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The present-time Milky Way stellar Metallicity Gradient

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Abstract. The present-time Milky Way (MW) radial metallicity gradient is a prime observable for galaxy evolution studies. Yet, a large diversity of measured gradients can be found in the literature, with values ranging from -0.01 to -0.09 dex kpc^{-1}, depending on the tracers used. In order to understand if this diversity comes from Galactic evolution processes or observational biases, stellar probes uniformly distributed across the disc and with accurately known ages and distances are needed. Classical Cepheids fulfil all these requirements and have been used to measure accurate abundance gradients in the MW. Here, I summarise some of the recent results based on Cepheids and on other stellar probes of similar age, and briefly discuss their implication for Galactic evolution.

Keywords. stars: variables: Cepheids – Galaxy: abundances

1. Cepheids as proxies of the gas-phase chemical composition

Classical Cepheids (Cepheids) have a number of properties that make them ideal proxies of the gas-phase chemical composition of the Galactic disc. In fact, they are luminous stars that can be seen even through severe dust extinction, and their individual ages and distances can be precisely determined on the basis of their periods (Bono *et al.* 2005, Inno *et al.* 2015). They are young (10-200 Myr), but compared to other young stars, they have lower temperature ($T_{\rm eff}$ ∼5,500 K) and hence their spectra, rich in metal absorption lines, allow for precise abundance determinations of many chemical elements (e.g. da Silva *et al.* 2016 and references therein). Unfortunately, the use of Cepheids as chemical probes is currently limited by the small number of known Cepheids in the Galaxy. With respect to external galaxies (as, e.g., the Magellanic Clouds), Cepheids are poorly mapped in the MW: only ∼600 have been identified until very recently, and, for the majority of them, accurate abundance measurements are available in the literature (Genovali *et al.* 2014). Even if limited in size, though, this sample allows us to probe a much larger volume of the MW disc with respect to the one accessible only through stars with geometric distances currently determined at comparable accuracy (∼5%, see Panel *a*) in Fig. 1).

2. The shape of the MW metallicity gradient

The metallicity of the Cepheids in this sample is shown Panel *b*) of Fig. 1 and compared to the gradients based on stellar tracers with similarly young age, such as Open Clusters (OCs), OB stars, and Red Clump (RC) stars with ages <1 Gyr (references in the caption). The agreement is remarkably good if we consider only the range of Galactocentric radii between 5 and 10 kpc, but it vanishes when the entire range of distances is taken into account. The metallicity distribution of OCs shows a break in the slope at about 10–12 kpc, with a steepening in the inner and a flattening in the outer part, while RC stars show an opposite trend, with a break at 6 kpc, a flat gradient in the inner

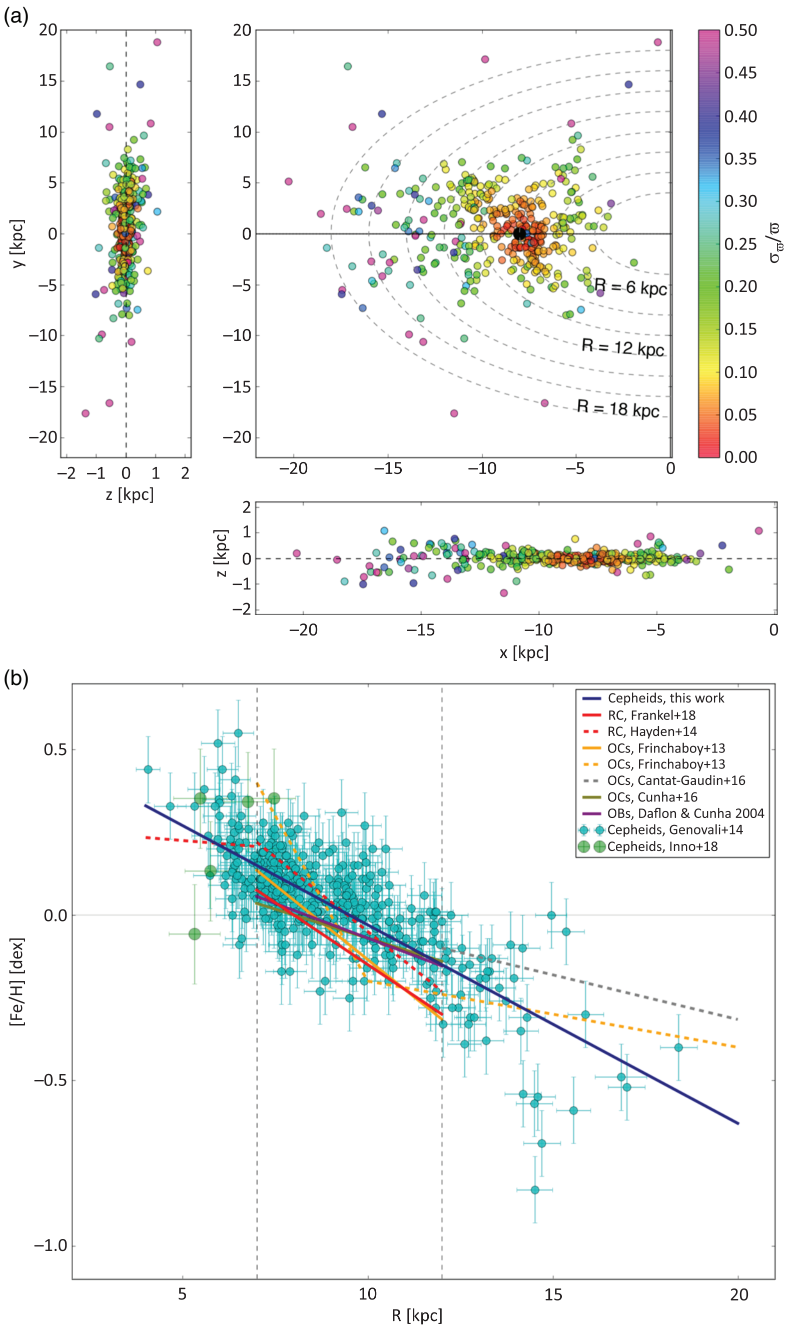

Figure 1. *Panel a)*: Distribution of the MW Cepheids projected into the Galactic plane and colour coded by the relative parallax error from Gaia DR2 (sample by Genovali *et al.* 2014). *Panel b)*: Metallicity distribution as a function of the Galactocentric radius R of the Cepheids in Panel a). Possible contaminants, such as Type-II (e.g. HQ Car, Lemasle *et al.* 2015) and Anomalous Cepheids (e.g. HK Cas), have been removed on the basis of their geometric parallax. A gradient of -0.057±0.002 dex kpc^{-1} is found (blue line) for the cleaned sample. The slopes of the metallicity gradient measured on the basis of OCs (Frinchaboy *et al.* 2013; Cunha *et al.* 2016; Cantat-Gaudin *et al.* 2016), OB stars (Daflon & Cunha 2004) and young RC stars (Hayden *et al.* 2014; Frankel *et al.* 2018) are also shown. The agreement is good for 6 kpc$\lesssim$R$\lesssim$12 kpc (vertical dashed lines) while different trends are found in the inner and outer regions.

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region and a steep gradient in the central Galaxy. However, recent results based on new Cepheids identified in the inner disc (Inno *et al.* 2018) do not support the steepening in the inner part, but suggest that there is instead an increase of the metallicity spread around R∼5 kpc, due to the dynamical interaction with the central Bar.

The possible flattening in the outer region remains an open question, as the current sample of Cepheids at R>15 kpc is limited and potentially also biased. At R∼10 kpc, the disc deviates from the planar geometry and warps. Therefore, it is unclear whether the Cepheids are only found at larger height above the plane because of selection effects (i.e., the heavy extinction towards the middle plane), or because they trace the warp. Such selection effects will be soon better understood and eventually removed, thanks to all-sky, time-domain surveys (e.g., Gaia, OGLE-IV, ASAS-SN, PanSTARRs), which have just recently identified >2,000 new Galactic Cepheids (Jayasinghe *et al.* 2018). To take full advantage of this paradigm shift, we have designed an ongoing program with APOGEE-2 to spectroscopically observe hundreds of the newly identified Cepheids and at least threefold the current sample. This final spectroscopic sample of MW Cepheids will thus be a gold-mine for future studies on the MW structure and recent history.

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