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B/T-ratios in the Hubble sequence

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Abstract. We discuss bulges in the Hubble sequence, based on the analysis of deep near-IR images for a sample of 216 nearby galaxies. Using a 2D multicomponent decomposition code, we find that the average bulge-to-total (B/T) flux ratio is less than 0.25 across all morphological types. Even 50% of the early-type galaxies (S0-S0/a) are found to have nuclear bars, inner disks or nuclear rings inside the bulge. Also, the shape parameter of the bulge is on average $\leqslant 2$ for all Hubble types. Our results are consistent with the picture in which bulges even in many early-type galaxies were formed by secular evolutionary processes. We find two galaxies that might be stripped spirals, belonging to the so far empty S0c morphological class introduced by van den Bergh (1979).

Keywords. galaxies: bulges, galaxies: evolution, galaxies: fundamental parameters

1. Introduction

Our Near-IR S0 galaxy Survey (NIRS0S) is based on a magnitude-limited sample of nearly 200 early-type disk galaxies (Laurikainen, Salo & Buta 2005; Buta *et al.* 2006). Combined with the Ohio State University Bright Galaxy Survey (OSUBGS, Eskridge *et al.* 2002) for spirals, it is planed to provide a homogeneous near-IR database to study the structural components of galaxies in the Hubble sequence. Our main objectives are:

(1) To derive the distribution of bar strengths which, when compared with simulation models, is expected to test how robust are bars and ovals over time.

(2) To make a detailed analysis of bars, bulges and ovals using a multicomponent decomposition code, and by applying Fourier methods for analyzing their morphologies.

(3) To form a coherent picture of the structural components in galaxies, by combining the morphological analysis with studies of the color index maps, and stellar kinematic studies for subsamples of galaxies.

2. Properties of bulges in the Hubble sequence

We found ovals/lenses in 70% of the S0-S0/a galaxies, and nuclear bars, nuclear rings or inner disks inside the bulge in 50% of these galaxies. For structural decompositions we use a 2-dimensional multicomponent code (Laurikainen, Salo & Buta 2004, 2005). For disks an exponential function is used, bulges are fitted by a generalized Sersic's function, whereas bars and ovals can be described either with Sersic's or Ferrers' functions. In Fig. 1 we show results for 216 galaxies. For consistency, only three components were included in the fit, but a comparison with our more sophisticated decompositions for early-type galaxies (Laurikainen *et al.* 2006) showed that the mean B/T-ratios are practically unaffected. A comparison to the decompositions by Simien & de Vaucouleurs (1986, SV),

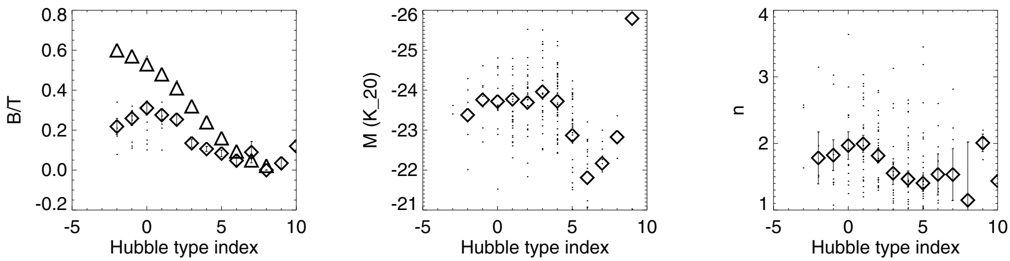

Figure 1. (a) Bulge-to-total mass ratio (B/T) v.s. Hubble type index T, derived for 216 galaxies (diamonds). For comparison, those derived by Simien & de Vaucouleurs (1986) for 98 galaxies in B-band (triangles) are also shown. We use a multicomponent approach with at maximum three components, whereas Simien & de Vaucouleurs used 1D-decomposition method. (b) Extinction corrected K-band absolute magnitudes, estimated to the surface brightness of 20 mag / arcsec^2 (from 2MASS). (c) Shape parameter of the bulge, n, taken from our decompositions. The large symbols are mean values in each Hubble type index bin.

made in the B-band, shows that the B/T-ratios found by us are considerably smaller for all Hubble types. However, this large difference to our results is not due to the wavelength used, because similar large values as found by SV, were recently obtained also by de Souza, Gadotti & dos Anjos (2004, SGA) in the K_s-band. A more reliable explanation is that both in the 1D decompositions by SV and in the 2D bulge/disk decompositions by SGA a large fraction of the bar flux goes erroneously to the bulge. If mass-to-luminosity ratio (M/L) is assumed to be constant, our result implies that the amount of mass locked up in the bulges is considerably smaller than the mass in the galactic disks.

We also found that the shape parameter n of the bulge is on average $\leqslant 2$ for all Hubble types. Similar small n-values have been found also by Graham (2001) for non-barred galaxies. Our results are consistent with the picture where a majority of bulges were formed by secular evolutionary processes. For late-type spirals this is expected to be due to star formation in the disk, and for early-type galaxies to some other mechanism, most probably related to bars. Interestingly, in two S0s the B/T ratios were found to be as small as in Sc-type spirals. This might indicate that they are stripped spirals, belonging to the so far empty S0c morphological class in the DDO classification system by van den Bergh (1979).

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Discussion

Ben Moore: What is you definition of SO? Since many of your SOs have features (inner disks, rings, etc.)

Eija Laurikainen: SOs have no spiral arms. The classification is from the de Vaucouleurs Atlas of galaxies by Buta, Corwin and Odewahn (2007). SOs typically have lenses/ovals that also Sandage and Bedke (1994) payed attention to in the Carnegie Atlas of Galaxies. Inner rings, inner disks and nuclear bars generally appear when the bulge component is subtracted.

Gerhard Hensler: Are the Sc-like SOs located in a special environment, like e.g. cluster?

Eija Laurikainen: We have only one or two candidates yet. So the answer is that I don't know.