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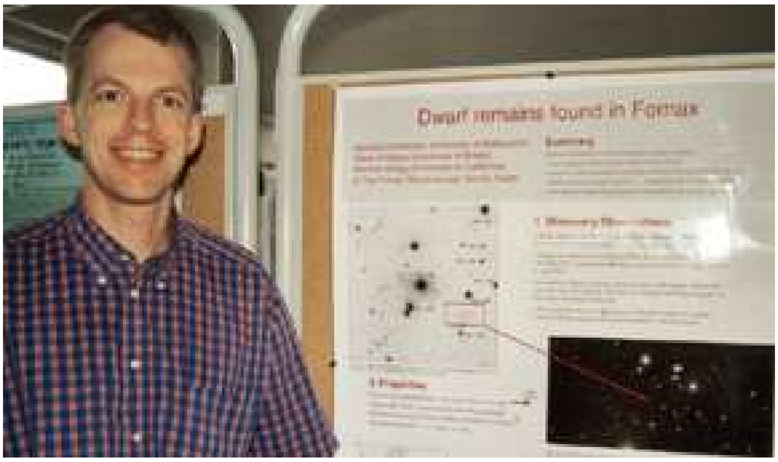
DWARF REMAINS FOUND IN FORNAX



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We have discovered a population of low luminosity compact objects in the Fornax Cluster which are unlike any known type of galaxy and appear to represent an entirely new component of galaxy clusters. These objects were discovered during our Fornax Spectroscopic Survey which is using the Two degree Field spectrograph of the Anglo-Australian Telescope to obtain the first complete spectroscopic sample of the Fornax cluster. Our survey is unique in that all objects (both stars and galaxies) in our magnitude limits ($16.5 < B_J < 19.7$) are measured, to eliminate morphological selection biases. The largest of the compact objects is just resolved in our photographic data, giving a scale size of about 80 pc; the others are all unresolved. They have optical spectra consistent with old stellar systems, but are more luminous ($-13 < M_B < -11$) than any known globular clusters. The luminosity distribution of these objects overlaps that of the nuclei of nucleated dwarf elliptical galaxies so they may be the remains of dwarf galaxies broken apart in the cluster environment.

1 Introduction

It has long been suggested that optical selection effects limit the galaxies in optical surveys to a narrow range of surface brightness (Disney & Phillipps 1983 and references therein). Low surface brightness (LSB) galaxies are lost in the sky noise and compact, high surface brightness galaxies are confused with stars. It now seems unlikely that there are large numbers of undetected giant LSB galaxies (Driver & Cross 2000) and the number of unresolved giant galaxies missed in photographic surveys is small (Drinkwater et al. 1999). However the situation for dwarf galaxies may be very different. In this paper we present the detection of a new population of compact dwarf galaxy in the Fornax cluster: these were unresolved in ground-based imaging and were discovered in our survey described below.

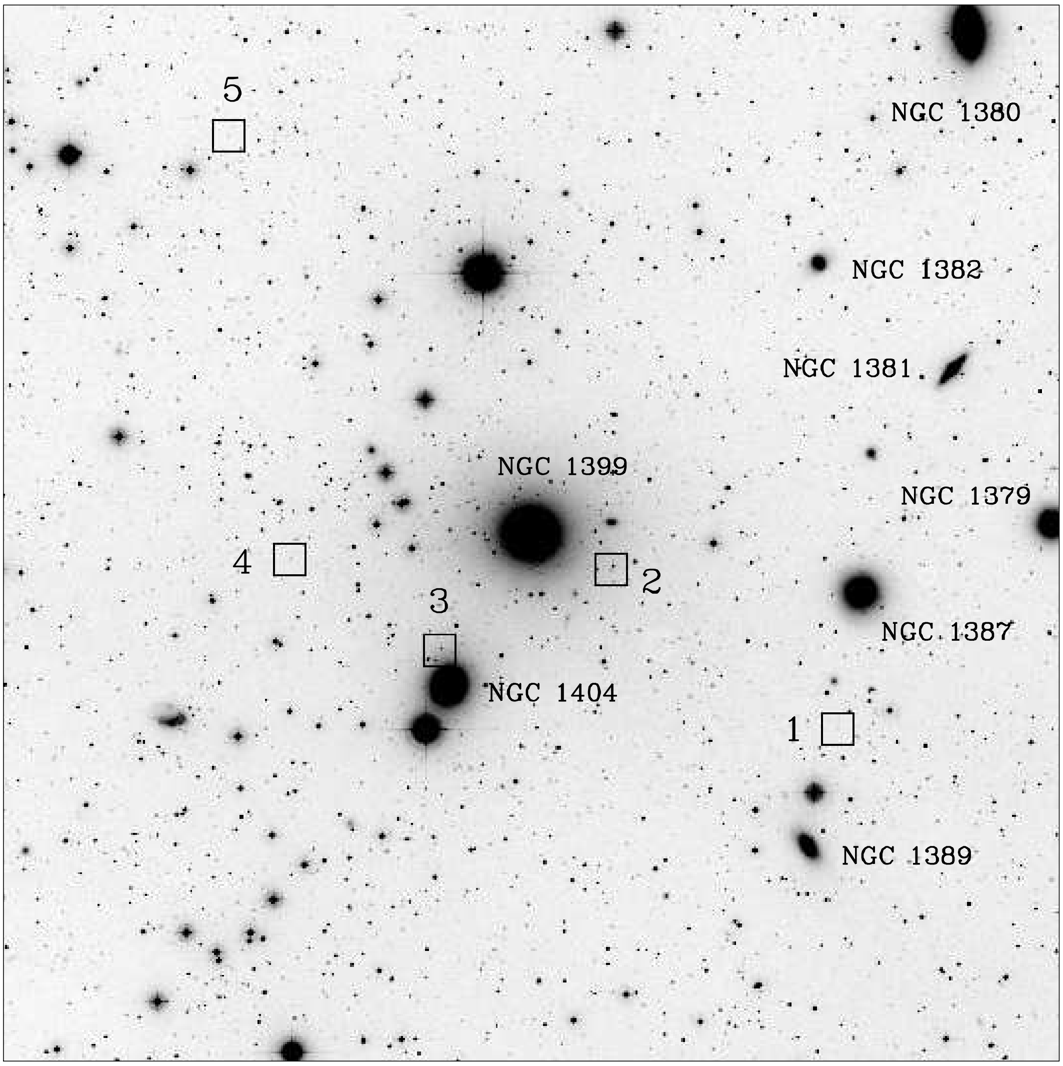

Figure 1: The central region of the Fornax Cluster with the positions of the new compact objects indicated by squares. This R-band photographic image is from a single UKST exposure on Tech-Pan emulsion, digitised by SuperCOSMOS (Miller et al. 1992).

2 Discovery Observations

The *Fornax Cluster Spectroscopic Survey* (Drinkwater et al. 2000a, FCSS) is the first complete all-object spectroscopic survey of a large area of sky. We have used the 2dF spectrograph on the Anglo-Australian Telescope to obtain spectra of the 3,600 objects with magnitudes $16.5 < B_J < 19.7$ in a 2-degree diameter field centred on the Fornax Cluster. We observed *all* objects both "stars" and "galaxies" in these limits in order to cover the full range of surface brightness. The sample is dominated by foreground Galactic stars and background field galaxies—but we can afford to use this complete strategy given the high multiplex advantage of the 400-fibre 2dF system.

When complete the FCSS will comprise some 14,000 objects measured over four 2dF fields in Fornax. Our initial results from the first field include the discoveries of high-velocity Galactic stars, unresolved compact giant field galaxies (Drinkwater et al. 1999) and a population of red quasars not detected by conventional multicolour selection (Meyer et al. 2000). We have also discovered a new type of compact galaxy in the Fornax Cluster itself described in the next section.

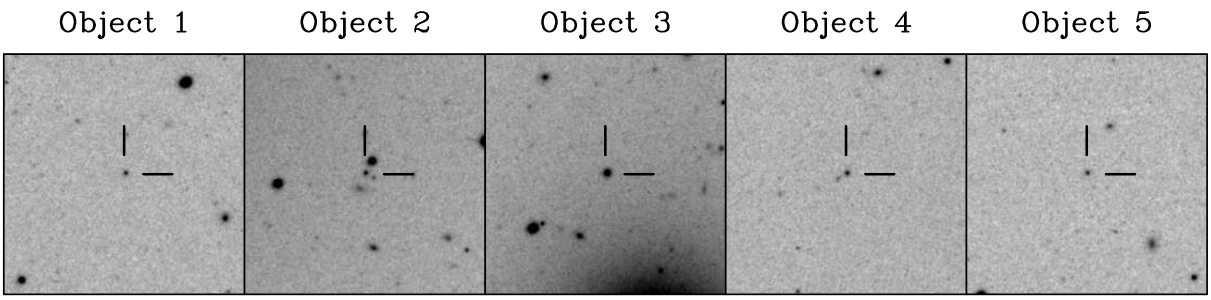

Figure 2: R-band photographic images of the new compact objects. The images are all from a single UKST exposure on Tech-Pan emulsion, digitised by SuperCOSMOS (Miller et al. 1992). Each image is 2.5 arcminutes across with North at the top and East to the left.

3 Properties of the New Galaxies

Among the 2000 "stars" observed, 5 were found to have redshifts of around 1000 km/s making them members of the Fornax Cluster with absolute magnitudes of $-11 < M_B < -13$. Their locations in the cluster are shown in Fig. 1. These objects are unresolved in ground-based imaging (see Fig. 2): we have V images of objects 1 and 5 obtained with the Anglo-Australian Telescope showing them to be unresolved in 1.5 arc second seeing corresponding to a physical size (HWHM) of 60 pc assuming a Fornax distance of 15.4 Mpc. We have not detected any extended low surface brightness halos around them at the 26.5 V mag per square arc second level. Full details of the compact objects are given in Drinkwater et al. (2000b).

They have spectra typical of old stellar populations but they are brighter than any known globular clusters, as is shown in Fig. 3. The luminosities of these compact objects overlap those of the fainter known dwarf ellipticals in the cluster, but they are morphologically distinct, being much more compact. The only objects they do resemble are the nuclei of nucleated dwarf ellipticals: perhaps they are the remnants of nucleated dwarfs which have been stripped in the cluster potential. These objects are unlike any known type of galaxy or stellar system and occupy a region of the surface brightness-magnitude plane (Fig. 4) that was previously empty.

4 Discussion

We will image these objects with the *Hubble Space Telescope* (HST) in Cycle 9 to measure their sizes. We already have STIS images of two comparison objects: a nucleated dwarf elliptical in the Fornax Cluster (FCC 303) and a globular cluster (AAT 62) belonging to the central galaxy NGC 1399. We will combine the HST data with velocity dispersions measured from the ground to derive the masses of our objects and determine which of the following hypotheses best describes them.

4.1 Hypothesis 1: disrupted dwarfs

Bassino et al. (1994) modelled the disruption of nucleated dwarfs captured by central cluster galaxies. Most of the remnants end up contributing to the large globular cluster populations of the central galaxies, but significant numbers of still larger remnants would be produced. These could not have been detected by any previous surveys. Our hypothesis is that the compact objects we have discovered are these larger remnants of disrupted dwarf galaxies.

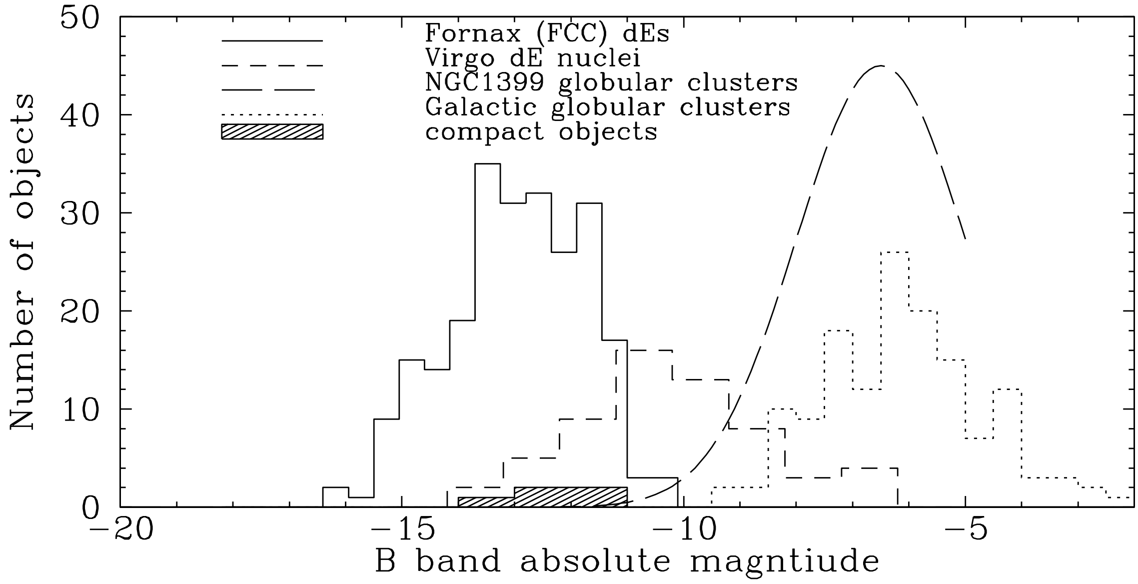

Figure 3: Distribution of absolute magnitude of the compact objects (filled histogram) compared to dEs in the Fornax Cluster (Ferguson 1989; solid histogram), nuclei of dE,Ns in the Virgo Cluster (Binggeli & Cameron 1991; short dashes), model fit to the globular clusters around NGC 1399 (Bridges et al. 1991; long dashes) and Galactic globular clusters (Harris 1996; dotted). The magnitude limit of our survey that found the compact objects corresponds to $M_B = -11$.

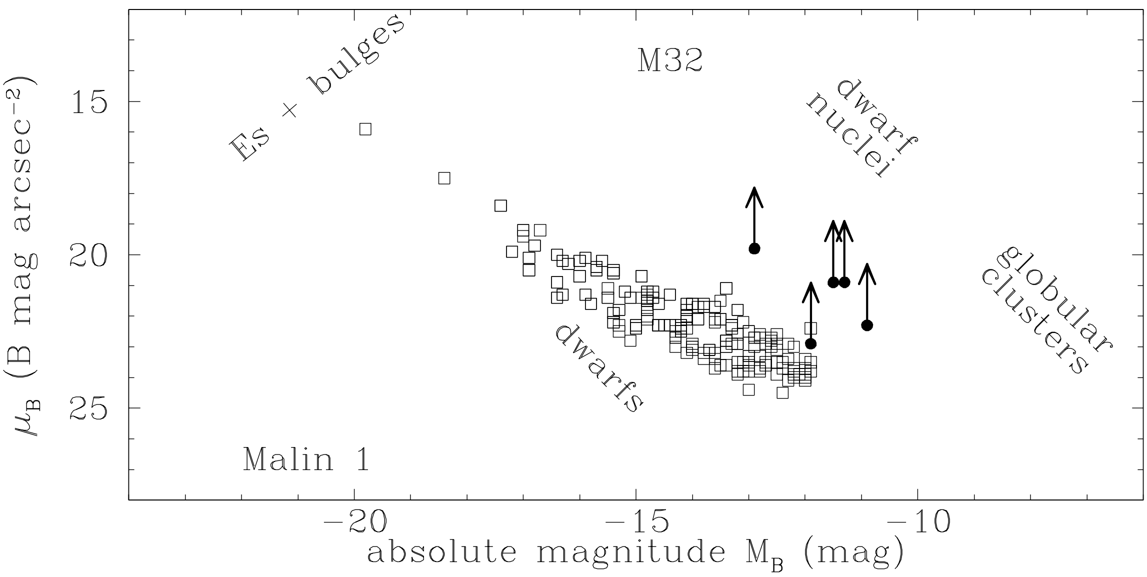

Figure 4: Absolute magnitude-surface brightness plane for stellar systems and subsystems. The squares indicate our measurements of dwarf galaxies in the Fornax Cluster and the filled circles the new Fornax compact objects (the surface brightness estimates are lower limits). The positions of other populations are from Ferguson & Binggeli (1994).

4.2 *Hypothesis 2: free globular clusters*

Central cluster galaxies like NGC 1399 in Fornax have exceptionally large populations of globular clusters (Kissler-Patig et al. 1999). The NGC 1399 globulars, like Galactic globulars, are less luminous than any of the compact objects we have found. However West et al. (1995) suggest that free globulars could form in situ in the intra-cluster medium, in which case they might be more luminous. Our alternative hypothesis is that the compact objects are super-luminous globular clusters, either the extreme end of the known population associated with NGC 1399 or a new population formed in the intra-cluster medium.

Acknowledgments

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References

Bassino L.P., Muzzio J.C., Rabolli M., 1994, ApJ, 431, 634

Binggeli B., Cameron L.M., 1991, A&A, 252, 27

Bridges T.J., Hanes D.A., Harris W.E., 1991, AJ, 101, 469

Disney M.J., Phillipps S., 1983, MNRAS, 205, 1253

Drinkwater M.J., Phillipps S., Gregg M.D., Parker Q.A., Smith R.M., Davies J.I., Jones J.B., Sadler E.M., 1999, ApJ, 511, L97

Drinkwater M.J., Phillipps S., Jones J.B., Gregg M.D., Deady J.I., Davies J.I., Parker Q.A., Sadler E.M., Smith R.M., 2000a, A&A, 355, 900

Drinkwater M.J., Jones J.B., Gregg, M.D., Phillipps, S., 2000b, PASA, 17, in press

Driver S.P., Cross N., 2000, in Mapping the Hidden Universe, eds Kraan-Korteweg, Henning and Andernach, astro-ph/0004201

Ferguson H.C., 1989, AJ, 98, 367

Ferguson H.C., Binggeli B., 1994, A&ARv, 6, 67

Harris W.E., 1996, AJ, 112, 1487

Kissler-Patig M., Grillmair C.J., Meylan G., Brodie J.P., Minniti D., Goudfrooij P., 1999, AJ, 117, 1206

Miller L.A., Cormack W., Paterson M., Beard S., Lawrence L., 1992, in 'Digitised Optical Sky Surveys', eds. H.T. MacGillivray, E.B Thomson, Kluwer Academic Publishers, p. 133

Meyer M.J., Drinkwater M.J., Phillipps S., Couch W.J., 2000, MNRAS, submitted

West M.J., Cote P., Jones C., Forman W., Marzke R.O., 1995, ApJ, 453, L77