The metallicity distribution in GES iDR2 from a population synthesis analysis

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Abstract

The formation and evolution of the thick disc of the Milky Way remain controversial. We make use of the Besancon model (Robin et al. 2003, 2014), which among other utilities can be used for data interpretation and to test different scenarios of galaxy formation and evolution. We examined these questions by studying the metallicity distribution of the thin and thick disc with the help of spectroscopy. We selected a sample of F/G/K stars from Gaia-ESO and developed a tool based on a MCMC-ABC method to determine the metallicity distribution and study the correlation between the fitted parameters. We compare these results with other analysis and discuss with regards to possible formation and evolution scenarios for the thick disc.

Besançon galaxy model

The Besançon galaxy model (**Robin et al. (2003,2014)**) computes the probable stellar content of our galaxy using a Population synthesis approach. To reproduce the stellar content of the Galaxy, it assumes a scenario of formation and evolution. It is not only a good way to test the different scenarios of galaxy formation and evolution, but also allows to trace galactic structure. The original model is divided in 4 different populations (thin and thick disc, bulge/bar and stellar halo) and each of these populations is characterized by SFR history, IMF, Age-Metallicity relation, density laws and kinematics.

Distances

We selected stars in different metallicity and log g ranges to separate giants, subgiants and dwarfs stars and compute the absolute magnitude from which we estimate the distance. The difference between distance estimate and the distance given by the model is given in figure 1. The results show that the accuracy is good with more than 91% of the stars inside 1.0 kpc accuracy but there is a small bias towards larger distances computed from our method.

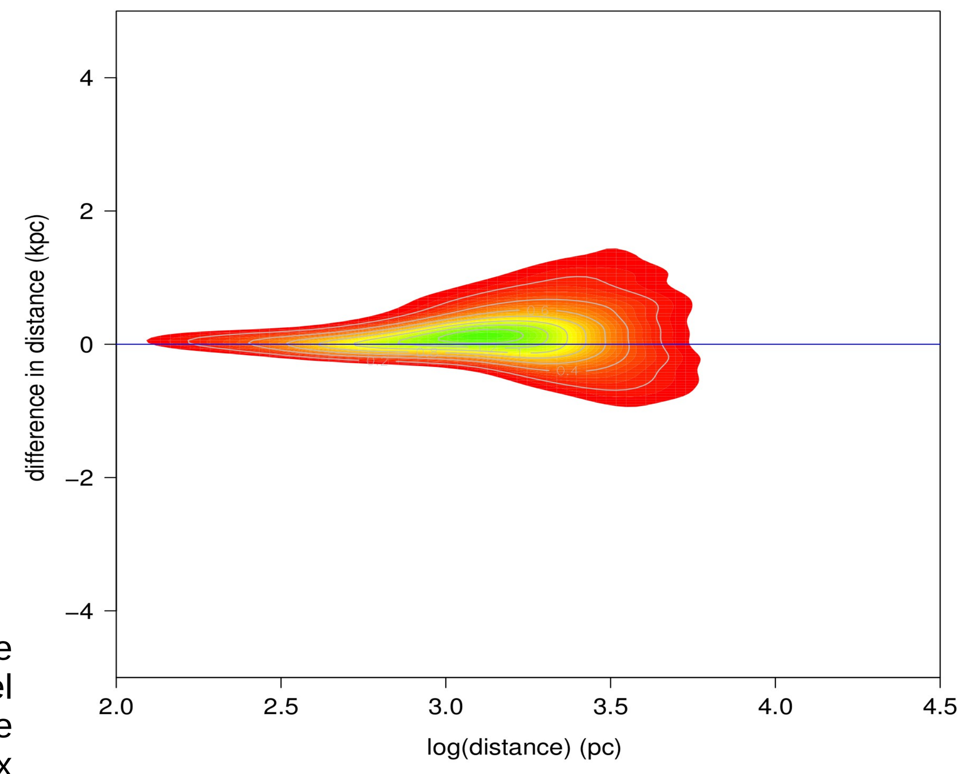

Figure 1. **Difference between distance estimate and the distance given by the model as a function of the log(distance) given by the model.**

Metallicity distribution

Figure 2 shows the total GES sample metallicity distribution along with the different components of the Milky Way as given by the single burst model (**Robin et al. 2014)** before the fit. The total metallicity distribution which is the mixture essentially of the thin and thick disc has a mean equal to -0.294 dex with a dispersion of 0.468 dex with a low metallicity tail.

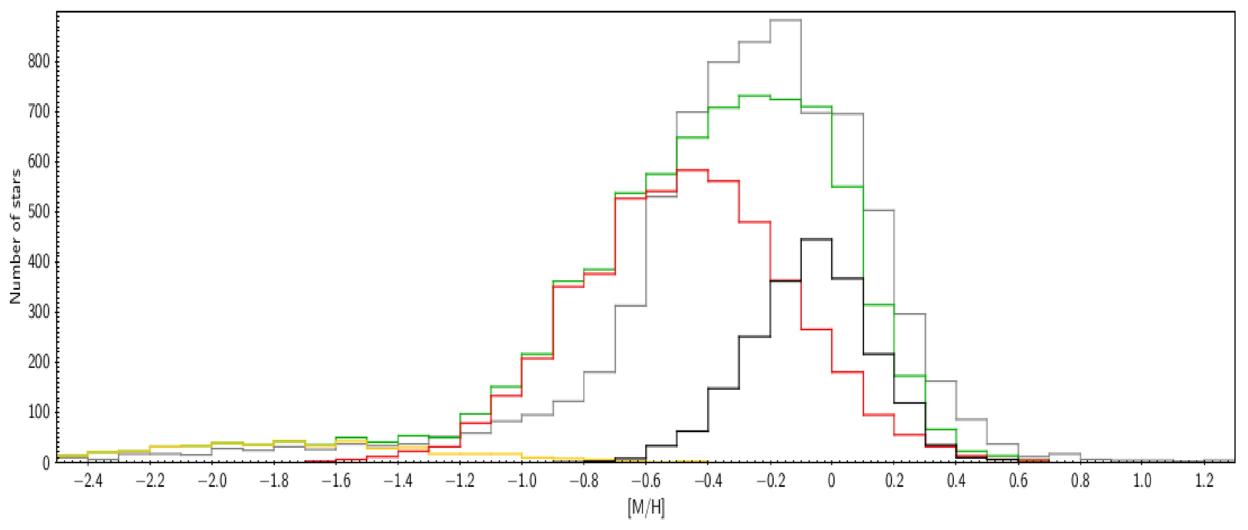

Figure 2. **Metallicity distribution of the total GES sample from observations (grey lines) and as given by simulations (Green lines). The different components as given by the model are: black lines: Thin disc; red lines: Thick disc; orange lines: Halo.**

GES iDR2 data and selection

For this study we use the GES iDR2 survey where we have selected FGK-type stars observed by GIRAFFE. We select disc fields where the mean reddening is smaller than 0.25 mag and disregard clusters and CoRoT fields. The total number of stars is 7470.

Simulations

In this analysis we use the single burst thick disc formation model (Robin et al. 2014). The photometric, S/N and spectral parameter errors are simulated. We assume an error of 0.1 dex, 100 k and 0.15 dex for metallicity, temperature and log g respectively (GES internal private communication). After applying the extinction (Schlegel et al. 1998) to the simulated stars, we selected stars in the simulated catalog by binning in the color (J-K) magnitude (J) space, with bins of 0.05 and 0.1 mags respectively, and selecting the same number of stars present in each bin of the color magnitude bins of the observations.

Preliminary comparison with the BGM

We present metallicity, temperature and surface gravity distributions for the fields at l=229°, b=18° and l=97°, b=-61° in figures 3 and 4. Field at l=229°, b=18° presents a good agreement for the effective temperature and log g distributions. The simulated metallicity distribution is slightly lower than the observed one. Field at l=97°, b=-61° presents a metallicity distribution similar to the former one. The simulated log g distribution is in agreement with the observational distribution at the 2σ level.

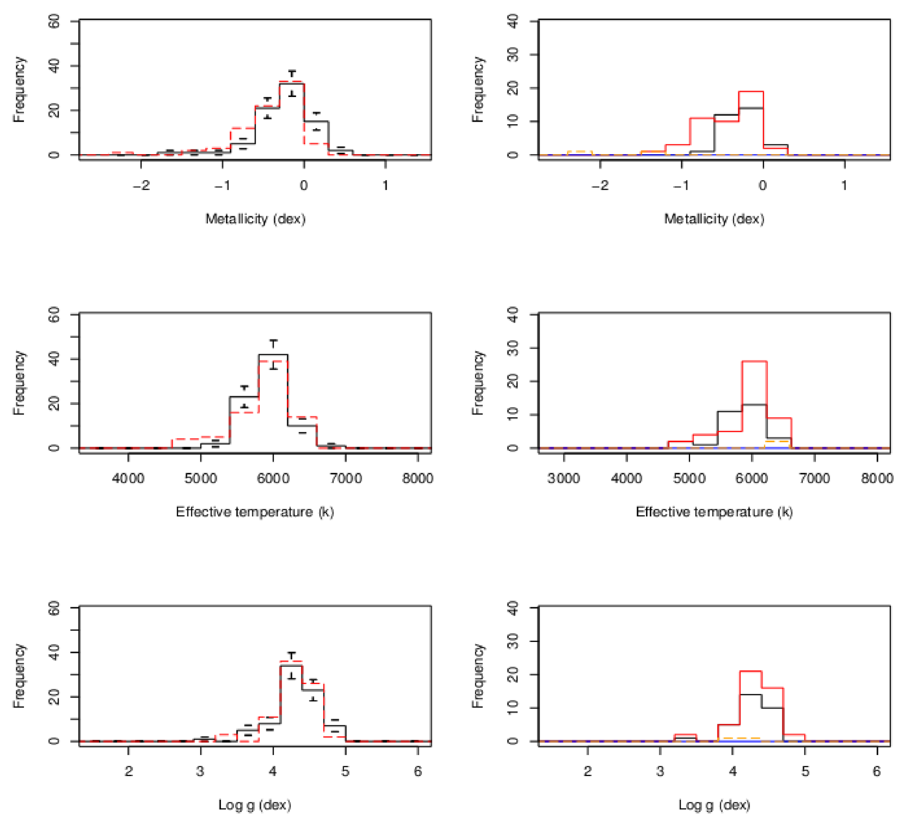

Figure 3. **Comparison of the spectrocopic observations and simulations for a field at l=229° and b=18°. Left panels: Black lines are observations and simulations are in red. The Poisson noise is represented by the small vertical bars. Right panels: Black lines are thin disc; red lines are thick disc; orange lines are halo.**

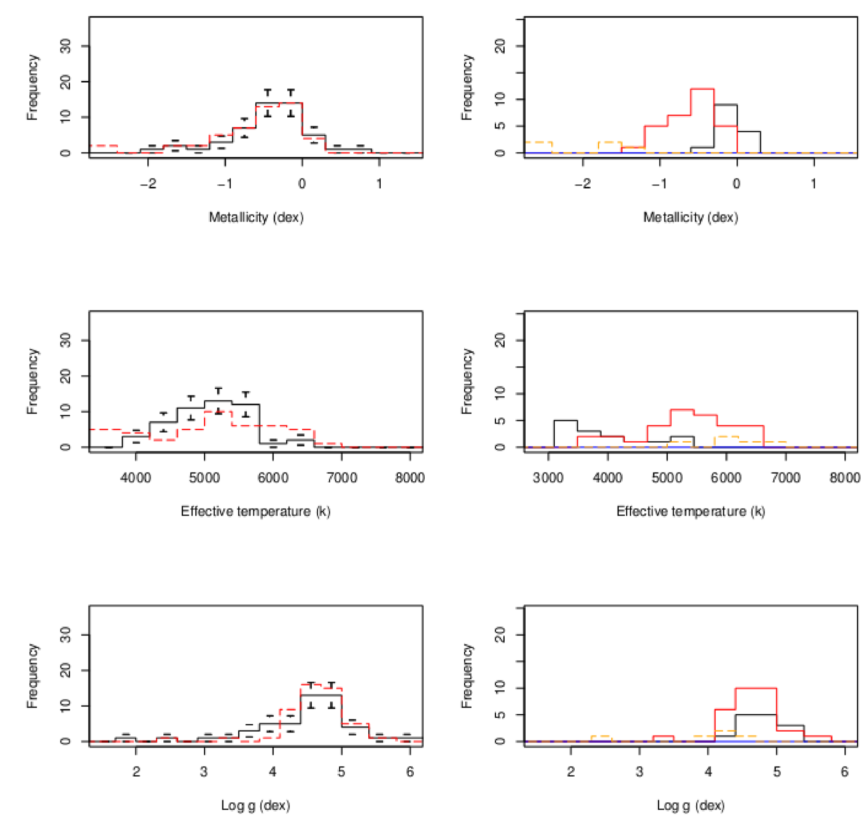

Figure 4. **Same as figure 3 for field l=97° b=-61°**

ABC/MCMC analysis for the GES sample

We use an ABC/MCMC (Approximate Bayesian Computation) method (Marin et al. 2011), where the sampling is done by a Metropolis-Hasting algorithm. The values of the fitted parameters are the mean of 10 different ABC/MCMC runs. The errors were computed from the final batch (the final 20% of the accepted chain). We explored possible correlations between parameters.

Results

A – Table 1 gives the fitted model parameters along with standard deviation for each parameter when fitting the thick disc along with the thin disc. The correlations are small apart from the radial metallicity gradient and local metallicity of the thick disc (0.421), the local metallicity and dispersion of the thin disc (0.374) and the local metallicity and dispersion of the thick disc (-0.376).

Thick disc			Thin disc				
$[Fe/H]$ (dex)	$\frac{d[Fe/H]}{dR}$ (dex kpc^{-1})	Disp (dex)	$[Fe/H]$ (dex)	$\frac{d[Fe/H]}{dR}$ (dex kpc^{-1})	Disp (dex)	$\mathcal{L}$	BIC
-0.254 ±0.036	0.008 ±0.025	0.229 ±0.023	0.077 ±0.038	-0.072 ±0.036	0.187 ±0.030	-401.45 ± 0.46	856.41

B – Table 2 gives the fitted model parameters along with standard deviation for each parameter when fitting the thick disc along with the thin disc and with the respective vertical metallicity gradients. The correlations are generally small. However, the determination of the thick disc vertical metallicity gradient is not possible due to a too strong correlation with the local metallicity.

Thick disc				Thin disc					
$[Fe/H]$ (dex)	$\frac{d[Fe/H]}{dR}$ (dex kpc^{-1})	Disp (dex)	$\frac{d[Fe/H]}{dz}$ (dex)	$[Fe/H]$ (dex kpc^{-1})	$\frac{d[Fe/H]}{dR}$ (dex)	Disp (dex kpc^{-1})	$\frac{d[Fe/H]}{dz}$ (dex kpc^{-1})	$\mathcal{L}$	BIC
-0.128 ±0.071	-0.003 ±0.026	0.231 ±0.023	-0.130 ± 0.061	0.086 ±0.055	-0.087 ±0.044	0.219 ±0.042	-0.042 ± 0.102	-397.60 ± 0.87	866.55

C – Table 3 gives the fitted model parameters along with standard deviation for each parameter when fitting the thick disc along with the 'old thin disc' (The 'old thin disc' are the model components of the thin disc with ages from 5.0 Gyr to 10.0 Gyr.). The correlations are small apart from the local metallicity and radial metallicity gradient of the thick disc (0.4). The local metallicities of the old thin disc and the thick disc are rather high compared with previous knowledge.

Thick disc			Old thin disc				
$[Fe/H]$ (dex)	$\frac{d[Fe/H]}{dR}$ (dex kpc^{-1})	Disp (dex)	$[Fe/H]$ (dex)	$\frac{d[Fe/H]}{dR}$ (dex kpc^{-1})	Disp (dex)	$\mathcal{L}$	BIC
-0.263 ±0.025	0.004 ±0.033	0.226 ±0.021	0.130 ±0.045	-0.081 ±0.045	0.135 ±0.012	-398.89 ± 0.412	851.29

Discussion and Conclusion

The local metallicities, for thick and thin disc, are higher compared with literature values which may indicate that the calibration needs improvement.

- The thick disc local metallicity obtained in this analysis is higher than the one obtained in our analysis of the SEGUE data (Martins et al. 2014, submitted) and in last studies from other surveys (~ -0.5 dex).
- The local metallicities are correlated with the vertical metallicity gradients in each component.

The thick disc presents no radial metallicity gradient which reinforces the indication, given by SEGUE analysis (Martins et al. 2014, submitted), of a thick disc which formed in an early epoch from a highly turbulent, well mixed gas producing a chemically homogeneous thick disc or that heavy mixing has occurred since its formation.

- The thin disc radial metallicity gradients are in agreement, inside errors, with results obtained from the SEGUE analysis (Martins et al. 2014, submitted) and recent literature values from the GES DR1 analysis of F/G/K stars −0.058 ± 0.008 dex kpc^{-1} (Recio-Blanco et al. 2014) and −0.044 ± 0.009 dex kpc^{-1} (Mikolaitis et al. 2014). These radial metallicity gradients are also in agreement with the ones obtained by the red giants analysis in APOGEE survey −0.066 ± 0.006 dex kpc^{-1} (Anders et al. 2014) and −0.09 ± 0.02 dex kpc^{-1} (Hayden et al. 2014).
- The thick disc presents no radial metallicity gradient independently of the thick disc model used (single or more extended epoch formation) in agreement with recent literature.

In the thin disc the fact that the older stars have higher scale heights and lower metallicity completely explain the observed vertical gradient.

- The thin disc implicit vertical metallicity gradient in the model is about −0.06 dex kpc^{-1} (due to the age metallicity and age-scale height relations). This result is in disagreement with the stronger negative vertical gradient determined by Hayden et al. (2014) (-0.21 ± 0.02 dex kpc^{-1}) but in agreement with Mikolaitis et al. (2014) (-0.079 ± 0.013 dex kpc^{-1}).

Perspectives

- This analysis will be performed on future releases with larger samples and improved calibrations.
- A new version of the model (Robin et al. 2014) has been developed, where the thick disc was tentatively divided into two parts of different ages in order to check for a longer epoch of star formation. Further studies will consider constraining the thick disc metallicity distribution with age and position in the Galaxy.
- Our method will also allow to combine the analyses of several surveys (SEGUE, Gaia-ESO, APOGEE, and further Gaia) to constrain the thin and thick disc evolution.

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