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Secular Evolution of Bulges Induced by Satellite Accretion

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Abstract. Satellite accretion events have been invoked for mimicking the internal secular evolutionary processes of bulge growth (Kormendy & Kennicutt 2004). In order to investigate this question, we perform N-body models of the accretion of satellites onto disk galaxies. A scaling between the primary and the satellite based on the Tully-Fisher relation ensures that the density ratios, critical to the outcome of the accretion, are realistic. Both the bulge-to-disk ratio and the Sérsic index of the remnant bulge increase as a result of the accretion. The dominant mechanism for bulge growth is the inward flow of material from the primary disk to the bulge region during the satellite decay. The models confirm that the growth of the bulge out of disk material, a central ingredient of secular evolution models, may be triggered externally through satellite accretion. This work is described in more detail in Eliche-Moral et al. (2006).

1. N-body Models Description

Aguerri et al. (2001, hereafter A01) performed N-body simulations of the accretion of dense, spheroidal satellites onto bulge+disk+halo galaxies. The bulges in their experiments grew mainly due to the deposition of the satellite undisrupted core in the remnant center. Our aim is to investigate if the same processes occur for satellites with lower densities and more complex structures.

Satellites in our experiments are a scaled replica of the primary galaxy: bulge+disk+halo (Kuijken & Dubinski 1995), with initial bulge-to-disk ratio $B/D = 0.5$. A Tully-Fisher (TF) scaling between primary and satellite ensures that density ratios are realistic and lower than those from A01. The following values for different parameters have been used: TF index $\alpha_{\rm TF} = 3.0, 3.5, 4.0$; satellite to primary galaxy luminous mass ratios: 1:6, 1:9, 1:18; and direct and retrograde orbits with pericenter equal to the length scale of the primary disk. In total, ten experiments have been run. Preliminary results of new models with initial $B/D = 0.1$ in the primary galaxy and higher orbital pericenter ($\sim 8h_{\rm disk}$) are also shown in the figures (four additional experiments). The running code was a TREECODE (Hernquist 1990), using 185,000 particles per experiment. Structural parameters of the remnants have been obtained by simultaneous Sérsic+exponential fits to the face-on radial surface density profiles (Graham 2001).

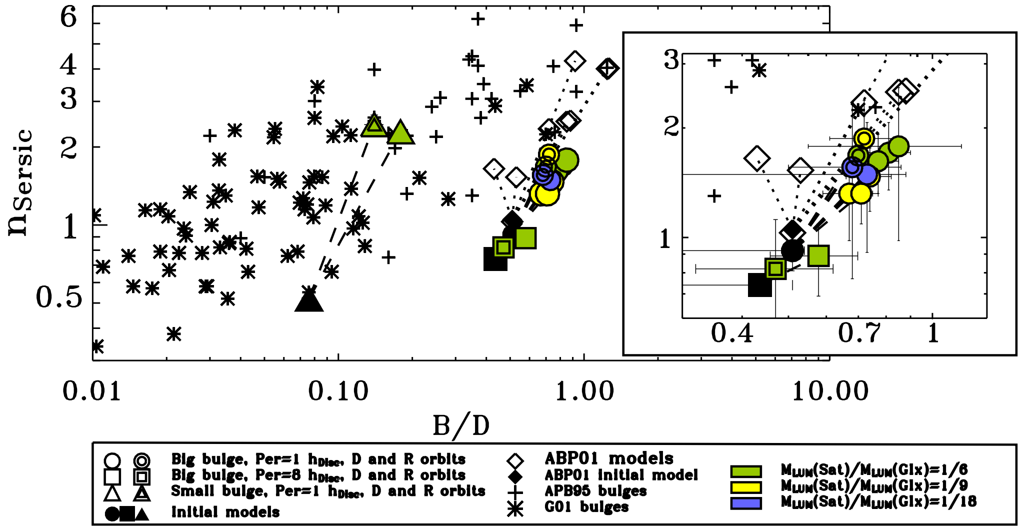

Figure 1. Growth vectors in the $\log(n)$-$\log(B/D)$ plane of our models. A01 models and observations by Andredakis et al. (1995) and Graham (2001) are plotted for comparison.

2. Growth of Bulges

Growth vectors in the plane $\log(n)$ vs. $\log(B/D)$ show that our satellite accretions lead to a simultaneous increase of B/D and Sérsic index n of the bulge, as in the models by A01. They also follow similar trends to the observations by Andredakis et al. (1995, see Fig. 1). Therefore, *our low-density accretions also cause the bulge to evolve towards earlier-type profiles*. The gentler increase in n found in the present experiments ($n = 1.0$ to 1.9) is welcome, as it alleviates the paradox posed by the suggestion from A01 models that exponential bulges are fragile to merging, given that galaxies with exponential bulges are very common. The satellite fully disrupts in all the experiments with $B/D = 0.5$, reaching the remnant center only in those cases with the most massive or densest satellites. In these cases, *the evolution of the bulge component is driven foremost by the injection of disk material to the center through transitory non-axisymmetric distortions*, and to a lesser extent by the expansion of the pre-existing bulge and by the deposition of satellite material. Some global structural photometric parameters evolve following trends similar to those observed in early- to intermediate-type disk galaxies (Balcells et al. 2007).

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