The middle age growth spurts of brightest cluster galaxies

Chris Lidman, (AAO), Gabriela Iacobuta (AAO), Amanda Bauer (AAO), Gillian Wilson (University of California Riverside, USA) and Adam Muzzin (Leiden Observatory, The Netherlands)

The brightest, most luminous and most massive galaxies in the Universe are the so-called brightest cluster galaxies (or BCGs for short). As their name suggests, BCGs are located in galaxy clusters. More often than not, they are usually located in the very centre of the cluster. See Figure 1 for an example.

Apart from their extreme masses and their special location, BCGs also appear to be special in other ways. For example, the light profiles of BCGs are much more extended than the light profiles of other large elliptical galaxies. In the not too distant past, BCGs were used as standard candles, and were therefore used to constrain the expansion history of the Universe, a role they fulfilled for several decades until it was discovered that Type Ia supernovae are much better standard candles.

In the hierarchical scenario for the formation of structure in the Universe, BCGs build up their stellar mass over time by accreting material from their surroundings. Between z~1 and today, recent numerical models [1] predict that the stellar mass increases by a factor of a two, and that most of the growth occurs through merging with other galaxies and not through converting gas into stars.

Janette Suherli, during her AAO student fellowship[1], showed that the stellar mass of BCGs does indeed increase with time. Janette found that, between z~0.9 and z~0.2, BCGs grew by a factor of 1.8 [2], in good agreement with recent numerical models.

1 The AAO student fellowship program runs twice a year. Students come from all over the world to work with astronomers and engineers at the AAO. For details on how to apply, check out the web page at http://www.aao.gov.au/AAO/students/aaosf.html.

From the strength of emission lines in the spectra of the BCGs, it was clear that the growth was not due to star formation. Instead it was suggested that most of the growth had to occur through merging, although it was not clear if this was via minor of major[2] mergers.

As part of her work as an AAO student fellow, Gabriela Iacobuta examined a larger sample of distant clusters to see if there was evidence for major mergers. This article summarises the work that she did. A more detailed description can be found in a paper that has been accepted for publication in the Monthly Notices of the Royal Astronomical Society [3].

2 A merger is classified as a major merger if the mass of the BCG is not more than four times the mass of the companion. The definition can vary between authors.

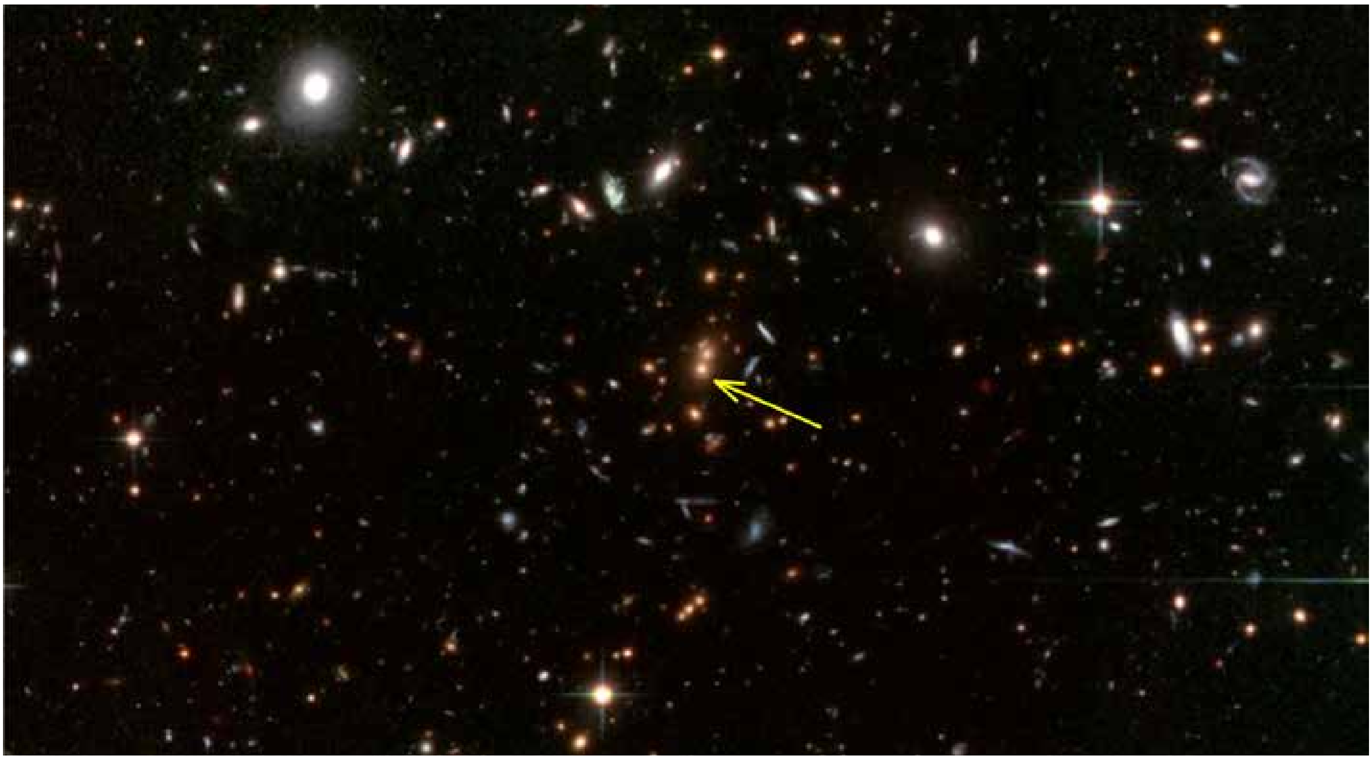

Figure 1: A colour image (courtesy of P. Rosati) of the centre of the z=1.23 galaxy cluster RDCS1252.9-2927. Note the two bright orange-coloured galaxies in the centre of the cluster. The yellow arrow marks the BCG. The colour image was made from a Ks-band image from the ISAAC instrument on the Very Large Telescope and i and z-band images from the ACS instrument on the Hubble Space Telescope.

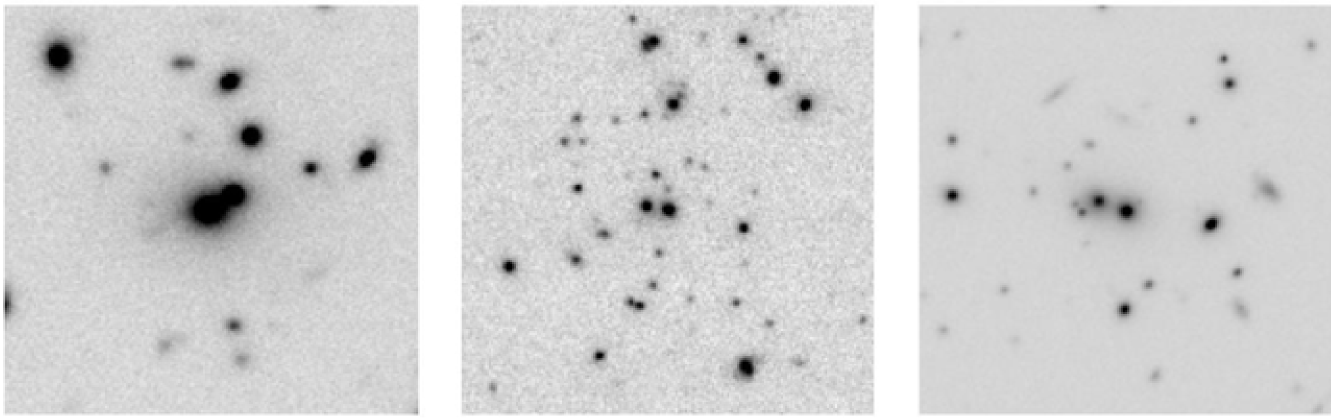

Figure 2: Images centred on the BCGs of the three clusters with bright companions. The projected separation between the galaxies in each pair is less than 30 kpc and the line-of-sight velocity difference is less than 500 km/s. The companions are amongst the brightest galaxies in their respective clusters. From left to right, the companion is the 4th, 3rd and 2nd brightest galaxy in the cluster.

The cluster sample and the frequency of bright companions

The sample consisted of 10 clusters from GCLASS[3] and 8 clusters from the HAWK-I cluster survey (HCS). The redshifts of these 18 distant clusters extends from z=0.84 to z=1.46, corresponding to look-back times ranging from 7.1 to 9.3 billion years[4]. Between the 18 clusters, there are over 600 spectroscopically confirmed cluster members. The high spectroscopic completeness enables us to clearly separate cluster galaxies from field galaxies, and to identify the BCGs.

Out of 18 BCGs, 14 of them are located close to the centres of their respective clusters. A closer inspection of these BCGs revealed that 3 of them have very luminous companions that are within 30 kpc of the BCG and with line-of-sight velocity differences that are less than 500 km/s. The three BCSs are shown in Figure 2.

Galaxies that are this close are likely to merge within 600 million years. Of course, these galaxies may simply be projections along the line of sight. We consider this unlikely for a couple of reasons. First, the companions are highly ranked in terms of their brightness. In the three examples shown in Figure 2, the companions are, from left to right, the 4th, 3rd and 2nd brightest galaxies. Second, compared to faint galaxies, there is a clear statistical excess of bright galaxies near to BCGs.

There is also the issue of how the cluster potential itself affects the time for mergers to occur, since the timescale quoted above has been computed for field galaxies. As these galaxies are located in the centre and appear to be at rest with the cluster, the mass outside their orbits can be largely ignored. This is one of the reasons for considering only the BCGs that are in the cluster centre.

Given the timescale for merging and the growth in mass that has been measured between z~0.9 and z~0.2 [2], we can calculate how many close massive companions we should have observed. Under the assumption that half of the mass of the companion is lost to the intra-cluster medium during the merger and half ends up in the BCG, we derive that we should see three close companions if the times-scale for merging is 600 million years. Interestingly, this is the number we observe.

Future Work

While the frequency of nearby neighbours is consistent with the notion that the build up of stellar mass in BCGs between z=1 and today mainly occurs through major mergers, we stress that the sample size is still small. The small sample size leads to large uncertainties. Extending this work to larger samples would help reduce the uncertainties.

It will also be interesting to see if BCGs continue to grow between z~0.4 (corresponding to a look-back time of 4.3 billion years) and today. There is a hint that the growth stalls at z~0.4 (see Figure 6 of [2]). Numerical models predict that significant growth still occurs between these two redshifts. Work, by Paola Oliva from Swinburne University, to measure the growth at lower redshifts using data from the GAMA[5] survey is underway. Stay tuned for the results of her work.

[1] Laporte, C. F. P. et al. 2013, arXiv:1303.1534

[2] Lidman, C. et al. 2012, MNRAS, 427, 550

[3] Lidman, C. et al. 2013, MNRAS in press, arXiv:1305:0882

3 Gemini Cluster Astrophysics Spectroscopic Survey http://www.faculty.ucr.edu/~gillianw/GCLASS/

4 The Universe is 13.7 billion years old.

5 Galaxy and Mass Assembly - http://www.gama-survey.org/