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Low Surface Brightness Galaxies and Tidally Triggered Star Formation

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ABSTRACT

We present counts of companions to LSB galaxies and compare these to counts of companions to normal galaxies obtained with the same techniques and criteria. Our results are consistent with LSB's having no clustered companions and support the hypothesis that LSB galaxies have low star-formation rates because they lack external tidal triggering.

Despite the typically large distance between galaxies, interactions and collisions appear to be fairly frequent. The theorized effects of such interaction have been used to explain a wide variety of phenomena including the morphology-density relationship (Dressler 1980), the ultra-luminous IR galaxies (Sanders *et al.* 1986), and the formation of cD galaxies (Ostriker and Tremaine 1975). There is strong evidence that, if gas is present, interactions, especially direct collisions, enhance star-formation rates (cf. Sanders *et al*, and Solomon and Sage 1988). Such observations suggest that galaxies with low star-formation rates may be lacking tidal triggering.

Most galaxy surveys are strongly biased against finding low surface brightness (LSB) galaxies. However, there have been several attempts to conduct surveys specifically designed to find them (cf. Schombert and Bothun 1988, and Schneider *et al.* 1990). As a result, there now exist catalogs with significant numbers of galaxies with low lifetime-averaged star-formation rates. By comparing the number of nearby galaxies (companions) to low star-formation galaxies vs. the number of companions to normal galaxies we can test the interaction hypothesis. Our low star-formation rate sample will consist of selected galaxies from a LSB galaxy survey, while our control sample will consist of selected spirals and ellipticals from the CfA catalogue (Huchra 1991).

We have used photographic plates, scanned by the Automatic Plate Measuring machine at Cambridge, to measure the number of companions around galaxies. Since each galaxy, regardless of whether it is LSB or normal, has few companion galaxies, this study must be done statistically. Such an analysis was first conducted for normal spirals by Holmberg (1969) and more quantitatively by Lorrimer *et al.* 1992. For our study of LSB galaxies, we have used as our set of primary galaxies the LSB galaxy sample being developed by D. Sprayberry and C. Impey. The galaxies in this sample are unfortunately somewhat heterogeneous, but they are all brighter than $M_B = -16$ with a peak in the distribution near $M_B = -19$. The sample includes irregulars, some ellipticals, and a few extreme disk galaxies similar to Malin 1 (C. Impey, priv. comm.).

The analysis techniques are described fully by Lorrimer *et al.*, who also presented measurements on the number of companions per normal galaxy. Basically, the technique involves estimating the background level of galaxies from galaxy counts at a large distance from the primary and subtracting this background level from the counts obtained near the primary. The residual is attributed to companions. There are subtleties regarding possible fluctuations of the background level across the sky and the effects of vignetting and plate edges, which we have investigated by using several tests. The most powerful and elegant test involves random removal of certain plates from consideration. This test investigates whether specific plates are dominating the results. No peculiarities were found. A second test involves counting the "companions" around a set of randomly chosen centers. Since there is no primary at this position, the number of companions should be zero. Many such randomly positioned centers are investigated to evaluate uncertainties. These and other tests are fully described by Lorrimer *et al.*.

We present our results for the number of companions brighter than $M_B = -16$ per galaxy, for normal and LSB galaxies, and for random centers, outside 20 kpc and within either 250 kpc, 500 kpc, or 1 Mpc in Table 1. Note that the number of companions to LSB galaxies is consistent with zero within all three radii. In comparison, the numbers for the normal galaxies are all inconsistent with zero companions and are all

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Table 1: Number of Companions Within Projected Radius per Galaxy

Radius	Normal Galaxies	LSB Galaxies	Random Centers
250 kpc	1.66 ± 0.17	0.22 ± 0.38	-0.009 ± 0.046
500 kpc	3.67 ± 0.41	-0.1 ± 1.4	0.01 ± 0.17
1 Mpc	9.91 ± 0.77	2.4 ± 4.8	-0.14 ± 0.59

greater than the measurements for the LSB galaxies by more than 1σ. Finally, note that the results from the random-center simulations indicate that there are no systematic problems with background subtraction.

The effect of companions on star-formation has been discussed by Icke (1985) and by Lacey and Silk (1991). We recount a simple argument that suggests that companions can produce significant perturbations on the ISM of the primary galaxy. For an impulsive encounter, the magnitude of the typical velocity impulse given in the center-of-mass frame of the affected mass is estimated from a combination of the resulting acceleration and the time over which the force is applied:

$$\Delta v \sim \frac{2GM_p r}{R^2 v_p}$$

(cf. Binney and Tremaine §7.2), where M_p is the mass of the perturber, r is the radius of the primary, R is the pericenter distance, and v_p is the relative velocity of the encounter. For a plausible combination of parameters ($M_p = 10^{11} M_\odot$, $R = 100$ kpc, $r = 15$ kpc, and v_p =300 km s^{-1}) the resulting change in velocity is 5 km s^{-1}. Since such disturbances are of order the sound speed in the ISM, it is plausible to presume that they may affect star formation rates. Although not every companion will have significant impact on the primary (in fact small companions that are not on eccentric orbits will probably not have a noticeable effect), many of the companions identified could create velocity disturbances in the disk of order a few km s^{-1}.

We have shown that LSB galaxies have fewer nearby neighbors down to $M_B = -16$ than do normal surface brightness galaxies. An analogous conclusion regarding bright neighbors was reached by Knezek and Schneider (1992). We believe that this result supports the contention that interactions are an important agent for star-formation, although other interpretations cannot be ruled out. The sample of LSB's is still small and heterogeneous. The most interesting subsample is that of the Malin 1-type disks. A study of companions around those galaxies, once the sample is greatly enlarged, should be a strong test of the interaction hypothesis.

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