THE OUTER STRUCTURE OF GALACTIC DISCS

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Abstract: We show measurements of the radial profiles in surface brightness in the R band of a sample of early-type unbarred galaxies. We classify them in three categories: Type I, an exponential profile with a single slope down to the noise level; Type II, a double exponential with the outer slope steeper than the inner; and Type III a double exponential with the outer slope shallower than the inner. Type II comes closest to what is considered a truncated profile. We compare these results with those of two previously published samples from our group: early-type (S0-Sab) barred galaxies, and late types (Sb-Sd), both barred and unbarred. We note the higher frequency of Type II profiles in late type galaxies , and of Type III's in the early types, notably in the unbarred. Theories developed to explain truncations must also explain why the majority of galaxies (Types I and III) are not truncated.

Keywords: Galaxies – Surface brightness – Truncations – Antitruncations.

1 Introduction

Radial brightness profiles of galaxies are basic tools to explain their formation and evolution. Galaxy discs in general show profiles which fall exponentially with radius. Freeman [4] noted that some profiles are less simple, showing an inner shallower and an outer steeper exponential, which he called Type II's, while those with single exponentials were Type I's. van der Kruit [9] found that some discs changed sharply from an exponential profile to an abrupt drop, which he called a truncation, at the edge. For over 20 years many researchers assumed that most galaxy discs are truncated. Pohlen et al. [6] showed that most truncations are not really abrupt. The outer fall-off is also exponential, but steeper than the inner exponential profile, so that they may

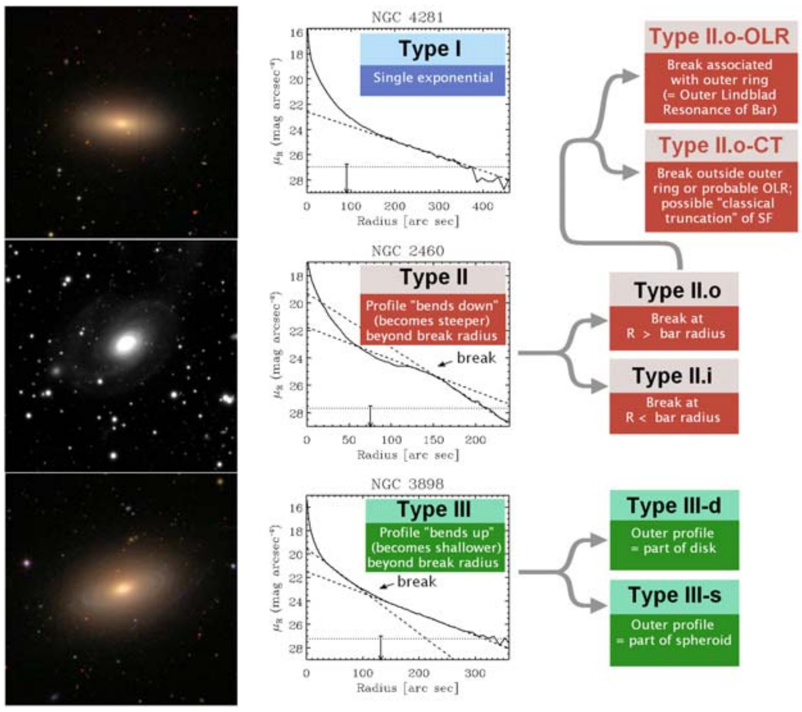

Figure 1: A representative selection of galaxies and profiles, in the R band, one profile of each Type: I, II, III. Also, our classification of the brightness profiles of disc galaxies is shown. This is more general than that used in this article, including barred as well as unbarred galaxies.

be considered as a species of Type II profiles. Erwin et al. [2] showed the existence of discs where the outer exponential is shallower than the inner. In [7] and [3] over 150 profiles were measured, and assigned to Types I, II and III. Here we show preliminary results of our most recent study, of unbarred early type discs, and include an initial classification of a complete sample of the over 200 galaxies analyzed up to now.

2 The present sample

The sample discussed here is of 46 galaxies, from S0 to Sb , previously classified as "unbarred". The accuracy of the photometric method, above all of the sky subtraction, is very important [3].

3 The classification scheme

In the right panel of Figure 1 we show our classification scheme. Types I, II and III are clearly distinguished, with corresponding examples. But within these basic, purely morphological types we propose subtypes based on our ideas of the underlying physics. Type II is divided into two: Type II.i and Type II.o, depending on whether the break between the two exponentials lies within, or outside the radius of the end of the bar. Type II.o is again divided into Type II.o.OLR, and Type II.o.CT. The former are caused by dynamical effects associated with the Outer Lindblad Resonance, while the latter, the "classical truncations" have no clear dynamical correlation. Type III is divided into two. In Type III-d the outer shallower exponential has the same ellipticity and position angle as the inner exponential, and is assumed to be disky, while in Type III-s the isophotes corresponding to the outer exponential profile gradually show decreasing ellipticity and we assume that the outer structure is dominated by a spheroidal distribution of stars.

4 The frequency distribution of profile types

In the present set of 46 galaxies the proportions of the profile types are:

Type I: 19%; Type II: 13%; Type II+Type III: 13%; Type III: 55%.

We should comment that the "Type II+ TypeIII" profile has three exponentials, the inner, with a given slope, the intermediate, with greater slope, and the outer, with a lesser slope. Concentrating on the outer disc, we should classify these as a sub-type of Type III, and in our figures we classify these as Type III (in a more complete future analysis of whole discs we will keep this as a separate type). To summarize across the full range of Hubble classes of disc galaxies, we have:

a) 85 late type galaxies, barred and unbarred [7]:
Type I: 10%; Type II (all subtypes): 60%, Type III: 30%

b) 62 early type barred galaxies [3]:
Type I: 27%; Type II (all subtypes): 43%, Type III: 30%

c) The complete sample of 193 galaxies of all classes, barred and unbarred:
Type I: 19%; Type II: 41%; Type III: 40%

In Figure 2 we represent our results and those previously published in two diagrams.

We can draw three empirical conclusions from the data in Figure 2. Firstly, while Type II dominates for late-type galaxies, for early-type galaxies Type I+Type III are more frequent. Secondly for the early types, there are more Type IIIs in unbarred galaxies, and the barred show equality between Types I and III. Thirdly there is a constant sum relation between Types I and III and also between Types II.o-OLR and II-CT. One hypothesis is that Type IIIs are produced by dynamical evolution of Type Is, and a more speculative hypothesis that there is an evolutionary link between the

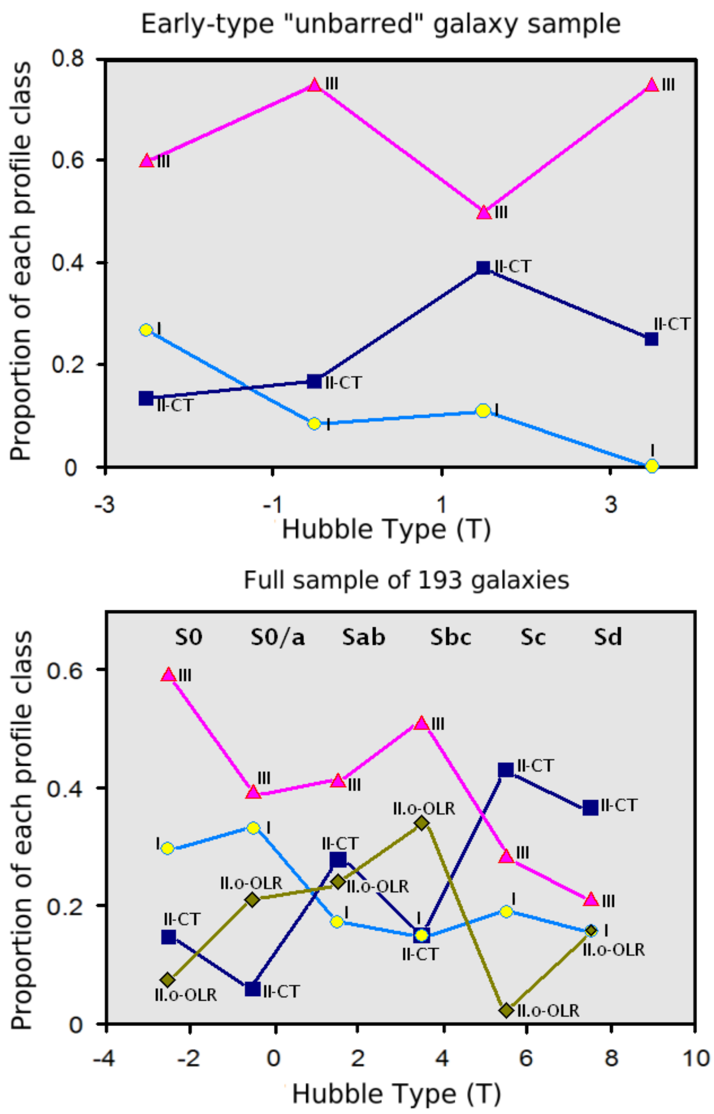

Figure 2: The frequency distributions of the profile Types of all 193 galaxies in our global sample. Hubble classes are represented conventionally from early to late types.

two subtypes of Type II.

5 General conclusions about the profiles

There is no fundamental reason why profiles should be exponential. Yoshii and Sommer-Larson [10] showed that an exponential disc arises if the viscosity and star formation time-scales are comparable. Governato et al. [5] have incorporated star formation into disc formation in a cosmological framework. But the dozens of articles on disc formation between these dates do not show that exponentiality is a fundamental disc property. Perhaps most surprisingly many discs maintain their exponential profiles out to 8 or 10 scale lengths from the centre, down to levels of 28 mag/arcsec^2. In no galaxy do we find an "edge", even down to fainter surface brightnesses.

6 Conclusions about truncations

In none of the 193 galaxies analyzed have we found a sharp cut-off, equivalent to van der Kruits truncations [9], although Type IIs do show steeper outer slopes. Any theory of disc formation must explain this, but must also explain the other types, and any relation between them and overall galaxy morphology. One clue is the correlation between Type IIIs and unbarred or weakly barred galaxies. Another is that profiles in B and R are very similar [7], which suggests that dynamics rather than star formation processes dominate the profile shapes. However, a radial colour dependence for Type IIs has been noted [1], with a blue maximum at the break radius, as predicted [8]. The interaction between observation and theory must continue.

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