A Deep CCD Survey for Field Low Surface Brightness Galaxies

Despite strong selection effects which hinder their detection, low surface brightness galaxies (LSBGs) are now known to exist with surface brightnesses down to 1 percent of that of 'standard' giant disc galaxies. Surveys of galaxy clusters (e.g. Turner et al. 1993) have shown that LSBGs can easily dominate, numerically, the whole galaxy population. A number of LSBGs are also known in the general field, but the detected ones are inevitably the largest members of their class (including such objects as Malin 1). In clusters, on the other hand, it is known that the numbers of LSBGs increase rapidly towards smaller physical sizes (e.g. Irwin et al. 1990). To enumerate the field LSBG population properly we therefore need to investigate samples complete to very small apparent sizes. (For comparison, note that even the nearby Fornax Cluster has only 15 LSBGs with scale sizes above 10").

We have therefore attempted a very deep CCD survey using data, from the Thomson CCD on the Anglo-Australian Telescope, which was previously used for deep galaxy number counts and galaxy clustering studies (see Couch et al. 1993). We have used 17 1024 by 1024 pixel frames covering a total of about 1.1 square degrees, imaged in the very broad VR bandpass.

In addition to the standard reduction procedures we have removed local changes in background (which obviously hinder efforts to detect objects at very low isophotal thresholds) via spatial median filtering. We must remember, though, that any very large LSBGs, of order of the size of the filter box, will be smoothed away too. We cannot get the best of everything! Objects of interest here, though, have scale sizes 2" to 15", so this is in fact not a serious problem for our filter size of about 1′. After the median filtering the backgrounds are very uniform and show only 0.3 percent pixel-to-pixel fluctuations. Detection thresholds used were typically 26.5 V magnitudes per square arc second. In total some 40,000 objects were found with areas above 4 square arc seconds. To cut these down to LSBG candidates only requires various cuts in our observational parameter space of isophotal magnitude against isophotal size. It is clearly going to be virtually impossible to distinguish any differences in profile for the very smallest objects detected, since they are only marginally resolved. We therefore first restrict ourselves to objects with isophotal areas of 9 pixels or more. Inter alia, this guarantees that all the sample have signal-to-noise ratios of at least 7.5, which has been shown to be a reliable criterion of 'reality' in such data (see Driver et al. 1994). Next we determined the loci of galaxies (with exponential profiles) with central surface brightness 22.5 V mag/sq arc sec and with scale lengths 2". We are only interested in objects more diffuse and of greater size than these two limits, which leaves a total of about 730 potentially interesting LSBGs. An eyeball check reveals that about 20 percent of these are actually spurious, generally artifacts in the outer halos of bright stars. This then leaves about 35 LSBG candidates per field on average. This is in very good agreement with the numbers estimated by Turner et al. (1993) from their off-cluster comparison field.

If these are all genuine fairly nearby LSBGs, as opposed to cosmologically dimmed 'normal' galaxies in the background, then we can estimate a rough number density for them. The larger Fornax and Abell 3574 LSBGs have scale sizes of order 2 kpc, so we will only be able to detect these out to distances of 200 Mpc or so. This gives a density around 0.5 LSBGs per cubic Mpc. This can be compared to the canonical density of bright galaxies of around 0.05 per cubic Mpc (brighter than a blue magnitude -17.5). This would indicate an order of magnitude more LSBGs than 'normal' galaxies, a result consistent with that found for the spiral rich low density cluster A3574 (i.e. one with a fairly 'field-like' galaxy population) by Turner et al. (1993). This of course requires that there is not too much contamination by more distant giants. We are currently attempting to estimate this contamination from the clustering of and between the different galaxy populations and from simulations of the expected appearance of very distant normal galaxies.

References

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Dwarf Galaxies at Moderate Redshifts

Redshift Surveys have shown that there may be very large populations of dwarf galaxies at moderate redshifts, say 0.2 to 0.5, which are probably absent today. Various pictures of galaxy evolution have been envisioned to account for this apparently dramatic secular change in the field galaxy luminosity function. However, while it is known that many rich nearby clusters possess large dwarf galaxy populations today, surprisingly little is known directly about the low luminosity galaxy population in clusters at earlier epochs (i.e. at higher redshifts). Attention in these clusters, as far as evolution goes, has generally been concentrated on the Butcher-Oemler effect, i.e. the fraction of blue galaxies among the brighter members, and on the spectroscopy of objects such as the so-called post-starburst galaxies, again among the brighter cluster members.

To try and remedy this situation, we have utilised data obtained as part of the Hitchhiker CCD Sky Survey (see Newsletter No. 3, p. 6) for a detailed examination of a moderate redshift cluster. Hitchhiker operates on the William Herschel Telescope on La Palma in parallel with scheduled spectroscopic observers (see Newsletter No. 1, p. 37) and is one of the few CCD survey instruments so far in operation. The data in question here was a rare pointed observation, made in discretionary time, rather than the usual serendipitous operation of the instrument, of the cluster Abell 963 (z = 0.206). Simultaneous 40 minute exposures in the B and R bands were obtained for a field approximately 3′ by 5′ (400 by 650 kpc) centred about 3′ (400 kpc) from the central cD galaxy (which thus appears in a corner of the frame).

Hitchhiker's CCDs are much more efficient in the red than the blue, so we will henceforth concentrate on the R band data. After carefully flat fielding the data (see Driver et al. 1994a for details), objects were detected using the FOCAS package. The detection limit was set at 12 contiguous pixels (1 square arc second) above a limiting isophote of 27 magnitudes per square arc second and a minimum S/N of 7.5. The data are complete down to a (total) magnitude limit R = 24.5, corresponding to an intrinsic red magnitude around -16.5 at the cluster. Magnitudes were corrected from isophotal to 'total' using realistic simulated frames to determine empirical correction factors. (Notice that the isophotal magnitudes can be as faint as 26 given our selection criteria). Comparison of our photometry with existing data in the range R = 18 to 21 (the brightest 50 Hitchhiker galaxies)