THE DISCOVERY OF THE SMALLEST BLUE COMPACT DWARF GALAXIES

M.J. Drinkwater 1, M.D. Gregg 2,3, R.M. Smith 4

1 School of Physics, University of New South Wales, Sydney 2052, Australia
2 IGPP, Lawrence Livermore National Laboratory, L-413, Livermore, CA 94550, USA
3 Department of Physics, University of California at Davis, Davis, CA 95616, USA
4 Dept. of Physics, University of Wales at Cardiff, PO Box 913, Cardiff CF2 3YB, UK

Abstract

In a spectroscopic survey of the Fornax cluster to $B_J = 17.5$ using the FLAIR spectrograph on the UK Schmidt Telescope we have discovered seven new compact dwarf cluster members. These were previously thought to be giant background spirals. These new members are among the most compact, high surface brightness dwarf galaxies known with absolute magnitudes of $M_B \approx -14$ and scale lengths of $\alpha \approx 400$ pc. One in particular may be the first high (normal) surface brightness dwarf spiral discovered. Three of the new dwarfs are blue compact dwarfs (BCDs); their inclusion in the cluster increases the faint end of the BCD luminosity function by a factor of 2 or more. We extended the survey 2.5 mag fainter with the 2dF spectrograph and in our first field found 7 bright emission line galaxies beyond the Fornax cluster which were unresolved on the sky survey plates. Galaxies of this type would be missed in most existing galaxy surveys.

1 Introduction

It is now well-accepted that selection effects can lead to significant biases in galaxy surveys, especially leading to detections of only a limited range of surface brightness. Disney[3] and others showed that it is very difficult to detect low surface brightness (LSB) galaxies in typical surveys because they do not register above the background of random sky fluctuations. Similarly, high surface brightness (HSB) galaxies would not show any extension and would be confused with stars. Much work has been done on LSB galaxies[6] but the HSB bias has generally been discounted[1]. In this paper we demonstrate that there is a real bias against HSB galaxies in two specific contexts: in nearby clusters where HSB dwarf galaxies—although resolved—are confused with background giant galaxies and also in field galaxy surveys based on photographic surveys where compact galaxies are unresolved.
Figure 1: Classification diagram of Fornax galaxies from a sky survey plate digitized by the automated plate measuring facility (APM). Each symbol shows the area of an image above the detection threshold as a function of apparent magnitude. Galaxies classified in the FCC as members (confirmed: filled squares; unconfirmed: open squares) are seen to be less compact than the background galaxies (confirmed: crosses; unconfirmed: dots). Stars are also plotted as dots forming a locus with minimum area. The new compact dwarf cluster members are plotted as large open circles.

2 Compact dwarf galaxies in the Fornax cluster

Our study of the Fornax cluster dwarfs was motivated by a desire to investigate the relationship between the different dwarf types as well as determining if there were any compact dwarf elliptical (cdE) galaxies in the cluster. For the former we were particularly interested to determine if any very compact dwarfs were missing from the Fornax Cluster Catalog (FCC) as these might represent the faded remnants of blue compact dwarf (BCD) galaxies. We therefore observed a large number of galaxies of small projected size that were classified as probable background galaxies in the FCC. The selection is illustrated in Fig. 1 which plots the parameters of a large number of stars and galaxies in the Fornax field based on photographic data (see caption).

We observed a large sample of galaxies with small image area with the FLAIR spectrograph on the UK Schmidt Telescope to determine if they were cluster members. We obtained redshifts for 453 galaxies, an almost complete sample of previously unmeasured compact galaxies with magnitudes brighter than $B = 17.3$. We also included 78 galaxies listed in the FCC as candidate compact dwarf elliptical galaxies in the FCC to a magnitude limit of $B = 17.7$. Our results showed that only one of the cdE candidates we observed (FCC B2144) was a member, but that its spectrum was of a blue, actively star-forming galaxy so we identify it as a BCD not a cdE.

From our data we found 7 new dwarf cluster members that were classified as probable background galaxies in the FCC. These are illustrated in Fig. 2: these are the most compact dwarf galaxies known in the cluster as is shown by their position in Fig. 1. We have obtained CCD images of FCC B2144 which emphasize the small size: it has an absolute magnitude of $M_B = -14.4$ and an exponential scale length of only $\alpha = 0.3$ kpc (for a cluster distance of 15.4
Figure 2: Images of seven new compact dwarfs in the Fornax cluster, a background giant galaxy (FCC 333: $M_B = -19.5$, $cz = 13600\text{km/s}$) previously thought to be a cluster member and seven new compact field galaxies we have discovered beyond the cluster ($-17 < M_B < -21, 13000 < cz < 55000 \text{km/s}$). J0334$-$1838 is at the same distance as FCC 333, albeit 2 mag fainter. The images are all from the Digitized Sky Survey in the $B_J$ band giving a region 2 arcmin across with North to the top and East to the left.

With a slit spectrum we detected rotation with an amplitude of around 20 km/s. The spectrum is very blue with strong emission lines so we classify it as a BCD. At least one of the dwarfs (FCC B0905) shows evidence of a disk-plus-bulge morphology and we suggest it may be a true dwarf spiral type, the first discovered.

Three of the new cluster dwarfs (the two mentioned above and B1379) show strong emission lines, so are BCDs. This actually doubles the number of confirmed BCDs in the cluster and extends their distribution to much fainter levels. However we prefer to leave the morphological classifications and instead consider the star-forming dwarf galaxies as defined by the presence of strong emission lines. We attempt to do this in Fig. 3 where we compare the magnitudes of the star-forming dwarfs to all cluster members in the FCC. This shows a strong increase in the number of star-forming dwarfs to fainter magnitudes although we prefer not to interpret this in terms of the frequency of star-formation bursts because we do not have evidence to link the different dwarfs in one evolutionary sequence.\[4]
Figure 3: Histogram of the absolute magnitudes of all Fornax cluster galaxies (upper histogram) and star-forming galaxies (lower, shaded) in the FCC. The star-forming dwarf galaxies were defined by taking all late-type dwarfs in the FCC (BCD, Im, Sm, Sdm), adding the new star-forming dwarfs we found and removing any for which we obtained spectra with no emission lines. The dashed line gives the limit of our spectroscopic measurements.

3 Compact giant galaxies in the background

We also searched for compact dwarf galaxies in the field behind the cluster sufficiently distant to be unresolved in the photographic data, i.e. at least 3 times farther away or 2.4 mag fainter, a limit of about 19.5. We are using the 2dF spectrograph on the Anglo-Australian Telescope to identify all objects brighter than $B = 19.7$ in a 12 deg$^2$ region at the centre of the cluster. We observed some 600 unresolved objects in our first 2dF run: seven of these were emission-line galaxies and not stars. These are also shown in Fig. 2. They were all farther away than we projected so they are not dwarfs, but compact bright galaxies (unless, as suggested at the meeting, they are dwarfs undergoing particularly intense bursts of star formation). Whatever these new galaxies turn out to be, they constitute at least 1-2% of the local galaxy population but have been missed by existing surveys based on the photographic sky survey data.

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