Low Surface Brightness Galaxies

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Abstract. A program to investigate the properties of low surface brightness galaxies involving surface photometry in U, B, V, R, I and Hα, HI imaging with the WSRT and the VLA and spectrophotometry of HII regions in LSB galaxies is underway. The goal is to verify the idea that LSB galaxies have low star formation rates because the local gas density falls below the critical density for star formation, and to study the stellar population and abundances in LSB galaxies. Such information should help understanding the evolutionary history of LSB galaxies. Here we report some preliminary results.

Introduction and Observations.

Low Surface Brightness (LSB) galaxies are galaxies whose light distribution is dominated by an exponential disk, which does not reach the canonical 21.6 mag arcsec $^{-2}$ central surface brightness that normal galaxies appear to exhibit (Freeman 1970, see also van der Kruit 1987). LSB galaxies have central surface brightnesses that are typically 1 - 2 mag arcsec $^{-2}$ fainter, and have a very low current star formation activity. Studies to date of a few LSB galaxies appear to favor the idea that after an initial phase of global star formation LSB galaxies have not been actively forming stars for the last few billion years and are just faded disks. The low gas densities found in a few cases (van der Hulst et al. 1987) and probably low metallicities (Webster et al. 1983, McGaugh 1992) support this idea.

In order to quantify more systematically the current gas content, star formation rate and stellar population we began a systematic program to observe a sample of about 20 galaxies in U, B, V, R, I and Hα at the 2.5-m Isaac Newton telescope at la Palma, and in the 21-cm HI line with the Westerbork Synthesis Radio Telescope (WSRT) and the Very large Array (VLA). In addition we recently obtained spectra of HII regions in about 10 LSB galaxies using the 4.3-m William Herschel Telescope at la Palma to estimate abundances. The 20 galaxies have been drawn from the new samples of Schombert and Bothun (1988) and Schombert et al. (1992).

Results and Discussion.

The HI distributions are fairly normal, but exhibit low peak column densities. Typical values are 4 - 8 $M_\odot$ pc^{-2}, systematically lower than what is found in normal galaxies

(Warmels 1989). The HI masses are, however, not abnormally low: the HI disks just are extended. A comparison with optical diameters determined from radial surface brightness profiles shows that the HI to optical diameter ratios are systematically larger than found for galaxies with normal surface brightnesses (see also McGaugh 1992)

From velocity - position cuts along the major axis of the galaxies we could make an estimate of the rotation curves and calculate epicyclic frequencies as a function of radius for a number of LSB galaxies. From these we can evaluate the critical density for star formation as a function of radius following the procedures developed by Kennicutt (1989). It appears that the observed HI surface densities are roughly similar or fall below the critical density throughout the entire disk of the galaxies studied. This suggests that the ISM does not fulfill the necessary conditions to sustain continuous, massive star formation, thus strengthening the idea that low surface brightness galaxies are objects in which active star formation ceased some few billion years ago, or is at most episodic and rare.

The colors of LSB galaxies on the other hand are rather blue, quite similar to the colors of late type high surface brightness galaxies. The colors show a large spread probably indicative for a large range in metallicities and star formation histories. A preliminary analysis of the spectroscopy indicates that the metallicities are below solar, about 1/5th to 1/3rd $Z_{\odot}$, similar to abundances in the outer regions of normal disk galaxies. This implies that part of the blue colors may be a result from metallicity effects. The bluest galaxies, however, can not be just faded disks and must have a complicated star formation history (Schombert et al. 1990, McGaugh 1992). A preliminary analysis of color distributions indicates that quite a few LSB galaxies show color gradients and become on average bluer in their outer parts.

These results indicate that LSB galaxies are in general unevolved, but do have a rather young population. The large range in colors and abundances imply that a single, simple scenario for the evolution is inadequate. The star formation history of LSB galaxies apparently is rather complex, perhaps episodec and may involve exotic IMS's

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