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Antitruncations

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Abstract. Since 1970 surface brightness profiles of disc galaxies were classified as Type-I, single falling exponentials, or Type-II, broken exponentials with steeper decline in the outskirts. For the past decade Type-III profiles, (antitruncations), with a shallower fall-off in the outskirts, have been shown to occur in a significant fraction of galaxy discs. Here we give a brief overview, characterizing these profiles and their distribution with galaxy type, with a look at recent explanations of their causes, and how they fit into the picture of galaxy evolution.

Keywords. Galaxies: evolution – galaxies: fundamental parameters – galaxies: structure

1. Systematic formulation of the antitruncation concept

Although previous authors had noted that the radial surface brightness profiles of some galaxies do not show edge truncations, but their profiles have shallower outer slopes than inner slopes, the first definition and systematic study of this phenomenon, as "antitruncation" was by Erwin *et al.* (2005). They also introduced the term "Type III" profiles, by analogy with Type I (single exponential) and Type II (downbending or truncated profile) introduced by Freeman (1970). Fig. 1 (taken from their article) shows two distinct sub-categories: Type III-d, with sharp breaks in the profile slope, and Type III-s with a progressive outward fall in slope. Using isophotal maps they showed that Type III-d profiles have projected disc geometry, while Type III-s profiles show decreasing ellipticities, and can be identified with halos. In Fig. 2 we show that a major fraction, around 50% of all profiles in the earliest-type disc galaxies are antitruncated, while in Fig. 3 we show that Type III profiles are characteristic of unbarred or weakly barred galaxies. Both properties give firm clues about their formation and evolution.

2. What causes antitruncations?

i) Type III-s profiles. It is possible that Type III-s profiles be caused by bulges with an intrinsically convex light profile, as suggested by Maltby *et al.* (2012). In this case the stellar halo would be a physical extrapolation of the bulge. Sandin (2015) suggested that antitruncated profiles might be artefacts resulting from an inadequate PSF subtraction. This is very unlikely for Type III-d profiles, because an observed sharp break cannot generally result from this effect. It can produce Type III-s profiles, but the effect is most critical for ground-based observed profiles, and much less for space observations (i.e. HST) and is significant only at surface brightnesses below 26 mag arcsec^{-2}.

ii) Type III-d profiles. These could be produced by minor mergers (Younger *et al.* 2007) in which matter transfer towards the centre, and outward angular momentum transfer steepen the inner profile and make the outer profile shallower. They could also be produced in major mergers. Comerón *et al.* (2015) linked this process with the

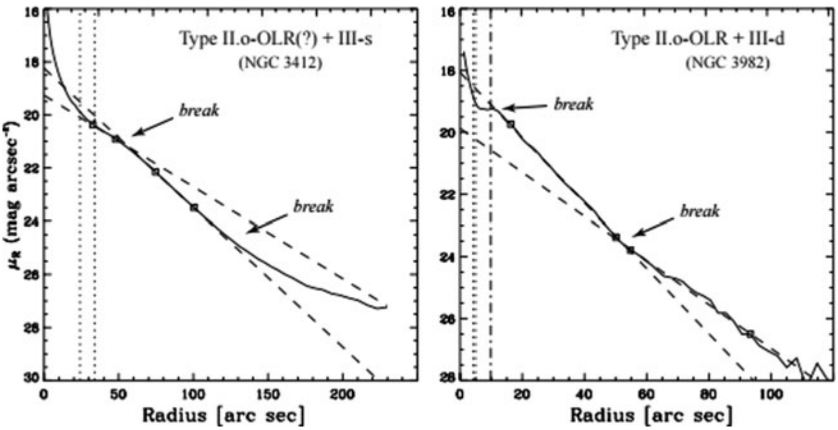

Figure 1. (From Erwin *et al.* 2005) shows the two types of antitruncated profiles: Right panel, Type III-s, (gradual flattening of slope, indicating halo-dominated outer profile). Left panel, Type III-d, (sharp break in profile, indicating disc-dominated outer profile).

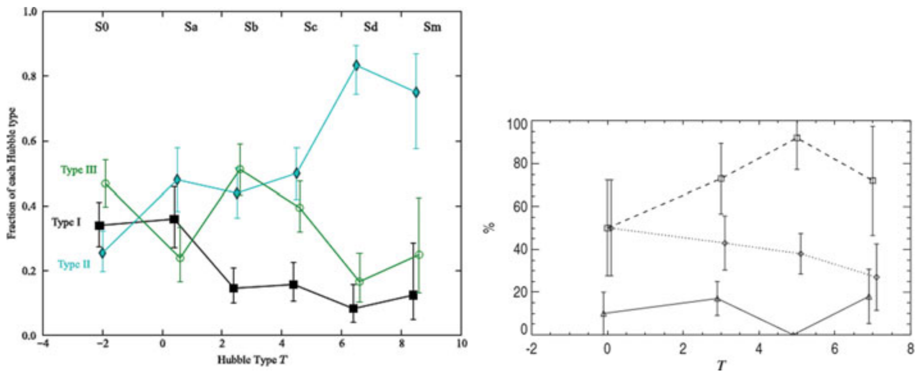

Figure 2. Distribution of profiles types with Hubble type. Left panel: for face-on galaxies from Gutiérrez *et al.* (2011). (dark green line gives proportion of Type III profiles). Right panel: for edge-on galaxies from Comerón *et al.* (2012) (fine continuous line gives proportion of Type III profiles).

production of thick discs, supporting the claim by edge-on profiles in the Spitzer near IR bands. They did not, however, find stellar counter-rotation between thin and thick discs, and suggested that if major mergers were the cause, half of all antitruncated discs should show counterrotation. This can be tested observationally.

In extensive simulation studies, Borlaff *et al.* (2014) and Eliche-Moral *et al.* (2015) have shown that a significant fraction of galaxies produced by the modelled major mergers show antitruncations, with a variety of scaling relations which agree well with those obtained from the observations of Erwin *et al.*(2008) and Gutiérrez *et al.* (2011). Fig. 4 shows a set of these results from Borlaff *et al.* (2014). This work, though clearly indicative, does not amount to a proof that all, or even most, antitruncated discs are produced in major mergers. In very recent work, Borlaff *et al.* (see paper in these proceedings) compare new observations of antitruncated discs at $0.2 < z < 0.6$. To summarize, they find that while the range of inner and outer scale-lengths and of their ratios is not different from that in local galaxies, the surface brightness at the break is 2 magnitudes fainter now than at z = 0.6, due to a combination of evolutionary fading plus a shrinking of the photometric scale radius (R_{23}).

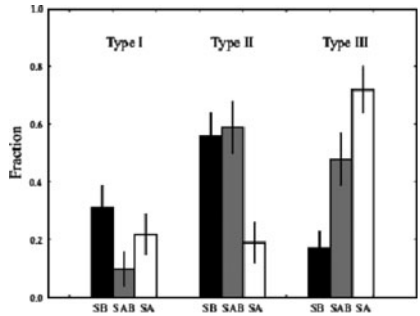

Figure 3. Distribution of profile types with bar strength, showing that antitruncated profiles are preferred by galaxies without bars or with weak bars.

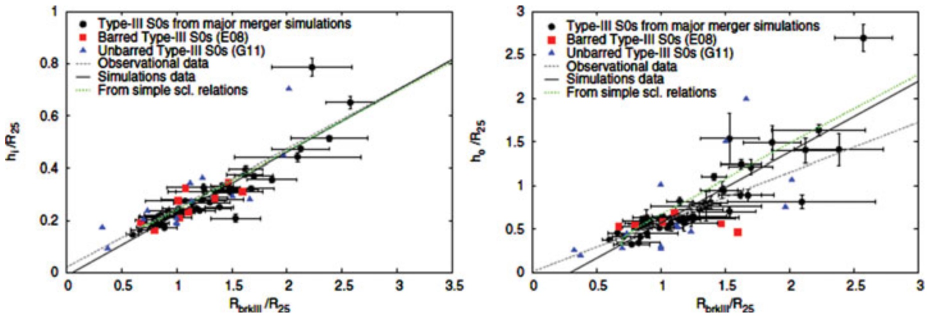

Figure 4. Scaling relations for antitruncated discs obtained from simulations by Borlaff *et al.* (2014) compared with observed values. The graphs show: Left panel: the inner scale length $h_{\rm i}$ vs. the break radius, $R_{\rm brkIII}$, both scaled by R_{25}, Right panel: the outer scale length $h_{\rm o}$ vs. the $R_{\rm brkIII}$, both scaled by R_{25}. Details of the data are in the legends of the figures.

3. Final comments

Antitruncated discs, Type III's are found in over 50% of S0 galaxies; they are more frequent in unbarred or weakly barred discs. They come in two classes, Type III-s, which are associated with stellar halos, and Type III-d which have disc symmetry and may be associated with a thin disc-thick-disc structure. Recent simulation studies suggest that mergers may well produce antitruncations, but this is not a conclusive proof. The ratios of inner and outer scale lengths in antitruncated discs at $z = 0.6$ are comparable with those in local galaxies. Type III's and their origins are useful probes of galaxy evolution scenarios.

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