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STUDY OF THE STRUCTURE AND FORMATION OF THE THICK DISC FROM STELLAR POPULATION MODELLING

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Abstract. The thick disc is a major component of the Milky Way but, its characteristics and history are still not yet well constrained. The use of a population synthesis model, based on a scenario of formation and evolution of the Galaxy, a star formation history, and a set of stellar evolution models, is a way to improve the constraints on this population. For this reason, we use the Besançon Galaxy Model (BGM, Robin et al. (2003)). This model in constant evolution has been, thanks to Lagarde et al. (2017), implemented with new evolutionary tracks (STAREVOL, Lagarde et al. (2012)) to provide global asteroseismic and surface chemical properties along the evolutionary stages. Thanks to this updated Galaxy model and the Markov Chain Monte Carlo fitting method (MCMC) we will be able to constrain the thick disc structure and history. We show preliminary results applying this MCMC method to analyse the 2MASS photometric survey.

Keywords: Galaxy: disk, Galaxy: stellar content

1 Introduction

The Milky Way disc is, due to our particular position, difficult to study. Gilmore & Reid (1983) distinguished two disc populations, an old thick disc and a young thin disc. Thanks to the recent spectroscopic survey (such as APOGEE, Gaia-ESO) we can now recognize the thin and thick discs with their chemical properties. In early studies, only kinematical properties allowed to distinguish them.
Some studies (Snaith et al. (2014),Snaith et al. (2015), Haywood et al. (2013),Haywood et al. (2016) Robin et al. (2014), Hayden et al. (2015), Kordopatis et al. (2015), Guiglion et al. (2015)) are in favor of a thick disk formation at high redshift (z between 1 and 2) when the gas turbulence was high enough to form stars at a large distance from the plane. During this period, the thick disc can slightly contract (Robin et al. 2014). Other scenarios considere a thick disc formed by heating of the thin disc, for example by satellite accretion (Quinn et al. 1993) or from radial migration (Sellwood & Binney 2002). Even so, the thick disc nature, its history and relation to the thin disc are still under debate.
In this work, we try to constrain the thick disc structure and age distribution with the help of a Markov Chain Monte Carlo method (MCMC).

2 Method and preliminary results

We make use of the same method as Robin et al. (2014). We fit photometric observations varying thick disc parameters in the simulations. The fitted parameters and their boundaries are listed in table 1. We assume that the thick disc covers the age range from 8 to 12 Gyrs and attempt to derive the relative density in 4 age bins of 1 Gyr width.

Contrarily to Robin et al. (2014), we do not use isochrones (Bergbusch & Vandenberg 1992) to simulate the thick disc, but a grid of stellar models computed with STAREVOL (Lagarde et al. 2012). This grid allows us to test multiple thick disc's age distribution to constrain the thick disc star formation history that could give us a clue for the scenarios of formation of the thick disc.

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	Scale length (pc)	Scale height (pc)	flare slope	flare radius (pc)	Relative density per age bin
Minimum value	1500	250	-0.1	0	0
Maximum value	4000	1200	0.2	16000	6

Table 1. List of thick disc parameters constrained by the MCMC and their boundaries. The thick disc is divided into 4 age bins of 1 Gyr width.

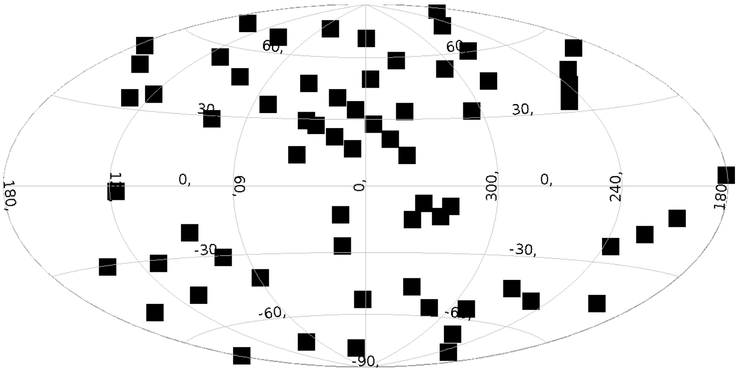

Fig. 1. 2MASS fields used to adjust the model in galactic coordinates

The new grid allows to compute extra stellar parameters, such as asterosismic quantities and chemical abundances.
We compare our simulations with 80 2MASS intermediate and high galactic latitude fields of 16 sq deg each (those fields are shown in figure 1).

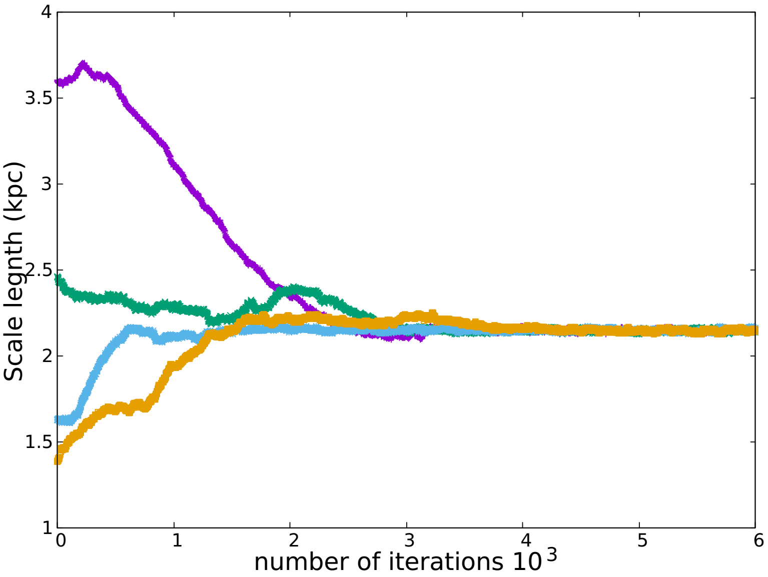

Fig. 2. Evolution of the thick disc scale length during the MCMC fitting process, for 5 MCMC independent runs with randomly chosen initial values. The scale length converges at about 2 kpc after 4 000 iterations.

To constrain the thick disc parameters, we maximize the log of the reduced likelihood (see eq. 2.1. where N_{sim} and N_{obs} are the numbers of simulated and observed stars present in a given color magnitude bin) using

	Scale length (pc)	Scale height (pc)	flare slope	flare radius (pc)	Relative density per age bin (in Gyrs)
Value of the best fit	2147.79 ± 7.40	576.48 ± 1.98	0.14 ± 0.04	9206.66 ± 31.01	[8;9]: 1.07±0.02; [9;10]: 0.81±0.03 [10;11]: 0.32±0.03; [11;12]: 0.30±0.02

Table 2. Thick disc parameters and their uncertainties obtained after averaging over 4 independent MCMC runs. The errors presented in this table do not take into account the correlations.

a MCMC scheme, starting with randomly chosen parameters within fixed boundaries given in table 1.

$$Lr = N_{sim} - N_{obs} + N_{sim} \times log(\frac{N_{obs}}{N_{sim}}) \qquad (2.1)$$

Except for the flare, the thick disc parameters generally converge towards the same thick disc from one MCMC run to another: a thick disc younger than 11 Gyr with an increasing star formation rate from 11 to 8 Gyr, as also proposed by Snaith et al. (2014). We also find a short scale length, in agreement with previous results (Bensby et al. (2011) and Robin et al. (2014)), and a scale height similar to Robin et al. (2014).

The values of the best fit are listed on table 2. Those parameters and their uncertainties are obtained after averaging over 4 independent MCMC runs. The errors do not take into account the correlations.

Figure 2 shows an example of the convergence for the thick disc scale length. For each MCMC launched, the scale length converges towards 2 kpc which is in agreement with values found in Robin et al. (2014), Bensby et al. (2011) and Cheng et al. (2012). The quality of the fit can be illustrated in figure 3 that shows for a 2MASS field the histograms of J-K in several K magnitude bins for the observations and best fitting model.

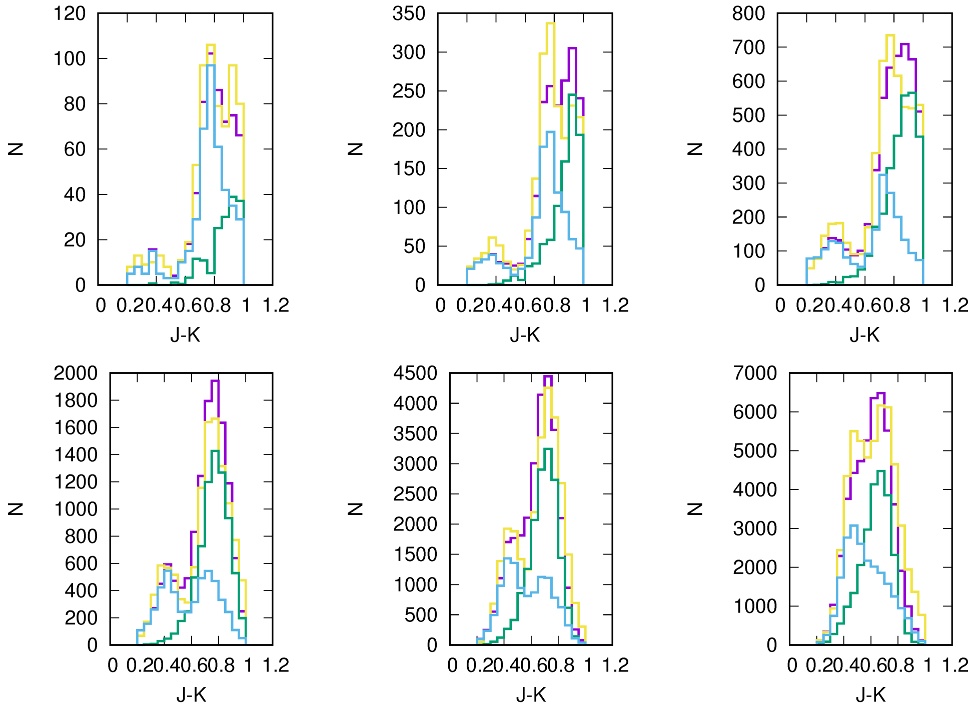

Fig. 3. Histogram of the J-K color for 6 K magnitude bins ([8;9], [9;10], [10;11], [11;12], [12;13], [13;14], [14;15]) the observations are in yellow, the simulations in purple, the thin disc in blue and the thick disc in green. This field is centered at galactic longitude of 11 ° and galactic latitude of -12 ° .

3 Conclusions

The results presented here were obtained with a fixed thick disc's average metallicity of -0.5 dex and a standard deviation of 0.3 dex. The initial mass function (IMF) was also fixed. It is planned to run MCMC on simulations with different thick disc metallicities, (in particular by adding an age metallicity relation for the thick disc) to observe their impact.

Focusing on 2MASS survey allowed us to test the thick disc without having to constrain the halo (its contribution is negligible at these magnitudes). However the lack of high latitude deep magnitude fields can bias the results obtained. To improve our results, we shall incorporate new observations from SDSS survey (Shadab et al. 2015), CFIS survey at CFHT (Ibata et al. 2017), and from Pan-STARRS (Chambers et al. 2017). To constrain the flare, it is also planned to add anticenter fields.

In the near future we plan to test the reliability of our results on the thick disc star formation history with detailed spectroscopic and asteroseismic data, such as the APOKASC data set (a combination of APOGEE spectroscopy and *Kepler* asterosismology, Pinsonneault et al. (2014)), CoroGEE (Anders et al. 2017), and CoRoT-GES (Valentini et al. 2016), allowing to get better constraints on its formation scenario.

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