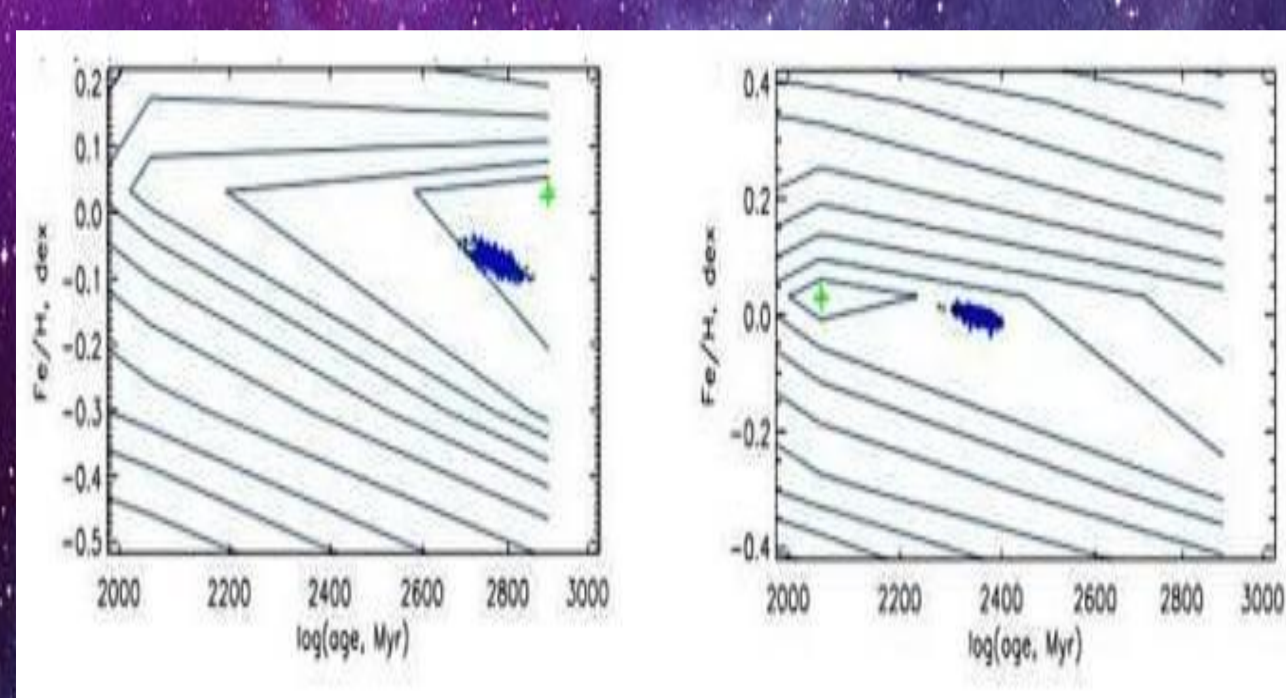

Figure 3. Stellar population of PGC026269 as determined by the Pegase.HR model. The local minima is indicated by the green +.

Figure 4. Stellar population of PGC026269 as determined by the Vazdekis-MILES model. The local minima is indicated by the green +.

By comparing Figure 3 and 4, the results are represented more accurately by the Pegase.HR model because the χ^2-value (indicated by the green cross) and the spread of the component are located in the same contour line (indicated by the blue line). Once again this is not the case for Figure 4.

Table 2. The mean ages of each stellar population (in Gyr) as determined by Pegase.HR for the BCGs observed by the Gemini and WHT telescopes.

	Component	Gemini No emission	Gemini Emission	WHT No emission	WHT Emission
1 SSP		9.46 ± 0.10	6.10 ± 0.07	5.85 ± 0.09	3.89 ± 0.04
2 SSP	First	4.90 ± 1.70	5.37 ± 0.50	3.48 ± 0.25	—
	Second	15.98 ± 0.48	13.70 ± 0.71	9.20 ± 1.15	—
3 SSP	First	0.56 ± 0.15	1.08 ± 0.55	0.61 ± 0.22	0.23 ± 0.17
	Second	8.25 ± 0.48	5.10 ± 0.25	7.59 ± 0.67	13.48 ± 1.62
	Third	17.59 ± 0.52	14.55 ± 3.17	15.00 ± 2.10	19.47 ± 0.48

Table 3 summarizes the mean ages, in Gyr, for each stellar population of the BCGs as determined by the Pegase.HR stellar population model.

- For the Gemini BCGs, without emission lines, the 2 SSP contains an intermediate and old component while the 3 SSP has a young, intermediate and old component.
- For the Gemini BCGs, with emission lines, the 2 SSP contains an intermediate and old component while the 3 SSP contains a young, intermediate and old component.
- For the WHT BCGs, without emission lines, the 2 SSP contains two intermediate components while the 3 SSP has a young, intermediate and old component.
- For the WHT BCGs, with emission lines, there are no galaxies where 2 SSP components provided the best fit. The 3 SSP contains a young and two old components.

Conclusions

Between the two models which were tested, the Pegase.HR model gave the best representation of the SFH of the galaxies. As shown by the example in Figure 1, the local minima converges with the spread of the three components.

The stellar population models determined that the best fit is given by a CSP for most BCGs, indicating that these BCGs have a more complex evolution and formation as first thought.

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SKA AFRICA SQUARE KILOMETRE ARRAY

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS