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The Shape of the Luminosity Profiles of Bulges

Y. Andredakis, R. Peletier and M. Balcells

Kapteyn Astronomical Institute, P.O Box 800, 9700 AV Groningen, The Netherlands

Abstract.
We extract the bulge light profiles of a sample of early type spirals, using K-band photometry and a new 2-dimensional decomposition method that does not assume a priori any surface brightness laws. We find that the shape of the light profile shows a good correlation with the morphological type of the galaxy, in the sense that the profiles tend to fall off more steeply at large radii for the later types. This trend shows that the formation of or interaction with the disk has probably affected the density distribution of the bulge. The fact that the transition in shape is continuous might also imply that most of the bulges of late type spirals were *not* formed by different mechanisms than the ones of early types.

1. Method and Results

The method that we use is an extension of the method introduced by Kent (1986). Its only assumption is that the bulge and the disk can each be described by isophotes of constant ellipticity. We can take advantage of the difference in ellipticity between these two components, to decompose the bulge from the disk and get a model-independent bulge profile. We extended this method to work using two-dimensional data. This decomposition method is then applied on a complete, diameter-limited sample of 30 early-type spirals, observed in the K-band. We complement our data with 22 later type galaxies from Kent (1986). After the extraction of the bulge profiles, each of them is characterized by the number **n**, of the best-fitting $r^{1/\mathbf{n}}$ law. (For example, a de Vaucouleurs profile has an **n** of 4, and an exponential profile an **n** of 1.) Our results are summarized as follows:

1. We find that **n** spans a large range of values, ranging from 6 to less than 1. Bulges display a rich diversity as far as the shape of their light profile is concerned; some bulges have profiles that are very shallow at large radii, and some others have profiles that fall off very steeply.

2. This range of **n** is *continuous*, i.e. the transition from $r^{1/4}$ law-like profiles to exponential-like ones is smooth and not discontinuous or bimodal.

3. There is a good correlation between **n** and the morphological type of the galaxy, as well as with the bulge to disk ratio. In S0 galaxies **n** has a mean value of 4; in Sa-Sb galaxies **n** drops down to 2.3 (i.e. they are described on average by an *r-to-the-half* law), and in Sb-Sc galaxies **n** is close to 1 (exponential profile).

2. Discussion

Given the good correlation of the shape of the bulge profile with the morphological type of the galaxy and the bulge to disk ratio, it is straightforward to explain the variety of the profile shapes as being due to the disk. There exists one more correlation of **n**, though, that complicates things; **n** is bigger for more luminous and more extended bulges. A similar result has been found for elliptical galaxies by Caon et al. (1993): ellipticals of lower luminosity tend to have profiles described by a smaller **n**. Since these ellipticals often have disks in their centers, one could try to explain the whole spectrum of **n** from bright ellipticals through bulges as an "increasing disk – lower **n**" sequence. For example, the development of a strong disk around a (primeval) bulge might be able to truncate an initial $r^{1/4}$ law profile into a steeper one. It is not clear at all, however, how this could be done; we are not even sure whether the bulge formed before or after the disk. Furthermore, disks in ellipticals are usually too small for such an effect. It is almost equally probable, therefore, that the shape of the profiles of bulges and ellipticals is an intrinsic characteristic of these objects.

As far as the implications for the bulge-formation scenarios are concerned, the continuity in the spectrum of **n** points rather to a common formation mechanism for all bulges (except of course box and peanut shaped ones; these objects have not been included in this study). Formation scenaria such as the ones of Pfenniger (1993) in which inflated bars can become small exponential bulges, whereas bigger bulges result from increasing effects of merging cannot be excluded. It would take, however, accurate tuning of the merging process in order to produce the sequence of shapes that we observe.

References

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