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Stellar metallicity gradients of the Milky Way disc from LAMOST

Maosheng Xiang

Max-Planck Institute for Astronomy, Heidelberg, Germany
email: mxiang@mpia.de

Abstract. Stellar metallicity gradients set important constraints on the formation and evolution history of the Milky Way. We present radial and vertical metallicity gradients of the Galactic disc for mono-age stellar populations from the LAMOST Galactic Surveys, and discuss their constraints on the disc assemblage history.

Keywords. Galaxy: disc, Galaxy: formation, Galaxy: evolution

1. Introduction

The stellar metallicity gradients of the Galactic disc are consequences of a series of fundamental astrophysical processes, such as gas infall (and inflow), star formation and element enrichment, galaxy merger and secular dynamic evolution (stellar migration), they thus serve as a very useful tool for Galactic archaeology (e.g. Grisoni *et al.* 2018).

Both the radial and the vertical stellar metallicity gradients have been derived with various tracers (see a summary in Xiang *et al.* 2015). It is widely found that both the radial and the vertical metallicity gradients exhibit significant spatial variations (e.g. Cheng *et al.* 2012, Hayden *et al.* 2014, Huang *et al.* 2015). On the other hand, although there are some efforts to characterise the temporal evolution of the disc stellar metallicity gradients (Maciel *et al.* 2003, Nordström *et al.* 2004, Magrini *et al.* 2009, Stanghellini 2010, Casagrande *et al.* 2011), the results are still not conclusive due to the lack of large stellar samples with reliable age estimates. The LAMOST Spectroscopic Survey of the Galactic Anti-center (Liu *et al.* 2014, Yuan *et al.* 2015, Xiang *et al.* 2017) delivers robust stellar parameters (including metallicity and age) for millions of disc stars with simple yet statistically non-trivial target selection function, thus provides opportunities for systematic studies on the disc metallicity gradients, especially their time evolution.

2. Results and discussion

Fig. 1 plots the disc stellar metallicity gradients derived from a sample of 0.3 million LAMOST main-sequence turn-off (MSTO) stars with different ages (Xiang *et al.* 2015). The left panel shows that the radial gradients vary significantly with both $|Z|$ and age. The oldest populations (age > 11 Gyr) have almost *zero* radial gradients at all heights above the disc mid-plane. The younger populations exhibit negative radial gradients, which flatten with $|Z|$. From the population with age > 11 Gyr to 8–11 Gyr, the radial gradient shows an abrupt change from zero gradient to a strong negative gradient. The 6–8 Gyr population exhibits the steepest gradient at all heights, which means that the trend of radial gradient with age is not a monotonous one but exhibits a reverse behaviour: from steepening to flattening with time (i.e., with decreasing age). Such a reverse trend has been further confirmed by a recent work using a million stars from LAMOST with improved stellar parameters (Wang et al., MNRAS, in press). The right panel shows that

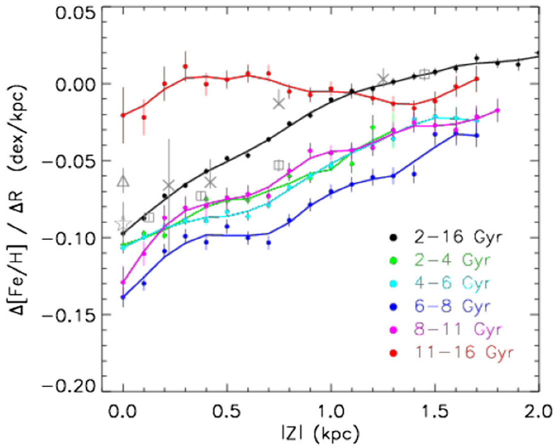

Figure 1. *Left*: Radial stellar metallicity gradient as a function of $|Z|$. *Right*: Vertical stellar metallicity gradient as a function R. Solid lines are smoothed results of the individual measurements (dots with error bars). Symbols in grey are measurements in literatures with different tracers (see Xiang *et al.* 2015 for details). The figures are adapted from Xiang *et al.* (2015).

the vertical metallicity gradients flatten significantly with R, and also vary with age. All populations, including the oldest one, exhibit negative vertical gradients.

Our results suggest the formation mechanism of the older (thick) disc is different to that of the younger (thin) disc. The old disc may have formed from gas with homogeneous metallicity distribution, which is probably consequence of a radially homogeneous star formation history or a fast and violent formation process. However, the negative vertical gradients suggest that the old (thick) disc was unlikely formed too fast and violent, and the upside-down mechanism may have played a significant role. The flattening trend of metallicity gradients with R and Z for the younger, mono-age populations are probably consequences of stellar migration and disc flaring (Minchev *et al.* 2014, Kawata *et al.* 2017). A flaring phenomenon for almost all mono-age disc populations have been predicted by simulations (Minchev 2016), and also been observed recently (Xiang *et al.* 2018). Nevertheless, mechanisms cause the reverse trend of metallicity gradient as a function of age need to be further understood.

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