On the light-profiles of spiral galaxy bulges and the Hubble sequence for spirals

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Abstract. Recent studies have claimed that the Hubble sequence of late-type spirals, and spirals in general, is scale-free. Within the photometric data used in these works, a trend exists between morphological type and bulge profile shape such that late-type spiral bulges are described by an exponential luminosity profile, where-as the early-type spiral bulges are better described by an $r^{1/2}$ or $r^{1/4}$ law. The universal application of an exponential light-profile to the disk *and* bulge of *all* spiral galaxies is not justified. Taking structural parameters from exponential disk models and the best-fitting $r^{1/n}$ bulge models (with n=1, 2 or 4), the mean effective-bulge-radius to disk scale-height ratio (r_e/h) increases at the 3 σ significance level. Additionally, the early-type spiral galaxies are shown to have a larger r_e/h ratio than the late-type spirals in all passbands.

Using structural parameters from exponential light-profile models fitted to both the disks and bulges of spiral galaxies, Courteau, de Jong & Broeils (1996) and de Jong (1996) claimed that the distribution of bulge-to-disk scale-length ratios was constant among all spiral morphological types. That is, they claimed the Hubble sequence of spirals is scale-free. With the notable exception of Moriondo, Giovanardi & Hunt (1998) this claim has remained unquestioned. This is somewhat surprising as this result contradicts the popularly established picture. In fact, Hubble's (1926) first criteria for the classification of spiral galaxies was the "*relative size of the unresolved nuclear region*".

However, with the arrival of the new millennium, we are seeing the application of refined galaxy models. The classical fitting functions (e.g. exponential model, $r^{1/4}$ law) are no longer found to be sufficient to describe the level of detail observed in galaxy images (Davies et al. 1988; Caon, Capaccioli & D'Onofrio 1993; Young & Currie 1994; Andredakis, Peletier & Balcells 1995; Graham et al. 1996; Binggeli & Jerjen 1998; Moriondo, Giovanardi & Hunt 1998, to mention a few). In fact, use of the $r^{1/4}$ law for ellipticals can result in systematic errors to the Fundamental Plane and in it's use as a distance indicator (Graham & Colless 1997; Graham 1997). Additionally, the universal application of an exponential profile has been shown to result in mis-representations of the μ_e–r_e plane for dwarf ellipticals (Jerjen & Binggeli 1997) and conclusions drawn therefrom.

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In de Jong's fitting of the Sersic $r^{1/n}$ profile (with n=1, 2 and 4) to the bulges of his selection of Sa-Sm galaxies, the n=1 model gave the best-fitting profile for only 50-60% of the sample. Most of the early-type spirals ($\leq$Sb) are best fit by models with n>1, while the late-type spirals are best fit with n=1. Using exponential disk scale-lengths (h) and effective half-light radii (r_e) from the best-fitting bulge profile models (either n=1, 2, or 4), we have re-investigated the distribution of values of r_e/h. The mean value of r_e/h, for the sample as a whole, was found to increase at the 2-4 σ significance level (depending on the passband used, BVRIHK), and indicates the importance of allowing for structural differences.

Additionally, in every one of the six passbands we find that the mean ratio of r_e/h is larger for the early-type spirals than it is for the late-type spirals. Applying Student's t-test, the probability that the difference in mean r_e/h ratios could be as large as it is just by chance, for distributions having equal means, is around the 1.5-2 σ significance level and therefore weakly suggests that the Hubble sequence of spiral galaxies is not scale-free. With de Jong's K-band data and the use of *only* exponential models, our analysis reveals that the mean r_e/h ratio for the early-type spirals is actually *smaller* than that of the late-type spirals at the 98% (3σ) confidence level. (*A fuller description will be presented elsewhere.*)

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