Abstract. Surface-brightness profiles for early-type (S0–Sb) disks exhibit three main classes (Type I, II, and III). Type II profiles are more common in barred galaxies, and most of the time appear to be related to the bar’s Outer Lindblad Resonance. Roughly half of barred galaxies in the field have Type II profiles, but almost none in the Virgo Cluster do. A strong anticorrelation is found between Type III profiles (“antitruncations”) and bars: Type III profiles are most common when there is no bar, and least common when there is a strong bar.

1. Introduction

Recent imaging studies of the disks of S0 and spiral galaxies have demonstrated that not all stellar disks have simple exponential surface-brightness profiles (e.g., Erwin, Beckman, & Pohlen 2005; Pohlen & Trujillo 2006; Hunter & Elmegreen 2006; Erwin, Pohlen, & Beckman 2007). Instead, disk profiles appear to fall into three general categories: single-exponential (Freeman 1970) Type I; Freeman Type II, with a shallow inner slope and a steeper outer slope (including so-called “truncations”); and Type III ("antitruncations"), with a steep inner slope and a shallow outer slope (Erwin et al. 2005). See Pohlen et al. (this volume) for more background and illustrations of the three types.

We report here on analysis of a deep imaging study of lenticulars and early-type spirals (Hubble types S0–Sb), focused on tracing the outer disk structure using azimuthally averaged surface-brightness profiles. The analysis of the barred-galaxy subsample (66 galaxies) is complete (Erwin et al. 2007); analysis of the 45 unbarred galaxies is nearly complete (see Aladro et al., this volume).

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Pohlen et al. (this volume) discuss the general trend of these disk types versus Hubble type, including the complementary late-type sample of Pohlen & Trujillo (2006); here, we highlight what we can learn about profiles in the earlier types and their connections to bars and galaxy environment.
2. The Nature of Type II Profiles

For barred galaxies, we can use the size of the bar as a measuring rod. Type II profiles (downward-bending broken exponentials) fall into two fairly distinct categories: those with the break inside the bar (Type II.i) and those with the break outside (Type II.o). The first category is rare (6% of the barred galaxies), but does match profiles of some \(N\)-body simulations (e.g., Athanassoula & Misiriotis 2002; Valenzuela & Klypin 2003), so we suspect that this is a side-effect of the bar formation process.

Type II.o profiles are much more common (42% of barred galaxies), but more difficult to explain. One possibility is “truncations” due to a threshold in star formation. Elmegreen & Hunter (2006) recently showed that such thresholds could produce broken-exponential Type II profiles. However, the threshold (gas) surface densities predicted by such models (e.g., 3–10 \(M_\odot\) pc\(^{-2}\) in Schaye 2004) are quite low. While this is plausibly consistent with some breaks in late-type galaxies (e.g., Pohlen et al. 2002), the surface brightnesses at the break radius which we observe correspond to stellar mass densities which an order of magnitude or more higher: 20–2000 \(M_\odot\) pc\(^{-2}\) (median \(\sim\) 100 \(M_\odot\) pc\(^{-2}\)).

One potential clue is that we often find outer rings in Type II.o galaxies with the ring located at or very close to the break (Figure 1). Since outer rings are well understood as an effect of a bar’s Outer Lindblad Resonance (OLR; see, e.g. Buta & Combes 1996), we suspect that these breaks are a related phenomenon. Supporting evidence comes from recent \(N\)-body simulations by Debattista et al. (2006), who found that Type II.o profiles could form at the OLR of a bar-driven spiral. This leads us to suggest that the breaks in most Type II.o profiles are OLR-related, and we refer to these as “Type II.o-OLR” profiles.

Figure 2 demonstrates that the break radii in our Type II.o profiles follow the same size distribution (break radius in terms of bar radius) as the outer rings in our sample, as well as the outer rings in the sample of Buta & Crocker (1993). A handful of galaxies have breaks at larger radii (> 3 \(R_{bar}\)) — corresponding to low stellar mass densities — which suggests that the star-formation threshold mechanism might be at work in these galaxies, instead of an OLR-related mechanism. Figure 1 shows one galaxy where this may be the case: the break is located well outside the bar’s outer ring, and is thus not connected with the OLR. We label such profiles “classical truncations” (Type II.o-CT).

Note that the CT profiles are rare in the early type galaxies (5% of the barred galaxies, 27% of the unbarred galaxies); however, Pohlen & Trujillo (2006) found that they are more common in late type spirals (see Pohlen et al., this volume).

3. Frequencies of Disk Types versus Bars and Environments

A striking contrast emerges when barred and unbarred galaxies are compared: unbarred galaxies are twice as likely to have Type III profiles (60% of unbarred galaxies, 32% of barred galaxies). This carries over into the barred galaxies themselves: weakly barred (SAB) galaxies are more likely to have Type III profiles than strongly barred (SB) galaxies. Similarly, the distribution of bar strengths (deprojected maximum isophotal ellipticity) is different for Type III
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Figure 1. OLR breaks (II.o-OLR) versus classical truncations (II.o-CT). Top: a Type II.o profile where the break coincides with an outer ring; bottom: a Type II.o profile where the break is well outside the outer ring. In both cases, the break radius is indicated by the dashed ellipse (left-hand panels) and the arrow (right-hand panels). For NGC 3504, we display an SDSS $r$-band image; for NGC 2950, we have subtracted a model of the outer disk from the SDSS image in order to bring out the (faint) outer pseudo-ring.

and non-Type III profiles: bars in Type III galaxies have a median (deprojected) ellipticity of $\approx 0.35$, versus $\approx 0.50$ for Types I and II.

Type II profiles (of all kinds) are clearly more common in barred galaxies (49% of barred galaxies versus 27% of unbarred galaxies). However, they seem to be relatively unaffected by bar strength: for example, the Type II.o frequency is essentially identical for both SB and SAB galaxies, and there is no difference in bar ellipticity between Type I and II.o profiles.

What does appear to affect the presence of the Type II.o profiles is the environment. Specifically, barred galaxies in the Virgo Cluster have a much lower frequency of Type II.o profiles (10%) than do barred galaxies in the field (49%). Most of the “missing” II.o profiles in the Virgo Cluster are Type I profiles instead. Although the numbers are relatively small, the result is significant at the 99.8% level. Why this should be so is hard to say, particularly since we don’t
yet know why some field galaxies have Type I profiles and others have Type II. One speculative possibility is that Type II.o-OLR profiles (which are the vast majority of the field II.o profiles) require several Gyr of interaction between the bar and gas in the outer disk. If the gas is removed rapidly enough, as might be the case for ram-pressure stripping of spirals which fell into the Virgo Cluster several Gyr ago, then the OLR break formation process might be choked off before it can proceed to completion.

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