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Dust effects on the derived Sérsic indexes of disks and bulges in spiral galaxies

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Abstract. We present a theoretical study that quantifies the effect of dust on the derived Sérsic indexes of disks and bulges. The changes in the derived parameters from their intrinsic values (as seen in the absence of dust) were obtained by fitting Sérsic distributions on simulated images of disks and bulges produced using radiative transfer calculations and the model of Popescu *et al.* (2011). We found that dust has the effect of lowering the measured Sérsic index in most cases, with stronger effects for disks and bulges seen through more optically thick lines of sight.

Keywords. Galaxy: disk, galaxies: bulges, Galaxy: fundamental parameters, galaxies: spiral, galaxies: ISM, galaxies: structure, (ISM:) dust, extinction, radiative transfer

1. Introduction

In recent years deep wide field spectroscopic and photometric surveys of galaxies (e.g. GAMA, Driver *et al.* 2011) are providing us with large statistical samples of galaxies with good quality imaging up to z=0.1. In parallel, automatic routines like GALFIT (Peng *et al.* 2002, Peng *et al.* 2010) or GIM2D (Simard *et al.* 2002) have been developed to address the need of fitting large number of images of galaxies with 2D analytic functions to characterise the surface brightness distribution of their stellar components. In particular Sérsic functions are the most common distributions that are used to describe the profiles of galaxies and their constituent morphological components. The derived Sérsic indexes are then used to classify galaxies as disk or bulge dominated ones (e.g. Kelvin *et al.* 2012) or in terms of a bulge-to-disk ratio when bulge/disk decomposition is performed (Simard *et al.* 2011).

One potential problem with the interpretation of the results of Sérsic fits is that the measured Sérsic parameters differ from the intrinsic ones (as would be derived in the absence of dust). This is because real galaxies, in particular spiral galaxies contain large amount of dust, and this dust changes their appearance from what would be predicted to be seen in projection based on only their intrinsic stellar distributions. Determining the changes due to dust is thus essential when characterising and classifying galaxies based on their fitted Sérsic indexes.

Here we present results of a theoretical study to quantify the effects of dust on the measured fitted Sérsic indexes, as a function of the relevant parameters: dust opacity, disk inclination and wavelength. The results are presented for pure disks and bulges, as seen through a common distribution of dust (in the disk of the parent galaxy). These results are part of a larger study that aims to quantify the effects of dust on all photometric parameters of young stellar disks, old stellar disks and bulges (Pastrav *et al.*, in prep) and builds on our previous work of Möllenhoff *et al.* (2006).

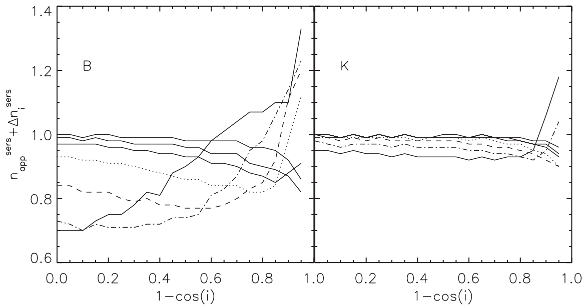

Figure 1. The inclination dependence of the derived Sérsic index, n_{app}^{sers}, corrected for projection effects, Δn_i^{sers}, for disk images in the B and K bands. From top to bottom, the curves are plotted for central face-on opacity in the B band $\tau_B^f = 0.1, 0.3, 0.5$ (solid lines), 1.0 (dotted), 2.0 (dashed), 4.0 (dashed-dotted), 8.0 (dashed-3 dotted).

2. The method

We based our study on simulated images of dust-attenuated disks and bulges for which their intrinsic parameters are known, being input for the simulations. We then measured the perceived (apparent) photometric parameters using widely used 2D fitting routines, in an attempt to exactly mimic what an observer would measure for a real galaxy. The difference between the measured parameters (affected by a combination of projection and dust effects) and the intrinsic ones (as used to construct the 3D distributions of stellar emissivity) provides knowledge on the effects of dust (and also on projection effects). The aim of the study is thus to provide observers with corrections for the "simplicity" of the templates commonly used to analyse images of galaxies, "simplicity" which is nevertheless necessary for practical purposes when dealing with large numbers of objects.

The simulated images were produced using radiative transfer calculations and the model of Popescu *et al.* (2011) (see also Popescu *et al.* 2000 and Tuffs *et al.* 2004). In brief the disks were built using a distribution of stellar emissivity described by a double exponential (in radial and vertical direction) while bulges were built using the deprojection of general Sérsic distributions, in particular of a distribution with a Sérsic index $n_0^{sers} = 4$ (de Vaucouleurs) and a Sérsic index $n_0^{sers} = 1$ (exponential). Both disks and bulges were attenuated by a common distribution of dust (present only in the disk). More details about the geometry of the model can be found in Popescu *et al.* (2011).

To fit the simulated images, we applied the commonly used GALFIT data analysis algorithm (Peng *et al.* 2002, Peng *et al.* 2010). Both disks and bulges were fitted by the commonly used 2D Sérsic distributions, corresponding to an infinitely thin disk. In both cases the Sérsic index of the fitted function was left as a free parameter of the fit.

3. Results

The results on the effects of dust on the derived Sérsic indexes are summarised in Fig. 1 (for the disk) and Fig. 2 (for the bulge). In each figure we plot the results on the measured Sérsic index corrected for projection effects. By projection effects we mean the difference between the projection of a distribution of stellar emissivity that has a vertical distribution in addition to a radial distribution, and the projection of an infinitely thin disk, which is assumed when fitting the images with analytical 2D Sérsic functions. This results in an alteration of the measured Sérsic index, even in the absence of dust. The corrections for projection effects are discussed and listed in Pastrav *et al.* (in prep). Here

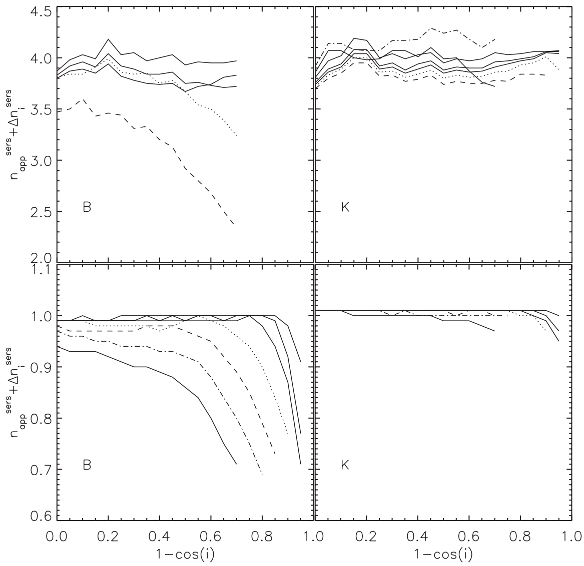

Figure 2. Upper row: The inclination dependence of the derived Sérsic index, n_{app}^{sers}, corrected for projection effects, Δn_i^{sers}, for de Vaucouleurs bulges ($n_0^{sers} = 4$), in the B and K optical bands. Lower row: The same, but for exponential bulges ($n_0^{sers} = 1$). Line styles are as in Fig. 1.

we only show the results on the measured Sérsic index after correction for projection effects.

In each figure we show the results as a function of inclination and for different values of central face-on opacity in the B band, τ_B^f, which are the two parameters of the radiative transfer model. In addition we show results at two different wavebands (B and K).

One can see that at longer wavelengths, in the K band, the effects of dust are negligible. Essentially one can measure the intrinsic Sérsic indexes for both disks and bulges, once corrected for projection effects. For example for intrinsically exponential disks the derived Sérsic index is ~ 1. Similarly, for intrinsically de Vaucouleurs and exponential bulges the derived Sérsic indexes are ~ 4 and ~ 1, respectively. At shorter wavelength, in the B band, the dust starts to affect the derived Sérsic indexes, with stronger effects for higher τ_B^f and larger inclinations. In most cases the effect of dust is *to lower the Sérsic index* from its intrinsic value. This is because of the large scale distribution of dust, which decreases exponentially with increasing radial distance, making the profiles flatter in the central parts.

Another result is that in most cases the *Sérsic index decreases with increasing inclination and* τ_B^f, except for very optically thick disks, which show a reverse trend.

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