The Spectral Energy Distribution of Galaxies
Proceedings IAU Symposium No. 284, 2011
R.J. Tuffs & C.C. Popescu, eds.

doi:10.1017/S1743921312008824

The dust distribution in late-type low surface brightness disks

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Abstract. Late-type low surface brightness (LSB) disk galaxies are common in the local universe and appear dynamically and chemically under evolved compared to their high surface brightness (HSB) counterparts. We have utilized multi-wavelength imaging and photometry of three edge-on, low-mass LSB disk galaxies to investigate the dust distribution in such systems. Through the use of Monte Carlo radiation transfer models to interpret the data, we find that the dust disk appears to have a vertical scale height similar to the stellar disk. This is in contrast to previous findings from HSB galaxies, where the dust is believed to be more concentrated in the galactic mid-plane. We believe the change in the relative scale heights of the dust and stellar disks is likely associated with the increased stability of the ISM against vertical collapse and the thin nature of the stellar disks.

Keywords. galaxies: ISM, galaxies: spiral, radiative transfer

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1. Introduction

Late type LSB disk galaxies, with B band central, face-on surface brightnesses below 23.0 mag arcsec^{-2} are a common class of galaxy in the local universe. Often their total HI masses are comparable to or larger than their HSB counterparts, while their HI surface densities are lower by a factor ~ 2 (van der Hulst *et al.* 1993). This fact may may lead to a lower than expected star formation efficiency causing LSB galaxies to evolve more slowly than HSB galaxies. These galaxies frequently show signs of being dark matter dominated at nearly all radii (de Blok & Bosma 2002). Due to the difficulties of directly detecting molecular gas in low mass LSB spirals (cf. Matthews *et al.* 2005), an alternative method to investigate the composition and structure of the cool phases of the ISM is to observe far-infrared (FIR) emission produced by dust.

2. Method

In order to investigate the dust content of such galaxies we have gathered multi-wavelength data (*GALEX*, SDSS, 2MASS and *Spitzer*) for a sample of three edge-on examples. By using Monte Carlo radiation transfer codes that include the effects of transiently heated grains and polycyclic aromatic hydrocarbon molecules (Wood *et al.*

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2008) in conjunction with GALEV (Kotulla *et al.* 2009) stellar population models we have attempted to model the dust distributions. As well as the diffuse dust component we also include a template for emission from small star forming regions that are below the current resolution of our models. This emission from compact regions, powered by young stars, is necessary to reproduce the observed far-infrared (FIR) emission

3. Results

We are able to reproduce the global, optical appearance of all three galaxies using smooth emissivity and dust distributions. Figure 1 shows optical, near and mid-infrared imaging of UGC 7321 along with our best fitting model images. The SEDs for the three galaxies studied can be seen in Figures 2, 3 and 4. Our smooth, axisymmetric models provide a good fit to the total FIR emission in all three cases.

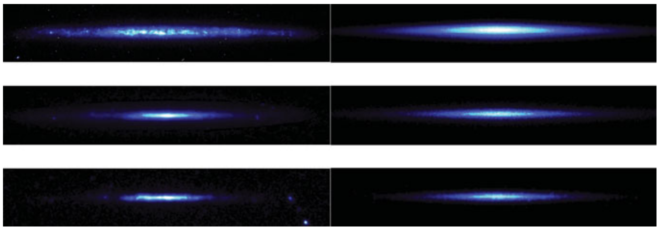

Figure 1. Observed (left) and synthetic (right) images of UGC 7321 at, from top to bottom: B band, 3.6μm, 8μm.

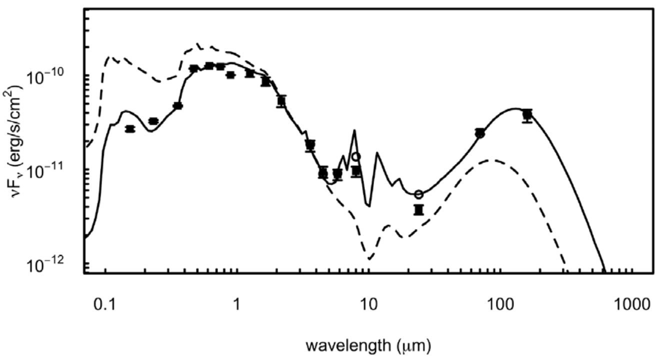

Figure 2. The observed and modeled SED of UGC 7321. Square points indicate an observed flux from one of our data sources either *GALEX*, SDSS, 2MASS or *Spitzer* IRAC/MIPS along with their associated errors. The solid line shows the model output SED. Open circles show the predicted fluxes for *Spitzer* IRAC/MIPS bands. The long dashed line indicates the input, unattenuated, stellar template plus star forming region dust emission template.

4. Implications

In our analysis we find that unlike high surface brightness galaxies previously modeled (Xilouris *et al.* 1999), the dust disks in edge-on LSB galaxies appear to have scale heights equal to those of the stellar disks. The comparable scale heights in the dust and stellar disks are likely associated with the increased stability of the ISM in low mass disks against vertical collapse (Dalcanton *et al.* 2004) and the thin nature of the stellar disks, which suggests minimal dynamical heating. Dust masses are found in the range 1.16

https://doi.org/10.1017/S1743921312008824 Published online by Cambridge University Press

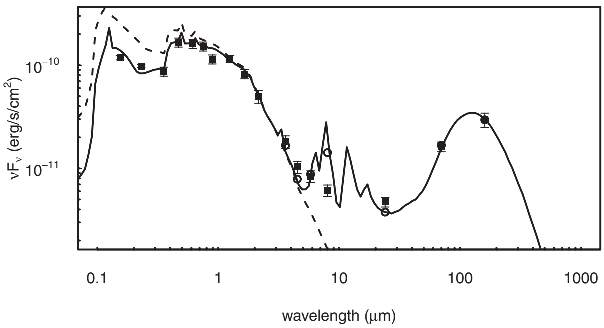

Figure 3. Same as Figure 2 but for IC 2233.

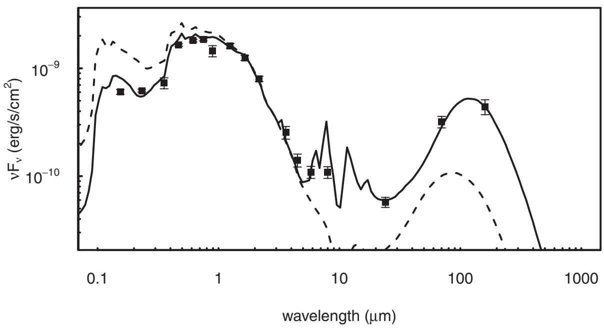

Figure 4. Same as Figure 2 but for NGC 4244.

to $2.38 \times 10^6 M_\odot$, corresponding to face-on (edge-on), V-band, optical depths $0.034 \lesssim \tau_{face} \lesssim 0.106$ ($0.69 \lesssim \tau_{eq} \lesssim 1.99$).

In future work we hope to develop our radiation transfer models to include small scale non-axisymmetric structures which may shed further light on the structure of the ISM and star formation processes in LSB disk galaxies. The inclusion of radial variations in the dust disk scale heights, associated with a flaring gas disk, could also prove important. Additional sub-mm observations may also allow us to uncover cold dust that is associated with the extended HI, as has been found in some HSB galaxies (Popescu & Tuffs 2003).

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