*Rediscovering our Galaxy*
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# Rediscovering the disc origin of the Milky Way bulge

**F. Fragkoudi[1], P. Di Matteo[1], M. Haywood[1], A. Gómez[1], S. Khoperskov[1], D. Katz[1], M. Schultheis[4], F. Combes[2,3] and B. Semelin[2]**

[1]GEPI, Observatoire de Paris, PSL Research University, CNRS, Place Jules Janssen, 92195, Meudon, France

[2]Observatoire de Paris, LERMA, CNRS, PSL Univ., UPMC, Sorbonne Univ., F-75014, Paris, France

[3]College de France, 11 Place Marcelin Berthelot, 75005, Paris, France

[4]Laboratoire Lagrange, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Bd de l'Observatoire, 06304 Nice, France

**Abstract.** We explore morphological, kinematic and chemical trends of boxy/peanut (b/p) bulges of Milky Way (MW)-type galaxies, to better understand the formation history of the MW's bulge. We show, using N-body simulations with both a kinematically cold and a kinematically hot disc, that colder populations develop a more prominent bar and X-shaped peanut as compared to their hotter counterpart. Colder discs also exhibit lower line-of-sight velocities (when viewed edge-on) at the edges of the b/p compared to hot discs, in agreement with what is seen for the MW bulge. Furthermore, we explore an N-body model which has three co-spatial discs with metallicities which correspond to the stellar populations of the inner Milky Way, where the $\alpha$-enhanced thick disc populations are massive and centrally concentrated. The metallicity trends seen in observations of the Bulge can be reproduced in the model without the need of adding any additional components, which hints to the disc origin of the MW's bulge.

## 1. Morphology and Kinematics

We explore the morphology and kinematics of the bar and b/p bulge which are formed in a dissipationless N-body simulation with two co-spatial disc components – a thin, kinematically-cold disc and a thick, kinematically hot disc – which evolve in isolation for 9 Gyr (see Fragkoudi *et al.*, 2017 for details), in order to understand the morphological and kinematic properties of stellar populations in the inner regions of the Milky Way (e.g. Haywood *et al.* (2013)).

We see in Figure 1 that colder populations form a more prominent bar, as well as a more pronounced peanut-shaped bulge (see also Di Matteo (2016), Athanassoula *et al.* (2016), Debattista *et al.* (2017)). As shown in Fragkoudi *et al.* (2017), this behaviour is related to the exchange of angular momentum between the two disc components and the halo, and the fact that the kinematically colder component loses more angular momentum than the hot component via the bar instability.

We also show in Fragkoudi *et al.* (2017) that, when the disc is viewed edge-on, the line-of-sight velocities at the edges of the boxy/peanut bulge region are *higher* for the hotter component than for the cold component – which is due again to the angular momentum transfer between the two components and the halo. This behaviour could explain, for example, the higher line-of-sight velocities of kinematically hot stellar populations at the edge of the MW bulge (compared to colder populations), as seen by the ARGOS survey in Ness *et al.* (2013).

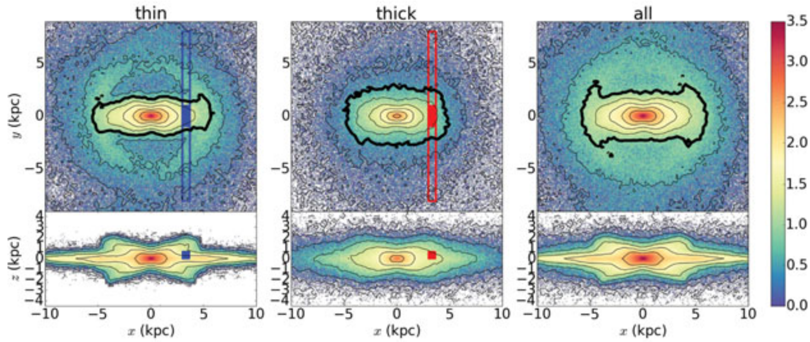


**Figure 1.** Face-on and edge-on views of the surface density of the kinematically-cold thin disc (left) and of the kinematically hot thick disc (middle) and of all particles together (right) at the end of the simulation at 9 Gyr. We see from the the isodensity contours that the bar is more prominent in the face-on view in the thin disc, and is weaker in the the thick disc. Furthermore we see that the X-shape of the boxy/peanut is more prominent in the cold population.

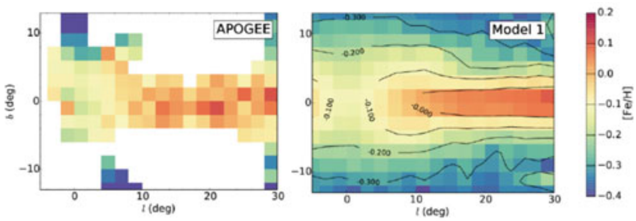


**Figure 2.** Mean metallicity along the line of sight in $l, b$. *Left:* APOGEE DR13 data. *Right:* The model with co-spatial stellar discs after 7 Gyr of evolution once a bar and b/p form. Only stars with distances between 4 and 12 kpc from the Sun are selected. Only pixels with more than 10 stars/particles are shown. Each bin is 2 degrees in $l$ and $b$.

## 2. Chemistry

We make use of a dissipationless N-body model with three co-spatial discs which have properties similar to those outlined in Di Matteo (2016), i.e. the old thick disc, the young thick disc and the thin disc – from metal-poor and $\alpha$-enhaned to metal-rich and $\alpha$-poor. The two co-spatial discs corresponding to the young and old thick disc together make up 50% of the baryonic mass budget of the model, and are centrally concentrated. In Figure 2 we show the mean metallicity along the line of sight for the MW bulge from APOGEE DR13 data and from our model (from Fragkoudi *et al.*, submitted). We see a remarkable resemblance in the metallicity maps of the model and the data, which points to the importance of the $\alpha$-enhanced thick disc in the inner regions of the MW.

### References

Athanassoula, E., Rodionov, S. A., Peschken, N., & Lambert, J. C. 2016, *ApJ*, 821, 90

Debattista, V. P., Ness, M., Gonzalez, O. A., Freeman, K., Zoccali, M., & Minniti, D. 2017, *MNRAS*, 469, 1587

Di Matteo 2016, *PASA*, 33, 027

Fragkoudi, F., Di Matteo, P., Haywood, M., Gómez, A., Combes, F., Katz, D., & Semelin, B. 2017, *A&A*, in press

Haywood, M., Di Matteo, P., Lehnert, M. D., Katz, D., & Gómez, A. 2013, *A&A*, 560, 109

Ness, M., Freeman, K., Athanassoula, E., *et al.* 2013, *MNRAS*, 432, 2092

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