Structures and Photometric Redshifts of Faint Spiral Galaxies

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We analyze WF/PC images of a sample of faint spiral galaxies with known spectroscopic redshifts, deriving separate bulge and disk (V-I) colors by decomposing the images into $r^{1/4}$ and exponential components. The color behavior of bulges with redshift in the range $z = 0.2 - 0.8$ is very systematic, tracking models for elliptical-galaxy populations with star formation confined to an initial burst. The relation is tight enough that even with the pre-STS-61 PSF, redshifts can be constrained to ± 0.1 from the bulge color alone. Disk colors show a wide range, scattering between the colors of bulges and the constant-SFR case.

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1 Introduction

HST imaging makes possible detailed morphological studies for vast numbers of faint galaxies at significant redshifts, far too many for detailed spectroscopic followup. Some investigations on faint-galaxy properties from such data (i.e. the Burkey et al. 1994 study of galaxy pairing at faint levels) require at least statistical redshift information for their interpretation. We consider here whether the detailed structural information implicit in WF/PC images can provide enough additional constraints to allow useful redshift estimates from colors of the individual morphological components of such galaxies. Since ellipticals are well-behaved in this regard and have only a single dominant component to deal with, we consider here the case of spiral galaxies.

2 Decomposing Bulge and Disk Spectra

We separated disk and bulge properties for sample nearby galaxies, as a first step in decomposing distant systems from colors and morphological information. For galaxies with known integrated spectra and photometric decompositions, we subtract a trial bulge spectrum (in practice, for an intermediate-luminosity elliptical such as NGC 3379) normalized to match the measured bulge-to-disk ratio at the appropriate wavelength. The residuals comprise the estimated disk spectrum, generally close to that expected from a population with constant star-formation rate.

We illustrate using NGC 3627 (fig. **??**), with the integrated spectrum from the Kennicutt (1992) atlas and photometry from Kent (1985). The strong wavelength dependence of disk-to-bulge ratio is sobering for doing Hubble classification at constant observed wavelength. The few galaxies for which data are readily available for such an analysis show an overall good fit for the elliptical + constant-SFR model, though variations are seen at a given Hubble type.

3 HST Data: Two-Dimensional Image Modelling

To measure disk and bulge colors from WF/PC images of galaxies at redshifts $z = 0.2 - 0.6$, we fitted combinations of $r^{1/4}$ and exponential profiles, convolved with the local PSF, to the original aberrated data. Deconvolved images were used to speed convergence of the fits by using them to give initial values for the geometric parameters - orientation and axial ratios - of the individual components. We took empirical PSFs from stars observed in the same program where available, and TinyTIM PSF models otherwise. This procedure gives estimates of galaxy structural parameters free of any biases introduced by deconvolution, *to the extent that these two components accurately describe a galaxy's morphology.* The fits are made in the two-dimensional image plane, using a χ^2-like criterion. It differs from an exact χ^2 approach in normalization, since the amount of blank sky or nearly-blank sky on the galaxy outskirts included in the fit is a matter of judgment and is often affected by companion galaxies or other neighboring objects. For galaxies with well-determined local PSF and symmetric structure, Keel & Windhorst (1993) show that the agreement among structural parameters determined by completely disparate approaches is quite reasonable.

For this initial comparison, we use a set of galaxies in the 53W field (covered by the Leiden-Berkeley Deep Survey, for example) in Hercules, which have deep WF/PC wide-field images (Windhorst et al. 1994) and MMT redshifts. The WFC data are in F555W ("V") and

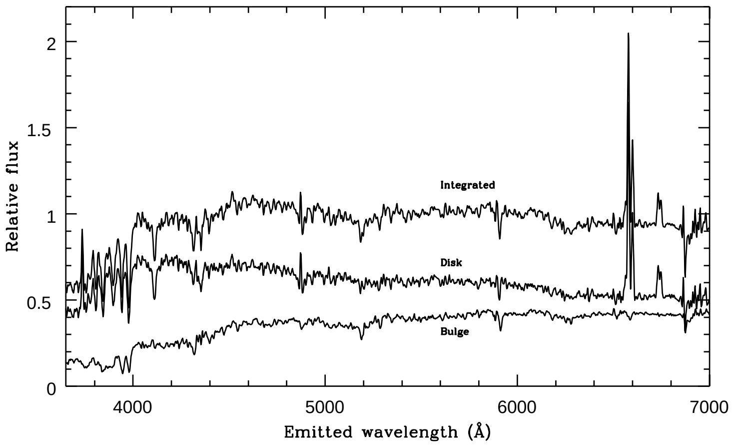

Figure 1: Derived spectra of morphological components of NGC 3627. The bulge spectrum is approximated by an elliptical galaxy scaled to match the photometric bulge:total intensity ratio at the V band, and the disk spectrum is as the residual from this subtraction.

F785LP ("I") filters; modelled quantities use the sensitivity curves for these same passbands as well.

4 Results

Figure **??** shows the behavior of bulge and disk colors in the WF/PC V-I system with redshift. Bulges are photometric well-behaved (particularly if errors due to the photometric decomposition are taken into account), while disks exhibit a wide color range at a given redshift. We superimpose models from Bruzual's GISSEL programs, for elliptical-like and constant-SFR cases. Bulge colors from these data predict redshifts to $\Delta z = \pm 0.1$, while disk colors are essentially constant with redshift (and widely scattered) over the relevant range. The particulars of the galaxy models shown are as follows: assumed Hubble constant was 50 km s^{-1} Mpc^{-1} and $q_0 = 1/2$; the elliptical model had an initial burst 13.75 Gyr ago, and the spiral disk model began star formation at a constant rate 10 Gyr ago. For $z < 0.8$, the color changes are dominated by passband effects (K-corrections) rather than genuine population evolution.

5 Summary

We have compared colors of disks and bulges for intermediate-redshift galaxies ($z = 0.2 - 0.8$), derived from WF/PC imagery, and redshifts. Bulge colors can be used as redshift indicators (mostly because of strong K-corrections) when spectroscopic redshifts are unfeasible, to an accuracy about 0.1 in z. Disk colors are very scattered, and indicate a wide range of star-forming histories from initial bursts to constant-SFR (which forms the blue envelope of disk color versus redshift).

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Burkey, J.M., Keel, W.C., Windhorst, R.A. & Franklin, B. 1994, ApJL, 429, L13

Keel, W.C. & Windhorst, R.A. 1993, AJ, 106, 455

Kennicutt, R.C., Jr. 1992, ApJS, 79, 255

Kent, S.M. 1985, ApJS, 59, 115

Windhorst, R.A. et al. 1994, ApJ 435, in press

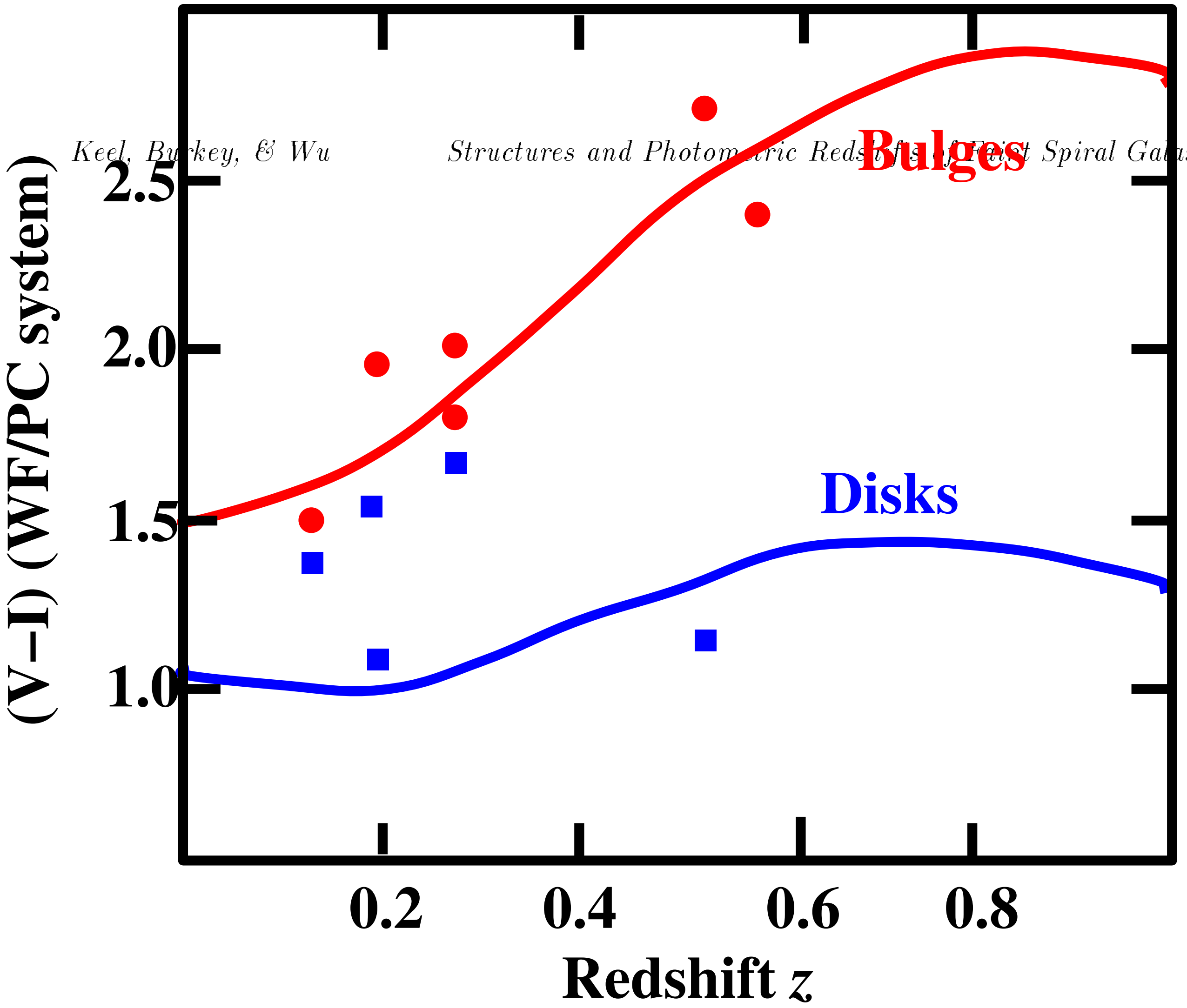

Figure 2: Colors of galaxy components in the F555W-F785LP (V-I) system derived from bulge-disk decompositions versus spectroscopic redshift. The upper curve is the elliptical-galaxy model, and the lower is a constant-SFR model. Filled circles are bulges and squares indicate observations of disks.