Structure and Star Formation Regimes of Low Surface Brightness Dwarf Irregular Galaxies in the Virgo Cluster

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by

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Contents

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Abstract

I present UBVRI, Hα and red continuum images for a complete sample of 29 low surface brightness dwarf irregular galaxies (LSB-dIs) members of the Virgo cluster, consisting of all the ImIV and ImV galaxies with $m_B \leq 17.2$, and compare them with similar data for a representative sample of high surface brightness (HSB) dwarf irregular galaxies, also in the Virgo cluster. Line fluxes and equivalent widths are listed for individual HII regions and total Hα emission is measured for the entire galaxies. Although significant line emission originates in the identified HII regions, it does not make up the entire Hα output of all galaxies. For those objects of the LSB sample with Hα emission I find typical star formation rates (SFR) of 6.9 10^{-3} $M_\odot$ yr^{-1}, to as high as 4.3 10^{-2} $M_\odot$ yr^{-1}. This is, on average, one order of magnitude weaker than for HSB objects, although the SFR overlap. On average, $\sim$2 HII regions are detected per LSB galaxy, for a total of 38 HII regions among 17 galaxies with Hα emission. The HII regions are smaller and fainter than in HSB galaxies in the same Virgo cluster environment, have Hα line equivalent widths about 50% of those in HSBs, and cover similar fractions of the galaxies. When more than one HII region is present in a galaxy I observe a strong intensity difference between the brightest and the second brightest HII region. The line-emitting regions of LSB galaxies are preferentially located at the periphery of a galaxy, while in HSBs they tend to be central. The Hα line strength of an HII region is correlated with the red continuum light underneath the region; this holds for both LSBs and HSBs.

The star formation activity of the LSB-dIs sample in the Virgo cluster was analyzed as a function of the radial velocity relative to the cluster mean velocity and the projected distance from the center of the cluster. The amplitude of the lopsidedness, the azimuthal angular asymmetry index, and the concentration of star forming regions, as represented by the distribution of the Hα emission, were quantified in an enlarged sample of 78 late-type irregular galaxies. The observed galaxies were binned in two groups representing blue compact galaxies (BCDs) and low surface brightness dwarf galaxies (LSBs). The light distribution was analyzed with a novel algorithm, which allows detection of details in the light distribution pattern. I found that while the asymmetry of the underlying continuum light, representing the older stellar generations, is relatively small, the Hα emission is very asymmetric and is correlated in position angle with the continuum light. The concentration of continuum light is correlated with the Hα concentration; this implies that the young star formation has the same spatial properties as the older stellar populations, but that these properties are more strongly expressed by the young stars. A model of random star formation over the extent of a galaxy was tested by simulating HII regions in artificial dwarf galaxies. A galaxy was traced by assuming red star clusters distributed on an underlying exponential disk of radius twice the scale length. The disk was allowed to change in apparent magnitude, scale radius, position angle, and ellipticity. The asymmetry-concentration distribution predicted by the simulations was compared with the real observed distribution; only LSBs match the distribution predicted by the model. The reason is that, independently of the number of HII regions, LSBs show no particular preference for the location of HII regions, whereas BCDs show current star formation activity restricted very much to the central parts of the galaxies. A consideration of the properties of the continuum light leads to the conclusion that most of LSBs can be approximated by exponential disks of radius twice their scale lengths; BCDs call, however, for much more concentrated underlying systems, with smaller scale lengths than assumed in the simulations. The implication is that random star formation over the full extent of a galaxy may be generated in LSB dwarf-irregular galaxies but not in BCD galaxies.

UBVRI surface photometry of the primary sample of LSB-dIs in the Virgo Cluster was performed. From this the central surface brightnesses, scale lengths, integrated magnitudes, and median colors were derived. The color distributions are discussed here in terms of radial surface brightness profiles, and color gradients are interpreted and compared with corresponding ones for low surface brightness spiral galaxies. The star formation histories are investigated using Hα and broad-band optical colors. Models derived from published libraries of evolutionary synthesis models are employed to describe the observed colors. The results show that the simplest models, of single and short star formation bursts cannot explain the evolution of these galaxies. The relative flux contribution of the young and the old population is constrained by a novel flux-weighted scheme and metallicities are derived from the best fit models. The conclusion is that LSB-dIs cannot be the faded remains of star-bursting dwarf galaxies and also cannot be objects where a low-key continuous star formation takes place. A more likely explanation is that in LSB-dIs episodic star formation takes place, at a lower intensity than in Blue Compact dwarf galaxies.