HI LINE OBSERVATIONS OF NEAR-INFRARED SELECTED LOW-SURFACE BRIGHTNESS GALAXIES

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ABSTRACT

A multi-wavelength study is being made of 4,000 Low Surface Brightness (LSB) galaxies detected in the 2MASS all-sky near-infrared survey. They have similar central K-band surface brightness as optically selected LSBs. About 1,000 of them were observed in the 21 cm HI line, and 30% were detected. Optical BVRI CCD photometry was obtained of 45 objects. These data provide us with important information on a large, homogenous sample of LSB galaxies (e.g., colours, gas content). They will be used to construct models of the star formation history and evolution of LSBs, and to search for deviations from the 'classical' Tully-Fisher relation.

A NEAR-INFRARED SAMPLE OF LOW SURFACE BRIGHTNESS GALAXIES

At present, the Low Surface Brightness galaxies (hereafter LSBs) constitute the least well known fraction of galaxies: their number density and physical properties (luminosity, colours, dynamics) are still quite uncertain, though studies [1] have indicated that they are very numerous. This is, per definition, mainly due to the fundamental difficulty in identifying them in imaging surveys and in measuring their properties, as their central surface brightness often does not even exceed that of the night sky.

LSBs have remarkable properties, which distinguish them from the more familiar objects on the Hubble sequence of 'classical' high surface brightness (HSB) galaxies, such as:

- they seem to constitute at least 50% of the total galaxy population in number, which has strong implications for the faint end slope of the galaxy luminosity function, on the baryonic matter density and especially on galaxy formation scenarios;
- their disks are among the less evolved objects in the local universe, universe since they have a very low star formation rate (SFR);
- they are embedded in dark matter halos which are of lower density and more extended than the halos around HSBs and they are strongly dominated by Dark Matter at all radii.

The initial report [2] of rare, red (B-I~1) LSBs with unprecedented properties (record high HI contents of M_{HI}/L_B~30-45 $M_\odot/L_{\odot,B}$, i.e. about 100 times the values found for an average HSB spiral galaxy, and objects whose rotational velocities are far too high for their luminosity) appears, at least in some cases, to be due to confusion with other, gas-rich galaxies within the beam of the Arecibo radio telescope [3].

Basically all previous studies of LSBs were made in the optical and most objects studied were blue. In order to further investigate the often baffling properties of the LSB class of galaxies we selected a large sample of them from the Two Micron All Sky Survey (2MASS), accessing a wavelength domain (the near-infrared) hitherto unexplored in the study

of LSBs. Though relatively less deep than some of the dedicated optical imaging surveys made of LSBs over limited areas of the sky, the 2MASS survey allows the detection of LSB galaxies extending over the entire sky. The near-infrared data will be less susceptible than optical surveys to the effects of extinction due to dust, both Galactic and internal to the galaxies.

We are at present undertaking the first large-scale study of LSBs selected in the near-infrared (J, H and K bands, centred at, respectively, 1.25, 1.65 and 2.2 μm wavelength), using a homogeneous sample of about 4,000 potential LSBs selected mainly from among 1.4 million objects listed in the 2MASS Extended Source Catalog (XSC). We also used a dedicated algorithm to find lower signal-to-noise LSB galaxies among those sources, which were not recognized as such during the standard source selection for the XSC. A generally used selection criteria to separate LSB galaxies from the 'classical' HSB galaxies is a blue (B-band) central surface brightness μ_B of 22 mag arcsec^{-2}, which corresponds to about μ_K 18 mag arcsec^{-2} in the K-band - which is the selection limit we used in our near-infrared survey. For the southern hemisphere, the 2MASS data will be completed by I-band data from the DENIS survey.

We compared (see Fig. 1) some basic 2MASS K-band photometric properties of the following subsets of our 2MASS LSBs sample with those of a number of optically selected galaxy samples, of both LSB and HSB objects:

Sub-samples from our survey:

- *2MASS L* : our larger LSB galaxies from the 2MASS survey catalogue with a 20 mag arcsec^{-2} K-band isophotal radius $r_{k20} \geq 20$ arcsec;
- *2MASS S* : same, smaller objects with 20 arcsec $\geq r_{k20} \geq$ 10 arcsec;
- *2MASS algo 2* : 2MASS sources with lower surface brightness, extracted using a dedicated algorithm.

Comparison samples:

- *NGC L* : larger optically selected "classical" HSB galaxies from the NGC, with $r_{k20} \geq 20$ arcsec;
- *NGC S* : same, smaller objects with $r_{k20} \leq 20$ arcsec;
- *LSB opt.* : optically selected LSB galaxies from UK Schmidt plates [4], detected by 2MASS.

These plots show that our 2MASS LSBs sample has the same range of central surface brightness in the K-band as the objects from a sample of optically selected LSBs that were detected by 2MASS using the same selection criteria we adopted for our sample.

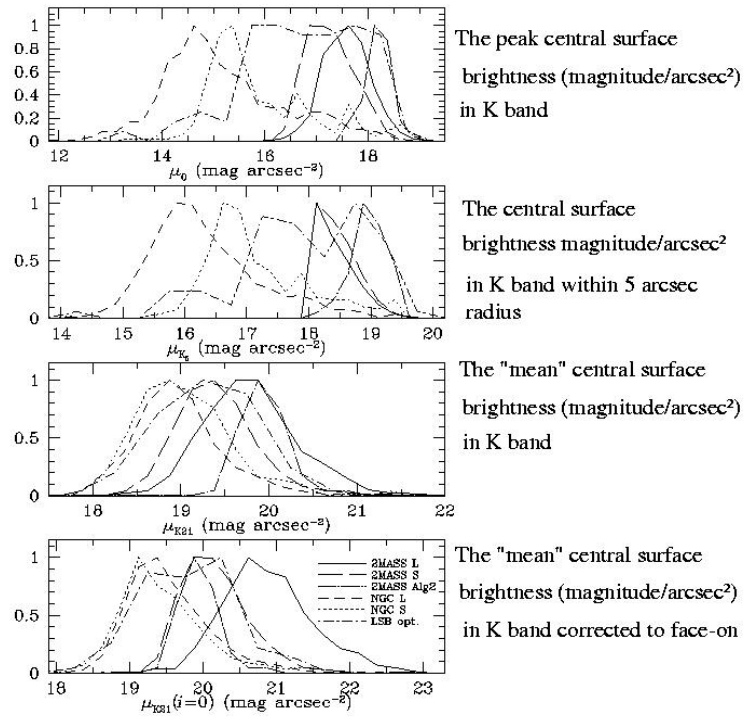

Figure 1; Comparison between various measurements of the K-band surface brightness of two subsets of our 2MASS LSB galaxies with those of other samples of LSBs and HSBs (see text).

We have also obtained optical broad-band BVRI CCD photometry of about 45 objects with the 1.5 m telescope at the San Pedro Martir Observatory in Mexico. B-band images of 6 objects are shown in Figure 2. The reduction and interpretation of these data is in progress. A first analysis shows a higher percentage of barred spirals and Irregulars than one would expect from a sample of field galaxies, as well as a number of cases, which appear to be in a state of interaction or even merging with another galaxy. The galaxies appear to be rather red, and their radial luminosity profiles indicate that their extrapolated central disc surface brightness values are just below the value μ_B of 22 mag arcsec^{-2}, which is generally considered as the separation limit between LSBs and HSBs.

Figure 2. False-colour representations of B-band CCD images of six of our 2MASS LSB galaxies.

Models of the chemo-spectrophotometric evolution of LSBs are under development [5]. Using realistic models of the chemical and spectrophotometric evolution of disc galaxies, and comparing these to observed properties of different samples of LSBs, we are exploring the idea that LSBs are similar to HSB spirals, but with higher angular momentum.

21 CM HI LINE OBSERVATIONS

We have observed a sub-sample of about 1,000 objects in the 21-cm HI line. Our observing strategy is based on the complementary characteristics of two recently renovated radio telescopes, at Arecibo (Puerto Rico) and at Nançay (France). The 300 m diameter Arecibo telescope was used for higher sensitivity observations of a total of 400 both larger and smaller diameter 2MASS LSBs (see Fig. 1) in the declination range it can cover, between 0° and 38°, while the 300 × 40 m Nançay telescope was used for 600 LSBs in the complementary declination ranges –38° to 0° and 38° to 60°. The rms. Noise in the Arecibo and Nançay data is about 1 and 3 mJy, respectively, for a velocity resolution of about 12 km/s.

This strategy has resulted in a similar detection rate of about 30% for both sub-samples, generally in the radial velocity range of 0-10,000 km/s. A first analysis of the data shows HI masses ranging from ~8 10^8 to 4 10^{10} $M_\odot$ (for a Hubble constant of 75 km s^{-1} Mpc^{-1}), and HI mass-to-blue luminosity ratios ranging from M_{HI}/L_B 0.07-2.5 $M_\odot/L_{\odot,B}$, i.e. from gas-poor to very gas rich, with an average ratio of ~0.6 $M_\odot/L_{\odot,B}$; for comparison, an average HSB spiral has an M_{HI}/L_B ratio of ~0.3 $M_\odot/L_{\odot,B}$.

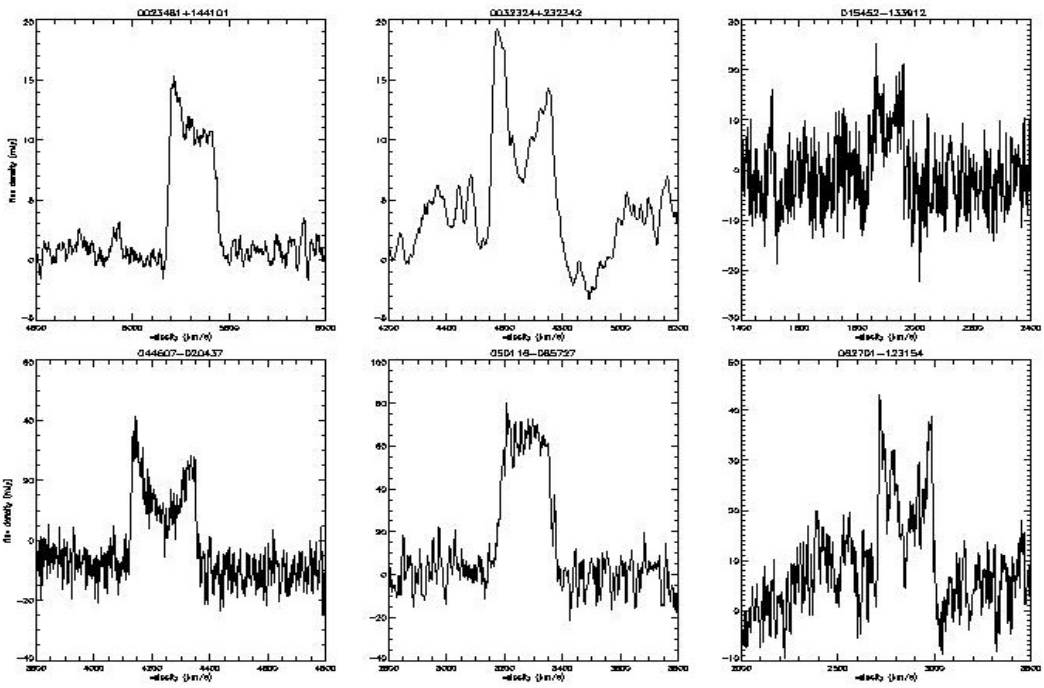

Figure 3: 21 cm HI line spectra of the six LSBs for which the images are shown in Figure 2.

A first analysis of the relation between their absolute luminosities in various photometric bands and HI profile widths corrected for the galaxies' inclinations (a measure of the rotational velocities), the so-called Tully-Fisher relation, has not shown any galaxies which are severely underluminous for their total mass.

This study is the PhD thesis project of D. Monnier Ragaigne. For published reports on the work in progress, see [6] and [7]; a series of refereed papers presenting the results of the project is in preparation.

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