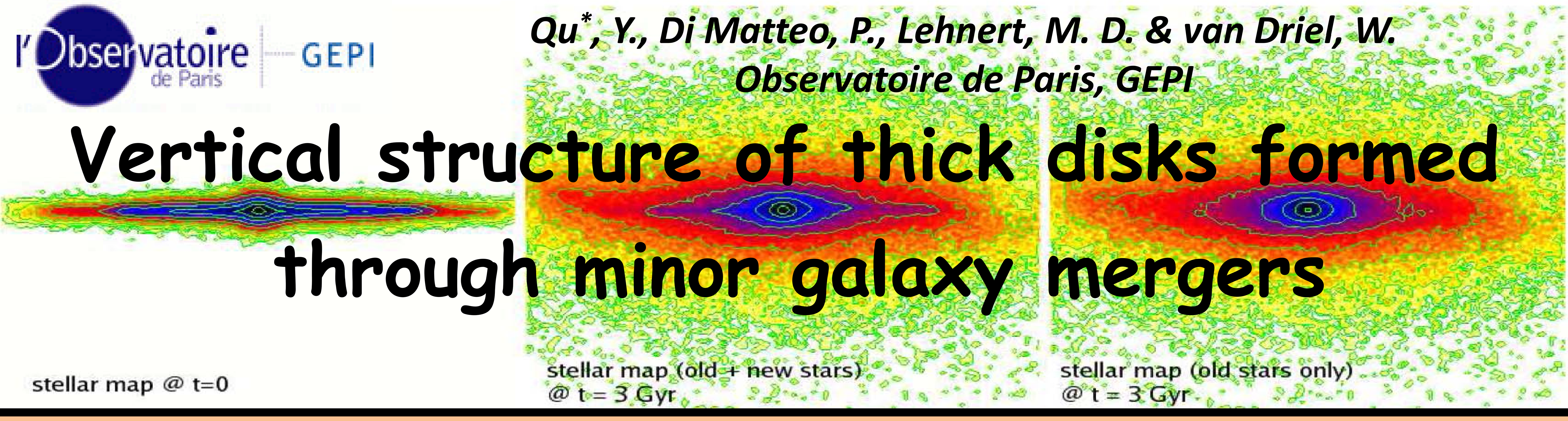
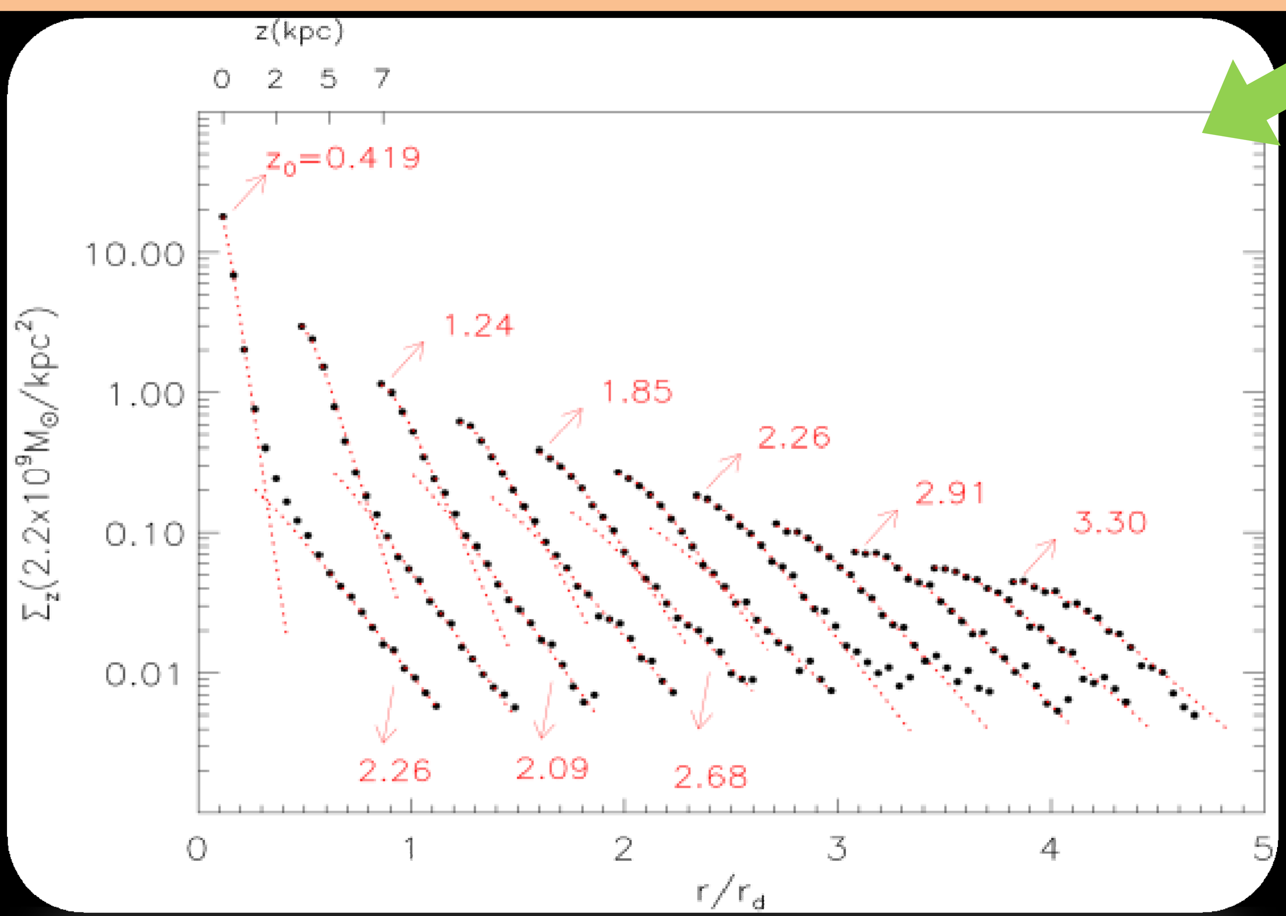
Qu*, Y., Di Matteo, P., Lehnert, M. D. & van Driel, W.
Observatoire de Paris, GEPI

Vertical structure of thick disks formed through minor galaxy mergers

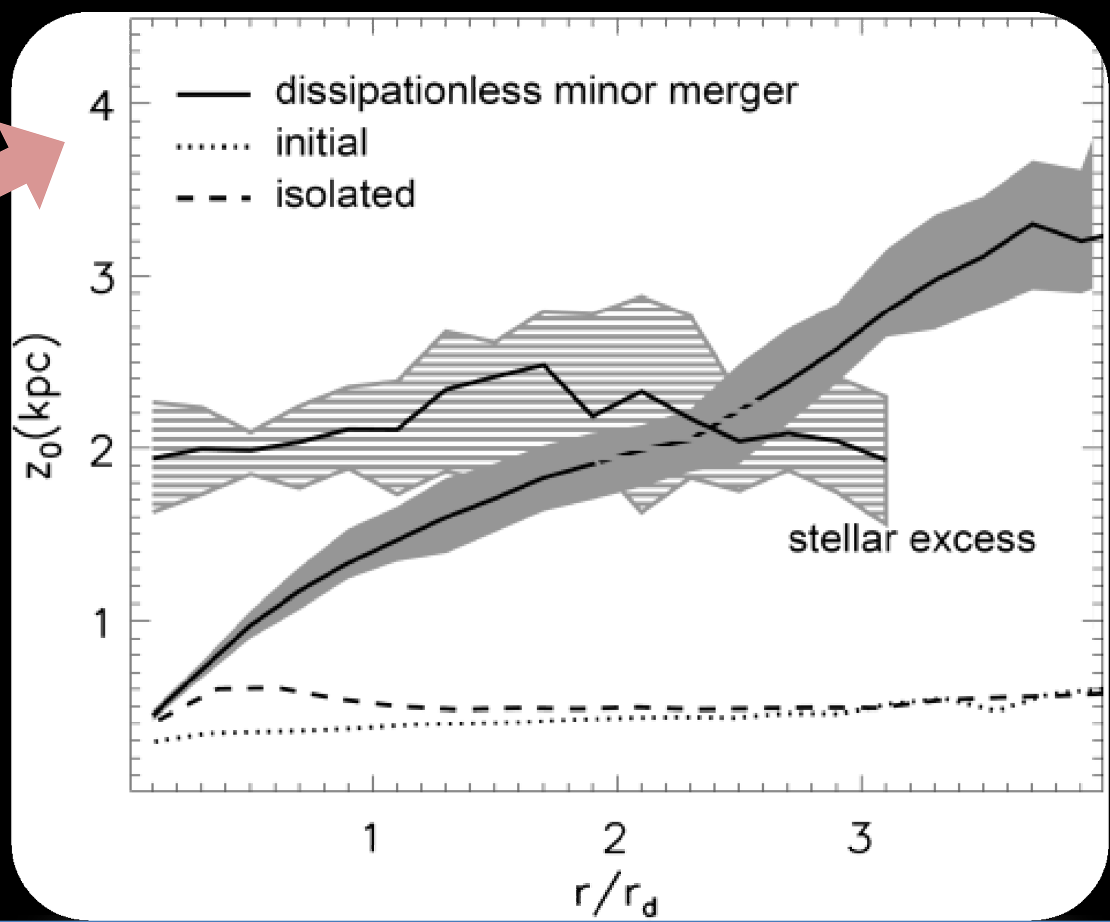


Abstract The main astrophysical process which drives thick disk formation remains unclear. During minor galaxy mergers pre-existing stellar disks are heated and the post-merger remnant disk is kinematically hotter and thicker. In this study we use N-body numerical simulations to investigate the vertical stellar distribution of thick disks formed in minor mergers. The vertical stellar surface density profiles of post-merger thick disks follow a sech function, and at large heights (z>2kpc) an additional stellar excesses can be found which also follows a sech function but with a much larger scale height. The thick disk scale height increases with radius, unlike the constant scale heights found in thick disks formed in secular processes, such as scattering by clumps in unstable gaseous disks. The disk scale height of merger-induced thick disks is sensitive to the simulation parameters, such as orbital configurations and gas fraction, and it can continue to increase in multiple mergers. We find that most of these results are in good agreement with the observed properties of thick disks and thus conclude that minor mergers are a viable mechanism for the creation of galactic thick disks. The accuracy of Gaia in its census of the stellar positions, proper motions, and velocities will provide unrivaled and powerful constraints on the models of the formation and evolution of the thick disk in the Milky Way.



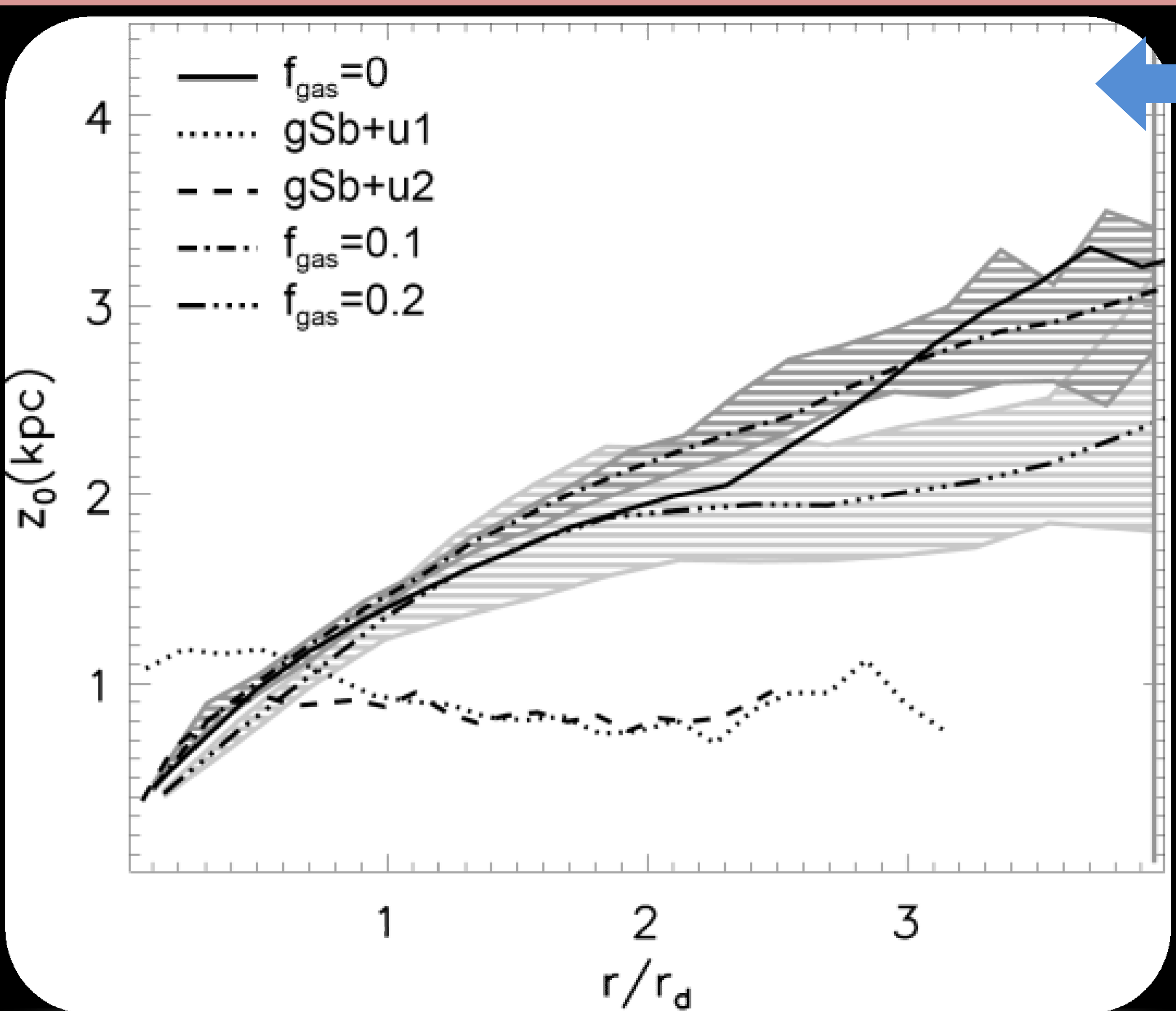
Vertical stellar surface density profiles of a remnant disk at 0.5 Gyr after a dissipationless (gas-free) minor merger (black). The profiles are shown at different distances along the major axis of the galactic mid-plane, in units of the exponential disk scale length r_d. The profiles can show two components: an inner high density part and a stellar excess at large heights (z>2kpc) at $r<2r_d$, both of which can be fitted with sech functions (red), but each having different scale heights. The disk thickening and the growth of the stellar excess begins at the first close passage of the satellite galaxy and stops at the end of merger. Thick disks formed through secular processes, such as scattering by clumps in unstable gaseous disks, do not have stellar excesses like those found in merger-induced thick disks.

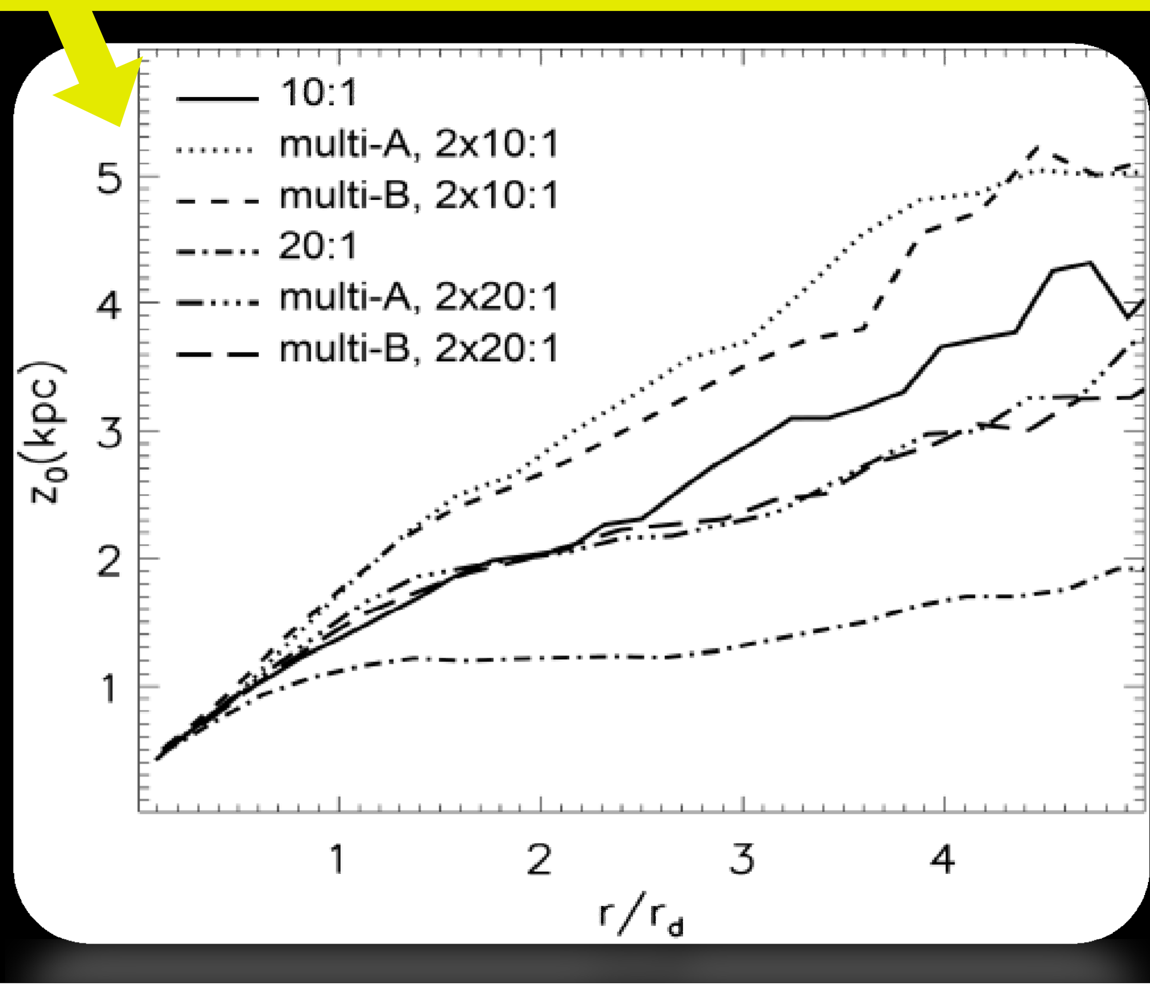
The thick disk scale height z_0 increases with distance along the disk major axis (in units of disk scale length r_d). Varying the initial orbital configurations causes a scattering of the thick disk scale height around the mean value $\Delta z_0/z_{0,mean}$<15% (marked by the shaded region). However, the scale height of the stellar excess is independent of the radial distances. For comparison, the scale height of the stellar disk in its initial state (dotted line) and after evolving in isolation for 3 Gyr (dashed line) are also shown. Shown here are results of dissipationless (gas-free) minor mergers.



The effect of two consecutive dissipationless minor mergers on disk thickening is found to be basically the same as that of a single dissipationless merger event of the same total mass, i.e., the effect of disk-heating is found not to saturate but is cumulative. This is in agreement with dynamical arguments about the conservation of energy and phase space density (Louiville's theorem). The bottom figure shows the accumulative thick disk scale height in a single (mass ratio 10:1 or 20:1) and two consecutive (2x10:1 or 2x20:1) merger events. Satellites in two consecutive minor mergers are accreted either from the same direction (multi-A) or from different directions (multi-B).

For dissipative minor mergers, with gas in the primary galaxy, results in a lower average thick disk scale height and a smaller increase with radial distance compared to dissipationless ones (e.g., the mean decrease is ~20% for a gas-to-stellar mass fraction f_{gas}=0.2). Secular processes, such as scattering by clumps in unstable gaseous disks with star-formation (gSb+u1 and gSb+u2), can also create a thick disk but with roughly constant disk scale height. This difference provides a way to disentangle different formation scenarios. (The shaded region in the figure marks the scattering of the disk scale height due to the varying initial orbital configurations.) The scale height of the stellar excess, on the other hand, is independent of either the radial distance or the gas fraction of the primary galaxy.





*yan.qu@obspm.fr