Secular evolution along the sequence of S0 Hubble types through minor mergers

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INTRO

Recent studies show that S0's present a strong coupling of the disk and bulge scalelengths [1,2], which is difficult to reproduce by current simulations of minor mergers.

This has left minor mergers in the backstage of S0's formation scenarios, favouring ram pressure stripping in clusters and internal secular evolution as the main drivers of the transformation of the traditional Hubble sequence (Sa-Sb-Sc) into a parallel one of S0's (S0a-S0b-S0c) [3,4].

However, ~70% of present-day S0's do not reside in clusters, but in groups (an environment where mergers and tidal interactions dominate galaxy evolution [5, 6]), and nearly half of them are not barred [2].

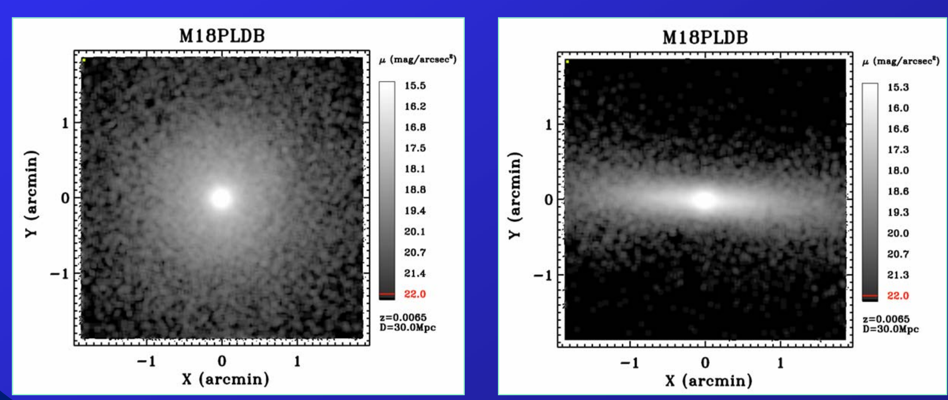
AIM

We investigate whether the remnants resulting from N-body simulations of dry minor mergers onto S0c and S0b galaxies evolve within the sequence of S0 Hubble types obeying global bulge-to-disk structural relations compatible with observations (Eliche-Moral et al., A&A submitted).

THE N-BODY MODELS

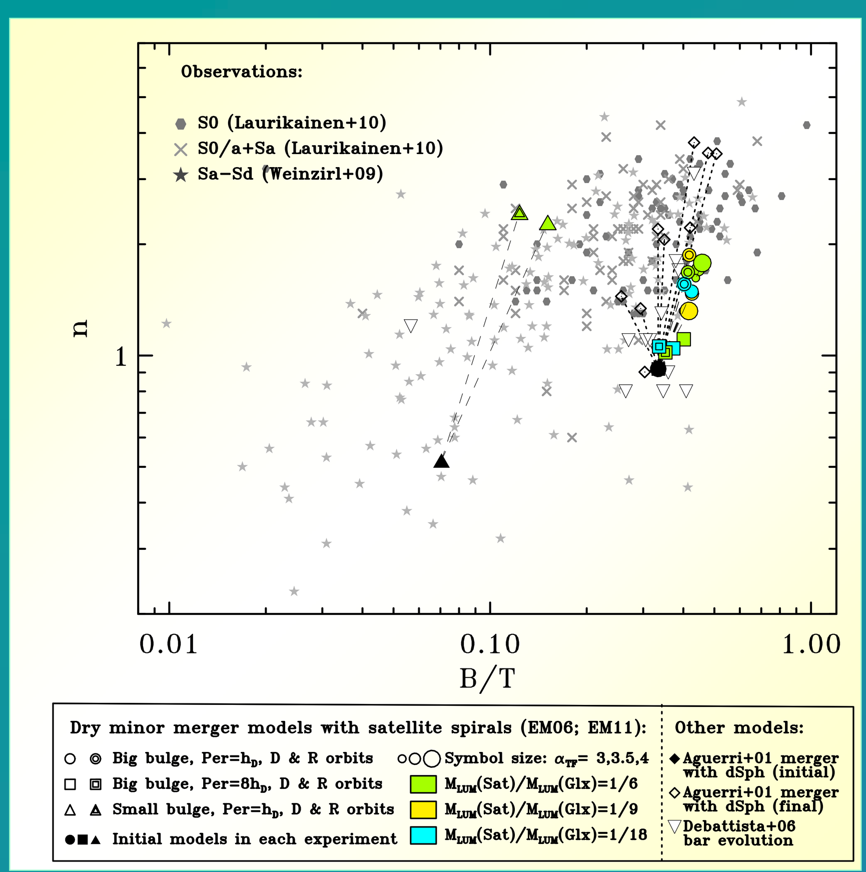
We have run a battery of minor merger collisionless simulations [7-8]. Different orbits, density ratios, and mass ratios (1:6, 1:9, 1:18) are considered, as well as two different models for the primary S0 galaxy: an S0b (B/D=0.5) and an S0c (B/D=0.08). The mergers take between ~2-5 Gyr.

Simulated K-band images of the resulting remnants considering the typical observing conditions of the NIRS0S survey [9] show that all of them are S0's (see Fig. 1). We have fitted a Sérsic+exponential function to their K-band radial surface brightness profiles to obtain bulge-disk photometric decompositions of the remnants.



F1: Simulated K-band images of one of the merger remnants assuming a distance of 30 Mpc, for face-on and edge-on views.

RESULTS

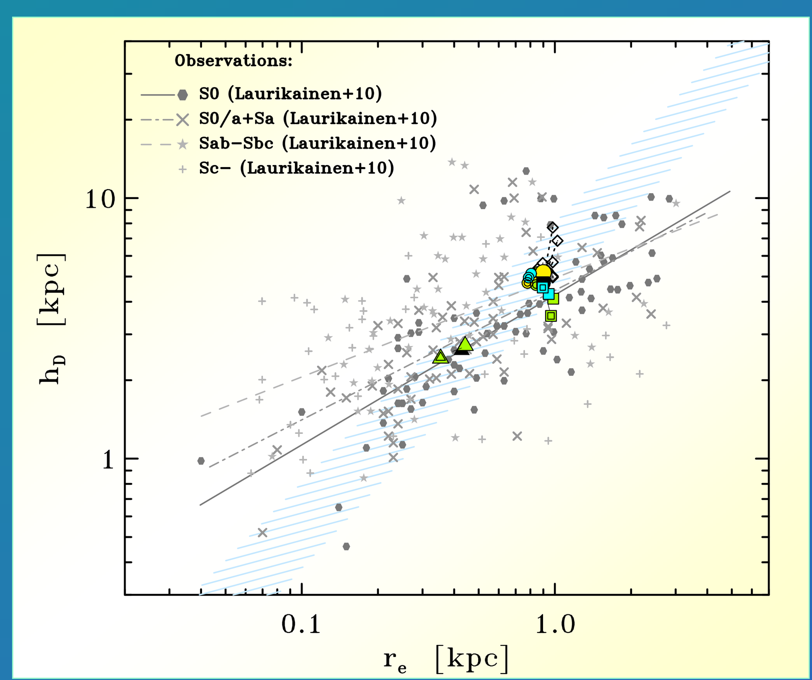


1 Dry minor mergers induce noticeable bulge growth, compatible with observations of S0's
S0c ⇒ S0b
S0b ⇒ S0a

Fig.2: Growth vectors in the Sersic index (n) vs. bulge-to-total luminosity ratio (B/T) plane driven by the mergers. See the legend in the figure.

Minor mergers can explain the evolution from S0's with low n and B/T values towards S0's with higher n and B/T.

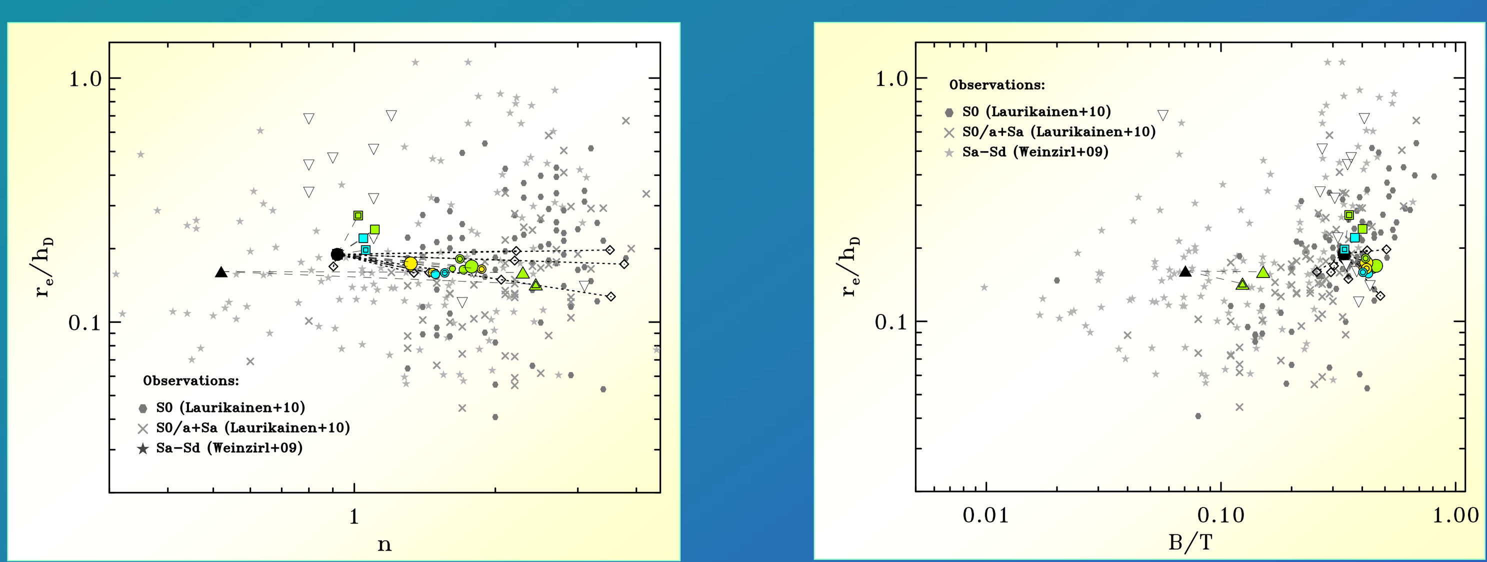
2 Dry minor mergers affect negligibly to the disk and bulge scalelengths. If coupling between them exists prior to the merger, the minor merger does not break such coupling.



F3: Growth vectors in the disk scalelength (h_D) vs. bulge effective radius (r_e) plane driven by the mergers. See the legend of Fig. 2. Our models can be placed at any location in the shaded region of the figure.

If h_D-r_e coupling is primordial in late types (as observations seem to support), minor mergers would just contribute to rise the dispersion of this relation towards earlier types.

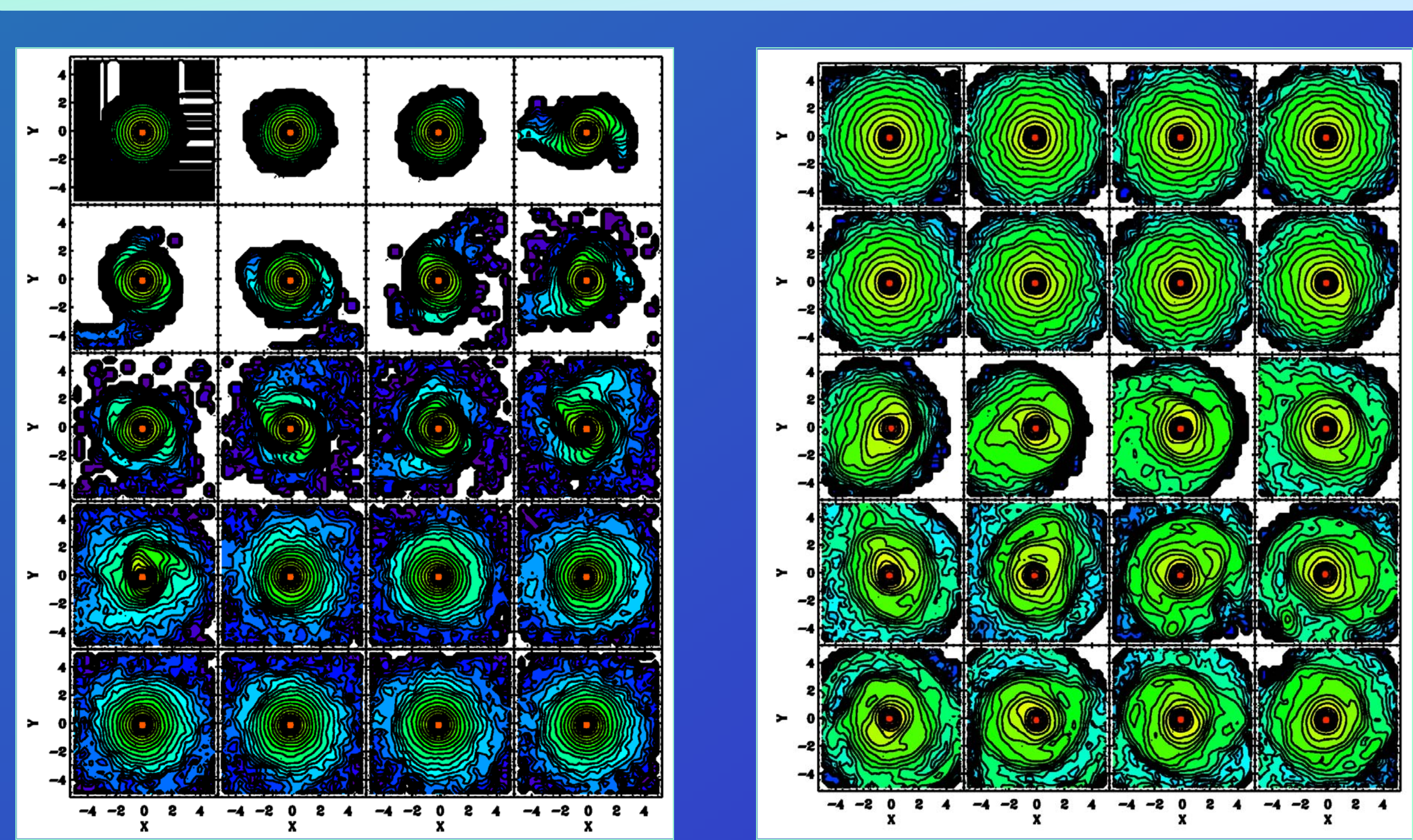
3 Minor mergers provide a feasible natural explanation for a scale-free Sequence of Hubble S0 types, accordingly to observations.



F4: Growth vectors in the r_e/h_D - n and r_e/h_D - B/T planes driven by the mergers. The lack of correlation between r_e/h_D and the Hubble type (given by n or by B/T) observed in real galaxies is still an open debatte ("the Hubble Sequence is scale-free", [10]). See the legend of Fig. 2.

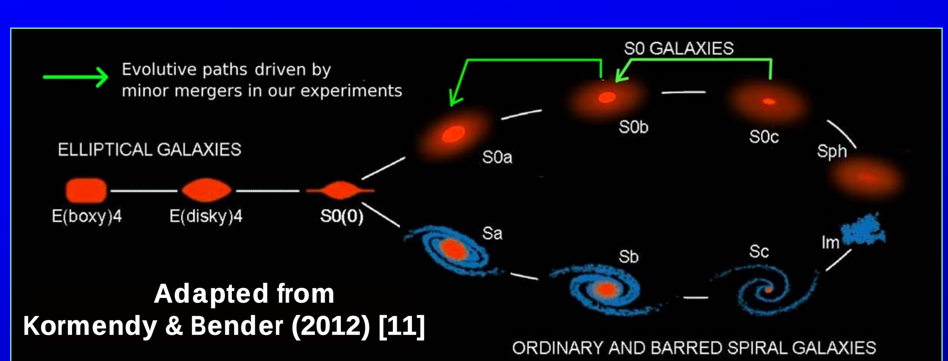
Minor mergers can explain why early-types accumulate at the right of these planes, showing a wide spread of r_e/h_D. While the remnant is always of a Hubble type earlier than the original galaxy, r_e/h_D does not change significantly after the merger. If late-type S0 galaxies originate with different r_e/h_D values, dry minor mergers would make them evolve towards higher n and B/T in the diagrams, but keeping similar r_e/h_D ratios.

4 The minor mergers induce transient distortions in the original disks that enhance the coupling between the disk and the bulge in the remnants.



F5 : Time evolution of the surface density of the primary disk stars in two merger models. Transient spirals (left panels) and oval distortions (right panels) inject disk material to the central bulge, enhancing the structural and dynamical disk-bulge coupling in the remnants [7,8].

CONCLUSIONS



Adapted from Kormendy & Bender (2012) [11]

Our models prove that dry minor mergers onto S0 galaxies make them evolve within the sequence of S0 Hubble types (S0c ⇒ S0b and S0b ⇒ S0a, see the Figure), obeying global bulge-to-disk structural relations compatible with observations.

Minor mergers may have played a key role in the evolution of S0's, mainly in environments such as galaxy groups.

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[10] Courteau et al. 1996, ApJ, 457, L73
[11] Kormendy & Bender 2012, ApJS, 198, 2

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