Surface Brightness Properties of LSB Galaxies with the ILMT

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Abstract

Low surface brightness (LSB) galaxies make up a significant amount of the luminosity density of the local universe. They have to be considered when building complete and homogeneous catalogs of galaxies. Their low surface brightness suggests a different formation and evolution process compared to more typical high-surface-brightness galaxies. LSB galaxies may hold important clues about the nature of dark matter, which is believed to be responsible for the observed rotation curves of galaxies, including LSB galaxies. Installed on the mountain of northern India, the ILMT provides surveys in g', r' and i' bands, which makes it possible to study the difference between red and blue LSB galaxies based on the *g*−*r* color criteria. Additionally, by investigating the surface brightness properties of LSB galaxies, the distribution and properties of dark matter in the universe can be learned in further research. In this project, the methods of image cleaning, LSB galaxies extraction, and surface brightness modeling are developing in progress.

Introduction

The Cosmological Principle states that the universe will appear homogeneous and isotropic to a typical observer, according to which our catalogs must be complete and homogeneous if galaxies are to be used as effective cosmological probes. However, beyond the Milky Way, most of our information about star abundance, kinematics, dark matter content, star formation history, and large-scale galaxy clusters is based on studies of galaxies with high surface brightness. As illustrated in Figure 1, LSB galaxies have a comparable number density to high surface brightness (HSB) galaxies. Therefore, LSB galaxies that make up a significant amount of the luminosity density of the local universe have to be considered when building complete and homogeneous catalogs of galaxies.

The International Liquid Mirror Telescope (ILMT) is a zenith-pointing telescope installed at Devasthal peak in the central Himalayan range in India. The operational wavelength of the ILMT is from 4000 to 11000˚A. Compared with other telescopes, there are several advantages of the ILMT. Since the ILMT cannot track stellar objects like conventional glass mirror telescopes, electronically stepping the relevant CCD charges is needed to secure the images. This purpose is achieved by using Time Delayed Integration (TDI), based on which every pixel in the image is generated by averaging over the response of 4K pixels along the column of the CCD [1]. This reduces flat field variations by a factor of ~ 4.5 magnitudes. Another advantage is that the ILMT always observes the same field at the zenith, so co-adding images are assured and the sky brightness and atmospheric scattering are minimized. These advantages make the ILMT well suited for studying LSB galaxies.

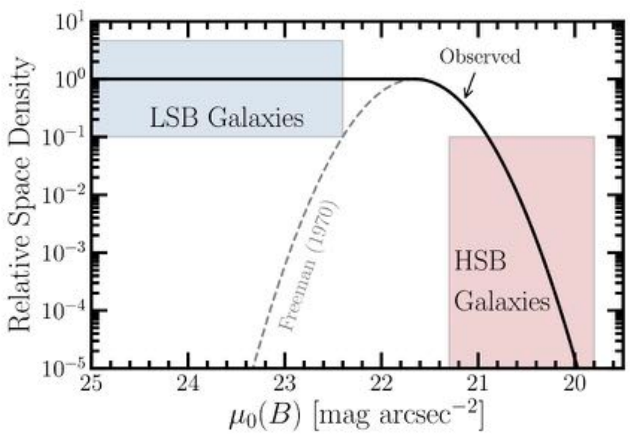

Fig 1. Plot of the relative space density of galaxies as a function of optical central surface brightness. The blue shaded region shows LSB galaxies, and the red shaded region shows high surface brightness (HSB) galaxies. The solid black line shows the observed distribution of galaxies [2]. The gray dashed line is the Gaussian curve that shows the predicted distribution from Freeman's Law [3]. Typical galaxies like the Milky Way fall near the peak of the Gaussian curve at $\mu_0(B) = 21.65\ mag\ arcsec^{-2}$. Figure from Greco [4].

Image Cleaning

Bright sources and their associated diffuse light were cleaned using Astropy's Photutils detect_sources alongside some transformations with binary masks. This replaces sources with the median background. Two thresholds were set in the cleaning process, one is the minimum size of source detection, the other one is the minimum brightness of the detected sources.

Fig 2. The original image from the ILMT is shown in the left panel. In the middle panel, the bright sources that are 4 standard deviation above the median of the sky background were cleaned if their size is larger than 1% of the image size. The subtracted bright sources are shown in the right panel.

LSB Galaxies Extraction and Modeling

A software program called SExtractor [5] is used for LSB galaxies extraction. It is particularly oriented towards the faint-galaxy photometry. It builds a catalog of objects from an astronomical image. The CLASS_STAR catalog parameter was used to determine if an extracted source is a star or a galaxy. We classify a galaxy as LSB if its *r*-band disc central surface brightness is fainter than 21 mag arcsec^{-2}. Then the selected samples were fitted with the Sersic 2D model provided by the Astropy package. Figure 3 shows an example of an LSB galaxy.

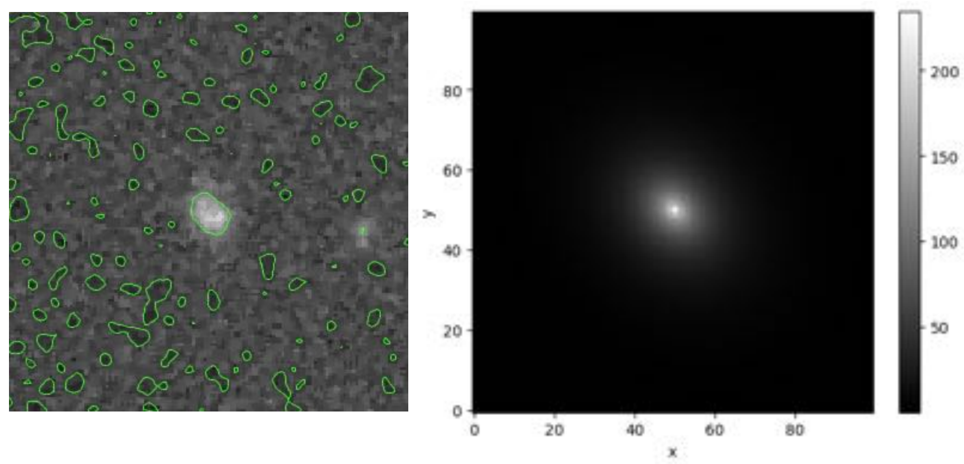

Fig 3. An example of an LSB galaxy observed by the ILMT is shown in the left panel. The green lines show isophotes, which were generated by SAOImage DS9. The right panel shows its image from which fitting parameters, including ellipticity and rotation angle, were derived.

Results

Since the project is still work in progress, here are the results of surface brightness properties obtained from an image taken by the ILMT on Oct 30, 2022. The central surface brightness and the effective radius were fitted based on the Sersic model.

Table 1. Observations and results

Number of LSB galaxies detected	1055
Median of central surface brightness	23.45 mag arcsec^{-2}
Median of effective radius	7.26 arcsec

Discussion

The current image cleaning program can only be used for small scale astronomical images (smaller than 2000 by 2000 pixels) while the size of the raw images from the ILMT is 4096 by 4096 pixels or even much larger. Therefore, a trim program will be combined with the image cleaning program. This is both bad and good. The disadvantage is that the analysis efficiency will be reduced. The benefit for analyzing a smaller image is that the local sky background estimation is more precise.

After analyzing the astronomical images in batches, the distribution of LSB galaxies with different surface brightness can be obtained. Additionally, since the ILMT provides surveys in g', r' and i' bands, it is also possible to study the difference between red and blue LSB galaxies based on the g'−r' colour criteria.

References

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