On the flaring of thick discs of galaxies: insights from simulations

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A new emerging picture for thick discs is changing what was previously thought about them. Three main aspects of this new picture are: 1) large optical surveys concluded that thick discs were flat, but more recent works have found flaring thick discs in external galaxies; 2) the concept of thick discs as being red, old, and metal poor components of the galaxy is being replaced by one which allows thick discs to have both variety and complexity in their age structure, i.e., age gradients; 3) the MW’s thin and thick disc are not distinct components but form a continuum in terms of their structure and stellar populations but this is unknown for external galaxies. For this last point, it is worth mentioning that this transition could change depending on how the thin and thick disc are defined.

Furthermore, it has been shown that while different Mono-Age Populations (MAPs) can have different levels of flaring, because of their radial surface density distribution, a flat thick disc can be recovered when all these stellar populations are superposed. This also contributes to the idea that thick discs are indeed complex and probably do not form in a single event.

Here, we analyze in depth 27 galaxies from a sample of galaxies simulated in their cosmological context to find the different flaring configurations of MAPs and their connection to the three aspects mentioned above. On top of that, we also look at the connections with the merger history of these simulated galaxies. The peculiarity of these simulated galaxies is that they share many features with the MW. Their dark matter halos range masses between $2.7 \times 10^{11}$ and $2 \times 10^{12} \, M_{\odot}$ and they live in relatively isolated environments, both agreeing with what we know of the MW. However, the sample also shows a large diversity of thick disc properties, which allowed us to study the connection between the formation history of a galaxy and its present day structure, and to place the MW in the context of the larger population of spiral galaxies.

Galaxies with flat thick discs

Flat thick discs or with minimal level of flaring when MAPs barely flare or when, due to inside-out formation, the flared MAPs do not carry a lot of surface density at the flaring radii compared to younger, less flared MAPs. This is in agreement with previous studies and an example of this can be found on the top panel of Figure 1. On Figure 2, the age gradient in the thick disc is represented against the slope of the thick disc for all the galaxies in our sample. The marker shapes indicate whether the thin and thick disc are different structures, and they are colour-coded by different galaxy features. It can be seen that when all galaxies in the sample are compared, galaxies with flat thick discs — occupying the most left part of Figure 2 — have some common features: they all have radial age gradients, and the thin and thick disc are a continuum as found in the MW but this is unknown for external galaxies. For this last point, it is worth mentioning that this transition could change depending on how the thin and thick disc are defined.

Although very often the terms thin and thick disc refer to the $\alpha$-poor and $\alpha$-rich components of the Milky Way’s (MW) disc respectively, hereafter we use them to refer to the thin and thick disc in geometrical terms, that is, a distinction based on the vertical distribution of the stellar density.
Although the number of galaxies is not high enough to do a proper statistical analysis, these results indicates that galaxies within certain mass range, disc thickness, age radial gradients in their thick disc, and the thin and thick disc forming a continuous structure, have quiescent merger histories. This is in agreement with what we know about the MW, including the discovery of the last major building block of the Galaxy, merging at early cosmological times.

Figure 2: Radial age gradient as a function of thick disc gradient, colour-coded by the mass ratio of the most massive merger in the last 9 Gyr. The marker shape represents whether there is no bimodality (circles), mild (squares), or strong bimodality (triangles).

Conclusions
These results can help us understand the emerging picture where thick discs are more varied and complex than previously thought and many of their features are connected. Likewise, as data on nearby galaxies are becoming more abundant and detailed, it is becoming more important to connect and compare what we know about the MW with what we find in galaxies in our neighbourhood. Thus, theoretical studies like this one help to understand findings in nearby galaxies as well as find links between the MW and those galaxies. Ultimately, this will establish the place the MW within the context of its neighbouring spiral galaxies.

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Galaxies with flared thick discs
On the other hand, flared thick discs form when MAPs carry a significant amount of surface density where they flare. The flaring of the global thick disc can be driven by a sequence of different flaring MAPs at different radii, by only a few MAPs spanning a couple of Gyrs if those MAPs dominate the surface density throughout the disc, or if a group of MAPs share the same scale-heights. If one of the two last cases happens, then a bimodal structure is created and thin and thick disc are distinct components in terms of the stellar populations inhabiting them. An example of the third case can be seen in the bottom panel for Figure 1. This effect is directly related with the merger history [14]. Flared thick discs are more diverse than their flat counterparts in terms of age radial profiles as seen in Figure 2 although a high fraction of them show small or flat age radial profiles. We also found that galaxies that underwent massive mergers or with high mass ratios tend to have flat age radial profiles as seen in [2].

Short CV
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