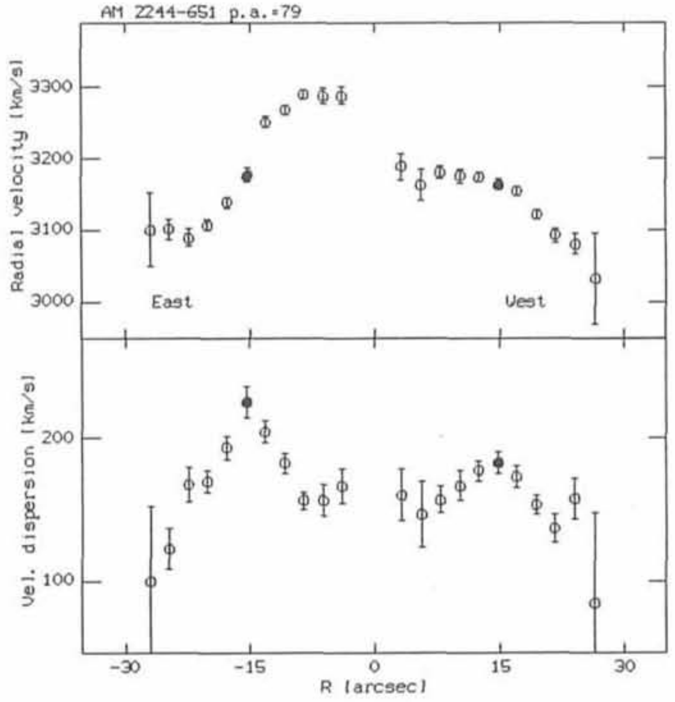

Figure 5: *The kinematical data along the line connecting both galaxy centres of AM 2244-651 show that the east component rotates rapidly. The generation of a large tidal tail as observed here requires such rapid rotation.*

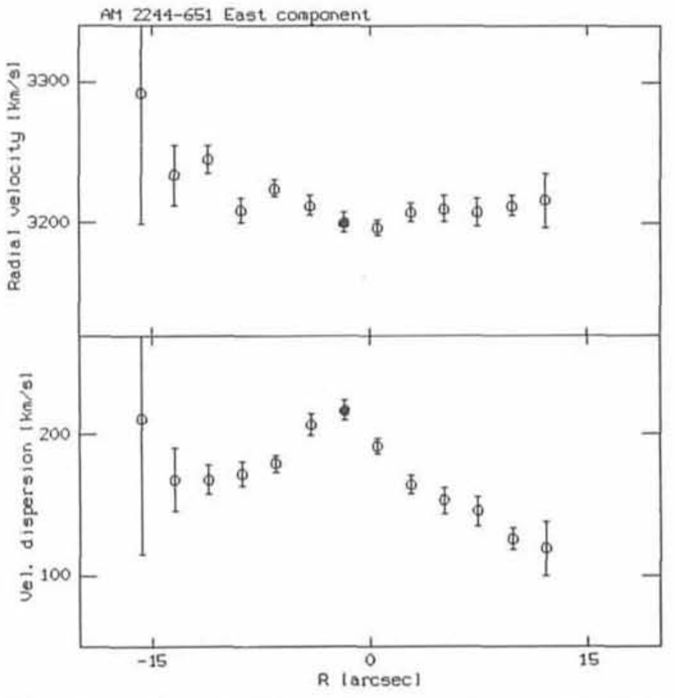

Figure 6: *The kinematical data for the eastern galaxy of AM 2244-651 perpendicular to the long-slit orientation of Figure 5. The galaxy shows no rotation along this orientation. The velocity dispersion decreases asymmetrically, probably a consequence of the tidal interaction.*

kinematics determine the strength of tidal interaction. When rotating galaxies are on prograde orbits, the interaction may lead directly to merging.

As shown, the morphology of interacting elliptical galaxies contains considerable information about the internal structure of galaxies. Only in a detailed morphological and kinematical investigation of interacting galaxies we can determine the different parameters in order to disentangle the various dynamical processes. Only then can we construct encounter scenarios and know how important are encounters in the evolution of galaxies.

Acknowledgements

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Galaxy Populations in Medium Distant and Distant Clusters

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1. Introduction

Observations of medium distant and distant clusters are of fundamental importance for the study of (a) the evolution of galaxies, (b) the evolution of clusters (c) the geometry of the universe.

Considerable efforts have been made in the past decade to understand the questions of galaxy and cluster evolution, galaxy and cluster formation but these questions are still open. Demonstrating the evolution of galaxies and clusters should be decisive for observational cosmology. Comparing galaxies and clusters of galaxies means to investigate their morphological, photometric and spectroscopic properties. The specific observations of distant clusters may also give information on the geometry of the universe. For example at $z \sim 0.7-0.9$, whether a cluster had time to form depends on the intensity of the corresponding peak in the initial density distribution, and also on H_o and q_o.

To detect evolution requires the comparison of similar clusters at various distance intervals. This means to define a local ($z \leq 0.05$), a medium distant ($z \sim 0.3-0.4$) and a distant ($z > 0.5$) sample of clusters and to investigate their photometric and spectroscopic properties.

We know that there is no detected evolution of the first ranked galaxies at $z \leq 0.4$. On the other hand, the Butcher-Oemler effect, i.e. the excess of blue galaxies in medium distant clusters in comparison with nearby clusters, is indicative of evolutionary phenomena within the last 5 Gy.

The dynamical time of galaxy clusters

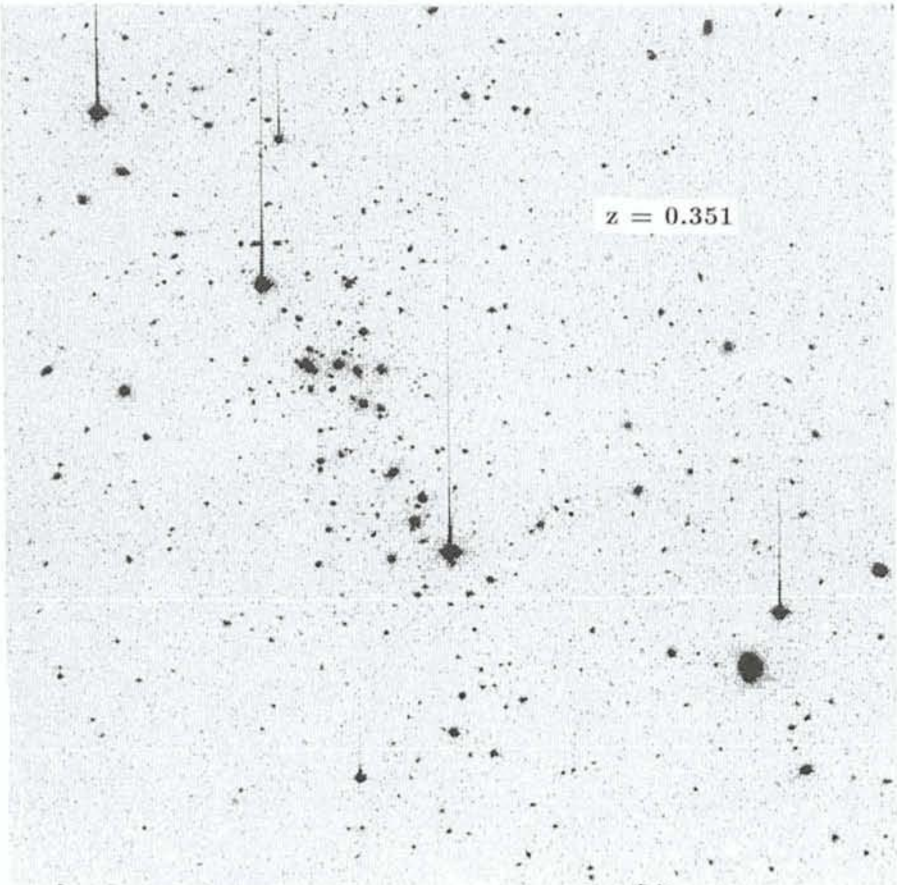

Figure 1: *A full field image of the southern cluster S 0067 at z = 0.35 obtained with EMMI and a Thomson CCD. EMMI is mounted at a Nasmyth focus of the NTT. The field is 7.5 × 7.5 arcmin. Exposure time is 10 min in R. Flat fielding was achieved using sky flats. The large field of EMMI allows to see the various morphologies of clusters and their environment. The limits of the clusters can be well defined as well as the change in colours of the objects as a function of the distance to the central condensation.*

is of the order of the Hubble time. It follows that clusters should be dynamically young. If the dynamical age and environmental effects are important, galaxies in various clusters may not be observed under similar conditions. Thus the first step before attempting to establish an evolutionary link between clusters at various distance intervals is to obtain extensive information on a variety of clusters in the same redshift range.

2. The Programme

The project is to observe 10 clusters at z=0.3 (GC3 project) and 10 clusters at z=0.5–0.6 (GC6 project). We will derive the luminosity functions, density variations and subclustering, colour distributions, colour-magnitude diagrams, and gradients of colours with respect to the cluster centre. Having a homogeneous sample is very important for testing the existence and universality of the Butcher-Oemler effect. Moreover, with the venue of the large field of EMMI it is now possible to measure colours out to rather large distances from the centres and thus to study the clusters in their environments. This means in particular that there is a possibility for testing whether clusters are linked to filaments or large-scale structures.

Multislit spectroscopy is the basic tool to derive stellar information on the galaxies of various colours and to check for cluster membership. With EMMI and low-noise CCDs it will be possible to multiply by a factor larger than 2 the number of spectra at a given exposure time (with respect to the 3.6-m) and to get spectra of some galaxies away from the cluster cores. Thus we expect to study possible variations in spectral types and eventually to follow some filaments a few arcminutes away from cluster cores. Our main project, however, is to study the populations in clusters and to search for some leading parameters whenever differences are found. For example we would like to know whether the rare clusters containing quasars have the same galaxy populations as the compact, rich clusters, or those with powerful radio sources. The GC3 and GC6 samples will be used to derive some information on the geometry of the Universe by application of the Tolman test.

The sample of the GC3 project is now well defined. Most candidates were selected from the Abell catalogue of southern clusters. Prominent structures detected near the limit of this catalogue should be at z≈0.2–0.4. Other candidates close to z = 0.4 were visually searched on CTIO 4-m plates. About 50 per cent of the candidates that we have observed look like real clusters. Most observations were done during test hours of the NTT and EFOSC 2. We give here examples of observed clusters and the redshifts that we have found (unpublished). These clusters are from the supplementary list of Abell et al. (candidates too distant for inclusion in the main catalogue): S 0067 (z = 0.35), S 0400 (z = 0.32), S 0506 (z = 0.32), S 0516 (z = 0.27), S 1115 (z = 0.34), S 1138 (z = 0.36). An image of S 0067 obtained with EMMI is shown in Figure 1. We have begun the photometric reductions using the INVENTORY context of MIDAS on one of the SUN workstations of the Astronomy Department at La Silla. We note in passing that the above clusters are rich enough to be good candidates for a specific search of gravitational arcs or arclets (cf. Key Programme of Fort et al., page 11).

The GC6 project started one year ago. The objective is to obtain photometry and a reasonable number of spectra in 10 southern clusters at z~0.6.This redshift range has been selected because this is the limit at which spectra of normally bright galaxies can be obtained in a reasonable amount of time. At this distance rich clusters contain at least 10 to 15 galaxies brighter than V=22.5. Our search for distant clusters started with Gunn's cluster candidates and with a list obtained from visual inspection of 4-m plates. The observations were made during the commissioning period of the NTT using a 1000×1000 TH CCD camera. At this distance our identification rate dropped to less than 20 per cent. In fact most of the observed candidates look like filaments. It is not clear whether the technique of identification begins to fail at this redshift or the structure of high density regions at that time was mostly filamentary. An example of a distant Gunn cluster (z=0.57) is shown in Figure 2.

Cluster-finding at faint levels is not an easy task. The contrast with the background depends in a complicated way on the mean colour difference between the cluster and the field. Thus the visibility of a cluster varies and gets generally worse with increasing redshift. If one wants to do the work by objective criteria, it is necessary to make a deep survey and to extract a machine-gener-

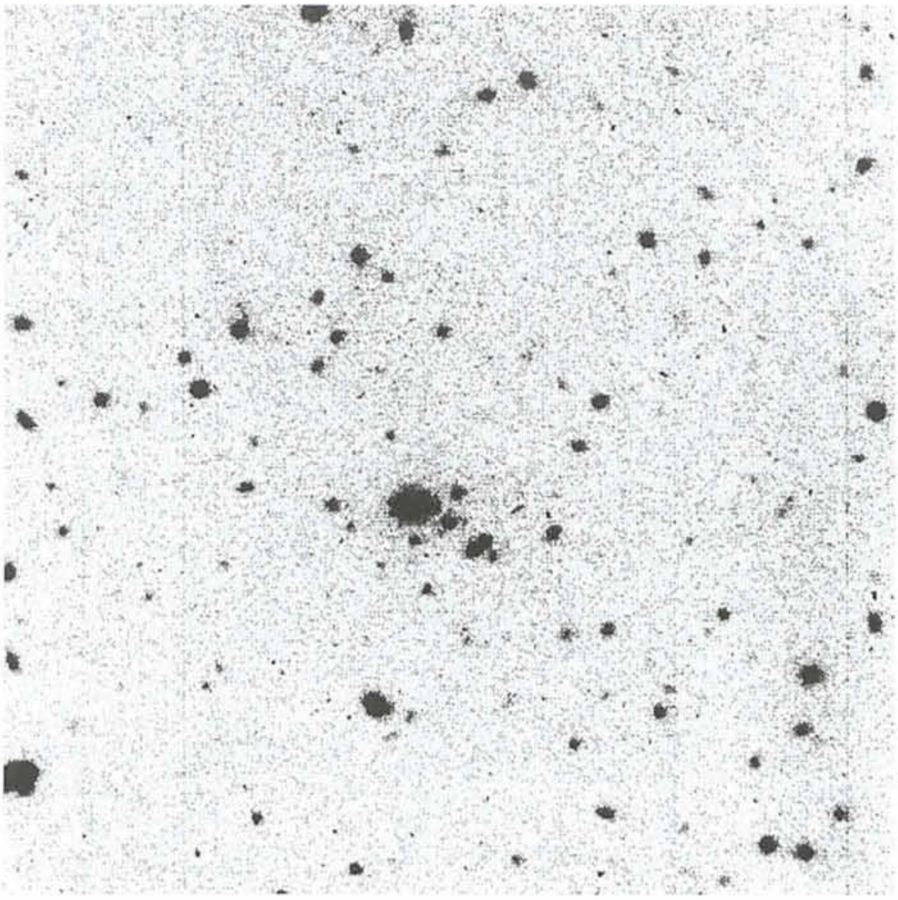

Figure 2: *An R-band image of a Gunn cluster at z = 0.56 obtained with EFOSC 2 at the NTT and a Thomson CCD. The size of the field of EFOSC 2 is much smaller (2.5×2.5 arcmin) than that of EMMI but the sampling of 0.15 arcsec/pixel gives images of higher quality when the seeing is good.*

ated catalogue such as the one being prepared by Gunn et al. at the 200" telescope. High redshift galaxies associated with radio sources may lead to the discovery of some clusters if radio galaxies are associated with high-density peaks in the initial density distribution. A cluster at z=0.75 was discovered by this method. The cluster around the quasar PKS 0405–12 at z=0.572 was also observed.

3. First Results

For clusters at redshifts of ~ 0.3–0.4, the (B–V) colour index can be used to make a first selection between "passive" and "active" objects because, at this redshift, it is sensitive to the 4000 Å break amplitude (B is below, V is roughly above). The main result is that the B–V colour distributions present large variations from cluster to cluster. In particular there are clusters with no Butcher-Oemler effect and clusters with a very large blue population (compared with nearby clusters) as well.

All colour histograms can be described by using 3 populations: a red population (B–V ≥ 1.4–1.5) which corresponds to old-populated galaxies, a very blue one (B–V ≤ 1.1–1.2) which contains mostly emission-line galaxies, and an intermediate population which is not homogeneous, containing objects with spectra similar to those of nearby spirals and post-starburst galaxies as well. I introduced this intermediate population because I found clusters with a red and intermediate population but with a poor very blue fraction, and also clusters where the blue fraction is more important than the intermediate one (Fig. 3). The reason why there are such differences in the "active" fraction of galaxies in medium distant clusters is still unknown.

All clusters observed so far in this programme or those found in the literature belong to one of five classes derived from these 3 populations. Our spectra show that the active fraction contains galaxies with spectra typical of late-type systems, and also objects whose spectral types are very rare in nearby clusters as (a) post-starburst galaxies, with well visible Balmer absorption lines, (b) some probable Seyfert I, and (c) high-excitation narrow-line emission galaxies. Spectra representative of the various types found in S 0506 are shown in Giraud (1990). The corresponding colours vary from B–V = 1.6 for objects with large 4000 Å break, deep G band, Hβ, and Mg b, to B-V = 0.9 for emission-line galaxies.

What is new is mostly that the Butcher-Oemler effect is not universal and that there are now some indications that the whole story is more complex than a simple variation of the blue-to-red population ratio with Hubble time. An interesting result came with the observation of the cluster associated with the quasar PKS 0812 + 02 at z = 0.403. The blue-to-red population ratio in this cluster is the highest we have observed so far at medium distance. This cluster is also peculiar in the sense that bright red galaxies, which are usually found in other cluster cores, are missing there. Finding that a cluster surrounding a quasar has a very large blue population may imply that this cluster is dynamically young whereas a cluster with a large and concentrated population of elliptical galaxies might have been formed much

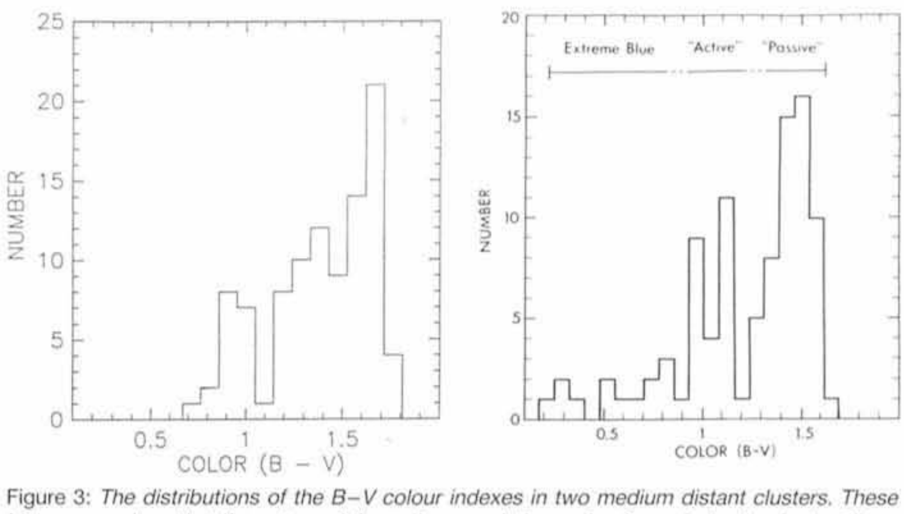

Figure 3: *The distributions of the B–V colour indexes in two medium distant clusters. These histograms show that the nature of the active population varies from cluster to cluster. There are clusters in which the active population is very blue whereas in others it is mostly yellow.*

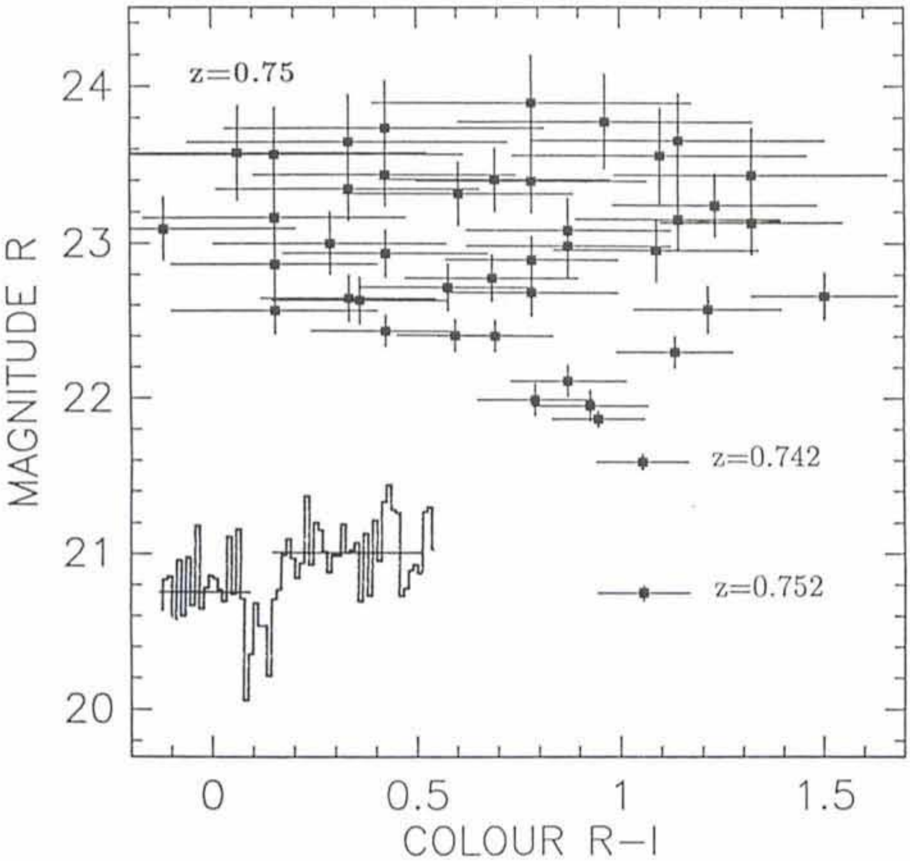

Figure 4: *A colour-magnitude diagram of a cluster at z = 0.75. We find that the blue fraction of objects is very high and that the red objects are slightly bluer than in the absence of evolution. These results should be taken with care, in particular because the contamination by field objects is very uncertain. In the left corner is the 4000 Å break of the first ranked object.*

earlier, possibly in high density peaks of the initial density distribution. In other words, a cluster with a high population of elliptical galaxies may have had high activity in the past, burning most of the gas, while a cluster found with a high degree of activity later would correspond to a slow growing fluctuation. These are the general ideas at this observational stage.

The use of the NTT, EFOSC 2 and a Thomson CCD are very important for the observations of distant clusters. The NTT, a seeing of 0.7 to 0.8 arcsec and a sampling of 0.15 arcsec/pixel made the separation of faint stellar-like objects from galaxies rather easy up to R = 22. To achieve good photometry in R and I, and obtain a spectrum far in the red, it was important to use the THCCD because it has low noise and no fringing in I.

Results on these clusters are still very preliminary. A colour-magnitude diagram of the cluster at z = 0.75, cleaned for stars and foreground objects, is presented in Figure 4. It shows that the R−I colours of red objects are somewhat bluer than if there were no evolution and that the blue-to-red ratio is of the order of 1, both properties suggesting that evolution has been detected (see also in Fig. 4 the rather low 4000 Å break amplitude in the spectrum of the first ranked object). However, the interpretation cannot be so crude for at least two reasons. First, the estimate of the real extent of the contamination by background and remaining foreground objects without multislit spectroscopy is very uncertain, and, second, we do not know if this cluster is representative or very peculiar, as it was detected by the presence of an ultra-steep spectrum radio source.

The trends presented here may be guidelines for a larger programme. Observing faint clusters of galaxies to investigate morphological and photometric evolution was one of the objectives of the wide-field camera of the Hubble Space Telescope (GTO Observing programme, October 1985). Frontier results should be within reach of the NTT and EMMI with a low noise CCD.

High-Resolution Imaging of Globular Cluster Cores

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Practically all of ground-based astronomy can benefit from improved angular resolution. Whereas specialized techniques exist (e.g., speckle) or are being developed (e.g., optical interferometry), they are often limited in field size and/or by the available signal level. A significant fraction of optical work relies on CCD imagery of fields of several arcmin, and will probably continue to do so for quite some time. Recent advances in telescope technology (the ESO NTT being the foremost example), careful selection of telescope sites, etc., can do a lot to improve the seeing. But once the hardware is firmly in place, and the data are taken, the only way to improve the resolution is by some image deconvolution technique. Possibly the best among them is the *Maximum Entropy Method.*

A combination of good seeing data and a powerful and reliable seeing deconvolution technique may achieve results from the ground which were once believed to be reserved for space-based observatories. Here we illustrate just such an approach to data taken at ESO as a part of our study of globular cluster cores. There is hardly a more crowded scene than the very centre of a post-core-collapse cluster, such as M30=NGC 7099.

The primary scientific motivation for our study is the discovery of colour and population gradients in the clusters which show the characteristic post-core-collapse morphology (Piotto, King, and Djorgovski, 1988; Djorgovski,