

# On the fine structure of the Cepheid metallicity gradient in the Galactic thin disk<sup>★,★★</sup>

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## ABSTRACT

We present homogeneous and accurate iron abundances for 42 Galactic Cepheids based on high resolution ( $R \sim 38\,000$ ) high signal-to-noise ratio ( $S/N \geq 100$ ) optical spectra collected with UVES at VLT (128 spectra). The above abundances were complemented with high-quality iron abundances provided either by our group (86) or available in the literature. We were careful to derive a common metallicity scale and ended up with a sample of 450 Cepheids. We also estimated accurate individual distances for the entire sample by using homogeneous near-infrared photometry and the reddening free period-Wesenheit relations. The new metallicity gradient is linear over a broad range of Galactocentric distances ( $R_G \sim 5\text{--}19$  kpc) and agrees quite well with similar estimates available in the literature ( $-0.060 \pm 0.002$  dex/kpc). We also uncover evidence that suggests that the residuals of the metallicity gradient are tightly correlated with candidate Cepheid groups (CGs). The candidate CGs have been identified as spatial overdensities of Cepheids located across the thin disk. They account for a significant fraction of the residual fluctuations, and also for the large intrinsic dispersion of the metallicity gradient. We performed a detailed comparison with metallicity gradients based on different tracers: OB stars and open clusters. We found very similar metallicity gradients for ages younger than 3 Gyr, while for older ages we found a shallower slope and an increase in the intrinsic spread. The above findings rely on homogeneous age, metallicity, and distance scales. Finally, by using a large sample of Galactic and Magellanic Cepheids for which accurate iron abundances are available, we found that the dependence of the luminosity amplitude on metallicity is vanishing.

**Key words.** stars: abundances – stars: variables: Cepheids – stars: oscillations – Galaxy: disk – open clusters and associations: general

## 1. Introduction

Recent findings concerning the metallicity gradient across the Galactic thin disk, based on high spectral resolution, high signal-to-noise ( $S/N$ ) spectra, and on stellar tracers for which we can provide accurate individual Galactocentric distances, are

\* Based on spectra collected with the spectrograph UVES available at the ESO Very Large Telescope (VLT), Cerro Paranal, (081.D-0928(A) PI: S. Pedicelli – 082.D-0901(A) PI: S. Pedicelli – 089.D-0767 PI: K. Genovali).

\*\* Figure 1 and Tables 1, 3–7 are available in electronic form at <http://www.aanda.org>

disclosing a new interesting scenario. The iron gradients traced by stellar populations younger than a few hundred Myr show a well-defined trend when moving from the inner to the outer disk regions. The iron abundances in the innermost disk regions ( $R_G \sim 5$  kpc) are well above solar ( $[Fe/H] \sim 0.4$ , Andrievsky et al. 2002; Pedicelli et al. 2009; Luck et al. 2011; Luck & Lambert 2011; Genovali et al. 2013, hereafter G13), while in the outer disk ( $R_G \sim 15$  kpc) they are significantly more metal-poor ( $[Fe/H] \sim -0.2\text{--}0.5$ , Andrievsky et al. 2004; Yong et al. 2006; Lemasle et al. 2008). However, the young stellar populations in the two innermost Galactic regions showing ongoing star formation activity – the bar and the nuclear bulge – attain solar

iron abundances, thus suggesting that the above regions have experienced different chemical enrichment histories (Bono et al. 2013).

The use of high-quality data and a homogeneous analysis of a large sample of classical Cepheids and young massive main-sequence stars provided the opportunity to overcome some of the systematics affecting early estimates of the metallicity gradient. However, current findings still rely on several assumptions that might introduce systematic errors.

- i) Distances – Cepheids are very solid primary distance indicators, but they only trace young stellar populations. The use of red clump stars is very promising, since they are found throughout the innermost Galactic regions. However, their individual distances might be affected by larger uncertainties, since we are dealing with stellar populations covering a broad range of ages and metal abundances (Girardi & Salaris 2001; Salaris & Girardi 2002).
- ii) Gradients – Recent spectroscopic investigations indicate that the use of homogeneous and accurate iron abundances decreases the spread along the radial gradient (G13). This means that they can be adopted to investigate the fine structure of the metallicity distribution (Lépine et al. 2011) and the possible occurrence of gaps and/or of changes in the slope (Lépine et al. 2013).
- iii) Ages – The central helium burning phases of intermediate-mass stars ( $M \sim 3.5\text{--}10 M_{\odot}$ ) take place along the so-called blue loops. During these phases an increase in stellar masses causes a steady increase in the mean luminosity. These are the reasons why classical Cepheids obey a period-age relation. However, the ages covered by Cepheids is quite limited ( $\sim 20\text{--}400$  Myr). Most of the current chemical evolution models predict a steady decrease in slope of the metallicity gradient as a function of age (Portinari & Chiosi 2000; Cescutti et al. 2007; Minchev et al. 2013). However, we still lack firm estimates of this effect since homogeneous estimates of distance, age, and chemical composition for a large sample of intermediate and old open clusters (Salaris et al. 2004; Carraro et al. 2007b; Yong et al. 2012) are still missing.

In this investigation we provide new accurate and homogeneous iron abundance estimates for 42 Galactic Cepheids based on high-resolution, high S/N spectra acquired with UVES at VLT. The total sample includes estimates for 75 Cepheids (74 classical Cepheids and one Type II Cepheid – DD Vel – that will be discussed in a forthcoming paper), whose abundances were partially published in Genovali et al. (2013). We also analyzed three high spectral resolution spectra for the Cepheids – TV CMa, RU Sct, X Sct – collected with NARVAL at the *Télescope Bernard Lyot* (TBL)<sup>1</sup> that we adopted to double check current iron abundance estimates. We also added a new estimate of the FEROS spectrum for the Cepheid CE Pup whose metallicity was already available in the literature (Luck et al. 2011).

The above iron abundances were complemented with similar estimates provided either by our group (Lemasle et al. 2007, 2008; Romaniello et al. 2008, 53 Cepheids) or available in the literature (Yong et al. 2006; Luck et al. 2011; Luck & Lambert 2011, 322 Cepheids). We ended up with a sample of 450 classical Cepheids, i.e., the 73% of the entire sample of known Galactic Cepheids according to the classical

Cepheids list in the GCVS (candidate Cepheids are excluded from this estimate). For the entire sample, we estimated homogeneous distances based on reddening-free near-infrared period-Wesenheit (PW) relations (Inno et al. 2013).

This is the eighth paper of a series devoted to chemical composition of Galactic and Magellanic Cepheids (see the reference list). The name of the project is DIsk Optical and Near infrared Young Stellar Object Spectroscopy (DIONYSOS). The structure of the paper is the following. In Sect. 2 we present the spectroscopic data sets adopted in the current investigation and the method adopted to estimate the iron abundances. The photometric data and the individual distances are discussed in Sect. 3, together with a detailed analysis of the errors affecting Cepheid distances. Section 4 deals with the metallicity gradient, while in Sect. 5 we investigate the dependence of the metallicity gradient on stellar age. In this section the metallicity gradient is compared with the metallicity gradients based on younger tracers (OB stars) and with intermediate-age tracers (open clusters). In Sect. 6 we address in detail the fine structure of the metallicity gradient and perform a thorough analysis of the Cepheid radial distribution across the Galactic disk. Section 7 deals with the longstanding open problem concerning the dependence of the luminosity amplitude on the metallicity, while in Sect. 8 we summarize the results and briefly outline the future developments of this project.

## 2. Spectroscopic data and iron abundances

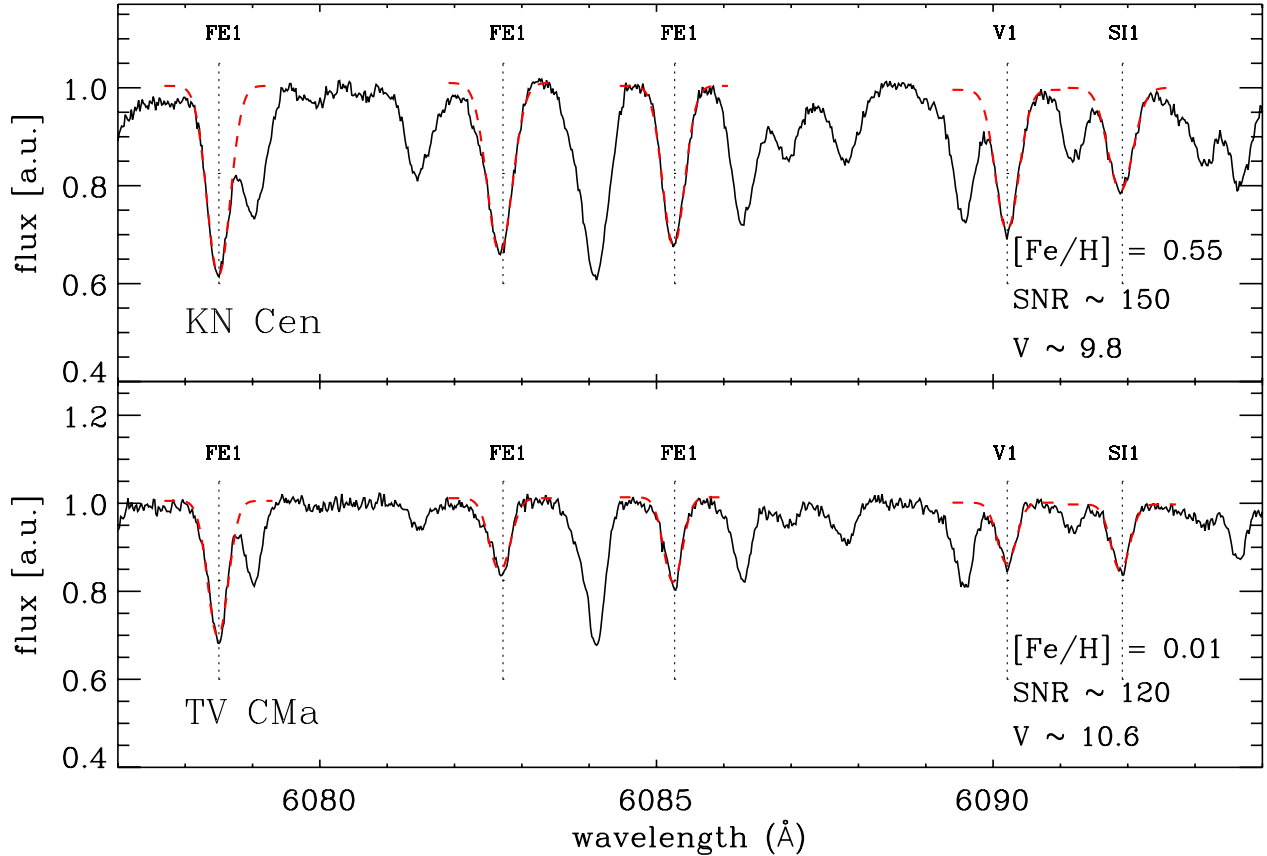
### 2.1. Spectroscopic data

In this investigation we present a spectral analysis based on high-resolution ( $R \sim 38\,000$ ) spectra collected with the UVES spectrograph available at the Nasmyth B focus of UT2/VLT Cerro Paranal telescope. Multi-epoch spectra for eleven Galactic Cepheids were collected during observing run B (P89). This sample includes 44 high-resolution spectra (from four to six spectra per star) for a total of eleven Cepheids. The covered spectral range is  $4726\text{--}5804 \text{ \AA}$  and  $5762\text{--}6835 \text{ \AA}$  over the two chips, collected by only using the red arm configuration and the cross disperser CD 3 (central wavelength at 580 nm). The S/N ranges from  $\sim 50$  to  $\sim 300$  (see Fig. 1). The seeing during the observations ranged from 0.5 arcsec to 2.5 arcsec, with a typical mean value of 1.2 arcsec, while the exposure times changed from 20 s to 1400 s.

We make use of an additional UVES sample partially presented in G13. The spectra were collected at random pulsational phases between 2008 October and 2009 April using the DIC2 (437+760) configuration with blue and red arms operating in parallel. The two arms cover the wavelength intervals  $\sim 3750\text{--}5000 \text{ \AA}$  and  $\sim 5650\text{--}7600/7660\text{--}9460 \text{ \AA}$  (two chips in the red arm). The exposure time ranges from 80 s to 2000 s, while the seeing ranges from 0.6 arcsec to 2 arcsec with a mean value of 1.2 arcsec. The S/N is typically better than  $\sim 100$  for all the echelle orders. The complete spectroscopic sample includes 84 spectra for a total of 77 Cepheids. The spectra of three Cepheids – WW Mon, V641 Cen, GQ Ori – were analyzed, but they were not included in the abundance analysis because the S/N of the individual spectra was not good enough. The entire sample of UVES spectra were reduced using the ESO UVES dedicated pipeline REFLEX v2.1 (Ballester et al. 2011).

For three Cepheids – TV CMa, RU Sct, X Sct – we also analyzed high S/N spectra collected with NARVAL at TBL. NARVAL has a spectral resolution of  $\sim 75\,000$  and covers the wavelength range  $3700\text{--}10\,500 \text{ \AA}$ . The NARVAL spectra were

<sup>1</sup> Based on observations collected with TBL (USR5026) operated by OMP and INSU under program ID L072N06 (PI: B. Lemasle).



**Fig. 2.** High-resolution ( $R \sim 38\,000$ ) UVES spectrum of KN Cen ( $[\text{Fe}/\text{H}] = 0.55 \pm 0.12$ , Genovali et al. 2013) and TV CMa ( $[\text{Fe}/\text{H}] = 0.01 \pm 0.07$ , Genovali et al. 2013). The apparent visual magnitude and the S/N in the spectral range  $\lambda \sim 5650\text{--}7500$  Å (red arm) are also labeled. The vertical dashed lines display selected lines (Fe I 6078.50, Fe I 6082.72, Fe I 6085.27, V I 6090.21, Si I 6091.92 Å) adopted to estimate the individual  $T_{\text{eff}}$  with the LDR method (Kovtyukh & Gorlova 2000) (red dashed lines).

reduced using the data reduction software Libre-ESPRIT, written by Donati<sup>2</sup>. We also included the re-analysis of a FEROS<sup>3</sup> spectrum for CE Pup (Luck et al. 2011) to better constrain possible systematic differences in the metallicity estimates of the outer disk.

As a whole, we provide in this investigation an updated spectroscopic estimate of the iron abundance for 42 classical Cepheids located either in the outer disk or in the solar neighborhood. Together with the iron abundances provided by G13 we ended up with a homogeneous metallicity sample of 74 classical Cepheids.

## 2.2. Method

We implemented a dedicated semi-automatic procedure able to determine the continuum and to fit the line profile by single or double Gaussian functions (see Fig. 2), depending on the line blending. We adopted the iron linelist presented in Genovali et al. (2013) and typically we measured the equivalent width (EW) of  $\sim 100\text{--}200$  Fe I and  $\sim 20\text{--}40$  Fe II lines, depending on the specific spectral range.

The abundance determination was performed by using the code *calrai* originally developed by Spite (1967) and continuously updated since then. Once the atmospheric

parameters are fixed, the code performs an interpolation over a grid of LTE, plane-parallel atmosphere models (MARCS, Gustafsson et al. 2008), and provides  $[\text{Fe}/\text{H}]$  and its intrinsic error. The abundances of the other elements will be discussed in a forthcoming paper.

For each spectrum we computed the curves of growth for both neutral and ionized iron. The process is iterated until a good match between the predicted and observed equivalent widths (and thus the curves of growth) is obtained.

The effective temperature –  $T_{\text{eff}}$  – for individual spectra was independently estimated by using the line depth ratio (LDR) method (Kovtyukh & Gorlova 2000). Typically, we measured two dozen LDRs per spectrum (see, e.g., Fig. 2). The estimated  $T_{\text{eff}}$  was validated by ensuring that Fe I does not depend on the excitation potential ( $\chi_{\text{ex}}$ ) i.e., the slope of Fe I vs.  $\chi_{\text{ex}}$  is minimal. The surface gravity –  $\log g$  – was derived by imposing the ionization balance between Fe I and Fe II. The micro-turbulent velocity –  $v_t$  – was estimated by minimizing the Fe I vs. EW slope. The atmospheric parameters estimated for each spectrum are given in Table 1.

The maximum EW value included in the analysis varies according to the metallicity itself and on the atmospheric parameters of the star. For a large fraction of our spectra we were able to use only relatively weak lines ( $EW \leq 120$  mÅ) located along the linear part of the curve of growth. In a few cases the spectra were lacking a significant number of weak lines (less than two Fe II lines); therefore, we also included in the analysis lines with EW up to 180 mÅ. These lines cause a mild increase in the uncertainties affecting the correlated atmospheric

<sup>2</sup> [http://www.cfht.hawaii.edu/Instruments/Spectroscopy/Espadons/Espadons\\_esprit.html](http://www.cfht.hawaii.edu/Instruments/Spectroscopy/Espadons/Espadons_esprit.html)

<sup>3</sup> Pre-reduced spectra are available at <http://archive.eso.org/wdb/wdb/eso/repro/form>

**Table 2.** Impact of uncertainties affecting intrinsic parameters on iron abundance.

| Name     | $T_{\text{eff}}$ | [Fe/H]           | $\log g$ | $v_t$ | Element | $\Delta T_{\text{eff}}$ |        | $\Delta \log g$ |       | $\Delta v_t$ |       |
|----------|------------------|------------------|----------|-------|---------|-------------------------|--------|-----------------|-------|--------------|-------|
|          |                  |                  |          |       |         | -100 K                  | +100 K | -0.3            | +0.3  | -0.5         | +0.5  |
| V340 Ara | 6060             | $0.22 \pm 0.01$  | 0.8      | 5.2   | Fe I    | 0.17                    | 0.31   | 0.28            | 0.22  | 0.27         | 0.23  |
|          |                  |                  |          |       | Fe II   | 0.25                    | 0.20   | 0.12            | 0.33  | 0.26         | 0.20  |
|          |                  |                  |          |       | [Fe/H]  | 0.21                    | 0.26   | 0.20            | 0.28  | 0.27         | 0.22  |
| V340 Ara | 4820             | $0.23 \pm 0.18$  | 1.0      | 4.4   | Fe I    | 0.14                    | 0.30   | 0.20            | 0.21  | 0.27         | 0.15  |
|          |                  |                  |          |       | Fe II   | 0.38                    | 0.22   | 0.14            | 0.46  | 0.42         | 0.20  |
|          |                  |                  |          |       | [Fe/H]  | 0.26                    | 0.26   | 0.17            | 0.34  | 0.35         | 0.18  |
| V500 Sco | 5280             | $-0.03 \pm 0.12$ | 0.4      | 3.8   | Fe I    | -0.11                   | 0.06   | 0.01            | -0.07 | 0.04         | -0.07 |
|          |                  |                  |          |       | Fe II   | 0.00                    | -0.07  | -0.16           | 0.09  | 0.02         | -0.08 |
|          |                  |                  |          |       | [Fe/H]  | -0.06                   | -0.01  | -0.08           | 0.01  | 0.03         | -0.08 |
| V500 Sco | 6020             | $-0.11 \pm 0.07$ | 1.1      | 4.0   | Fe I    | -0.18                   | -0.05  | -0.09           | -0.13 | -0.08        | -0.13 |
|          |                  |                  |          |       | Fe II   | -0.11                   | -0.11  | -0.21           | -0.01 | -0.05        | -0.15 |
|          |                  |                  |          |       | [Fe/H]  | -0.15                   | -0.08  | -0.15           | -0.07 | -0.07        | -0.14 |
| V510 Mon | 5505             | $-0.16 \pm 0.06$ | 0.9      | 3.4   | Fe I    | -0.25                   | -0.07  | -0.16           | -0.08 | -0.08        | -0.19 |
|          |                  |                  |          |       | Fe II   | -0.14                   | -0.19  | -0.05           | -0.10 | -0.10        | -0.21 |
|          |                  |                  |          |       | [Fe/H]  | -0.20                   | -0.13  | -0.11           | -0.09 | -0.09        | -0.20 |

**Notes.** Error budget for V340 Ara, V500 Sco, and V510 Mon. Columns 7 to 12 list plausible changes in atmospheric parameters: effective temperature ( $T_{\text{eff}}$ ), surface gravity ( $\log g$ ), and microturbulent velocity ( $v_t$ ) together with their impact on Fe I and Fe II abundances. The mean [Fe/H] abundance for each set of intrinsic parameters is also given.

parameters and become on the order of  $\Delta \log g = 0.3$  dex and  $\Delta v_t = 0.5$  km s<sup>-1</sup>. The impact that typical uncertainties on effective temperature, surface gravity, and microturbulent velocity have on the mean iron abundance are listed in Table 2. Data given in this table indicate that the difference in iron is on average smaller than 0.2 dex. Moreover, the difference in iron does not seem to depend, within the uncertainties, on the pulsation phase.

The mean iron abundances given in Col. 8 of Table 3 are the weighted mean of [Fe I/H] and [Fe II/H] with associated errors, i.e.,  $\sigma_{\text{Fe}} = \sqrt{\sigma_{\text{Fe I}}^2 + \sigma_{\text{Fe II}}^2}$ , where  $\sigma_{\text{Fe I}}$  and  $\sigma_{\text{Fe II}}$  are the standard deviations of [Fe I/H] and [Fe II/H] estimates given by the lines measured in a single spectrum. For Cepheids in our sample with multiple measurements the weighted average abundance and the standard deviation  $\sigma_{\text{Fe}} = \sqrt{\sum_i \sigma_{\text{Fe},i}^2}$  are also listed. The iron abundances were estimated by assuming the solar iron abundance provided by Grevesse et al. (1996), i.e.,  $A(\text{Fe})_{\odot} = 7.50$ .

In order to validate current iron abundances we adopted the NARVAL spectra, since they have a spectral resolution that is a factor of two higher than the UVES spectra and similar S/Ns. We found that the iron estimates for X Sct, TV CMa and RU Sct based on the NARVAL spectra agree quite well with those based on UVES spectra, and the difference is on average smaller than  $\sim 0.1$  dex.

### 3. Photometric data and distance estimates

#### 3.1. Photometric data

In order to provide a homogeneous sample of Galactocentric distances ( $R_G$ ), we adopted near-infrared (NIR) photometric data together with the reddening-free PW relations in the  $J, H, K_s$  bands derived by Inno et al. (2013). We estimated individual distances for a significant fraction of Galactic Cepheids (93% of the known Galactic Cepheids). To improve the precision of individual Cepheid distances, we adopted the NIR photometric

catalogs provided by Laney & Stobie (1992) and by Monson & Pierce (2011). The above subsamples were complemented with NIR photometry from the 2MASS catalog.

The SAAO data set includes published mean magnitudes from Laney & Stobie (1992) and new multi-epoch measurements (C.D. Laney, priv. comm.). The individual NIR measurements of the former sample cover the entire pulsation cycle and the accuracy of mean  $J, H, K_s$  magnitudes is typically better than 0.01 mag. Some of the Cepheids in the latter sample lack detailed coverage of the light curve. For these objects the number of phase points ranges from four to 14 and they are marked with a dagger in the column notes of Table 3. The mean magnitudes were estimated using a cubic spline. The SAAO NIR magnitudes were transformed into the 2MASS photometric system by using the transformations provided by Koen et al. (2007).

We also adopted the NIR photometric catalog from Monson & Pierce (2011). They provided accurate NIR magnitudes for 131 northern hemisphere Cepheids. Their NIR mean magnitudes were transformed into the 2MASS photometric system using the calibrating equations provided by the same authors. The measurements properly cover the entire pulsation cycle and the typical accuracy on the mean magnitudes is better than 0.01 mag.

The above samples were complemented with 2MASS single-epoch NIR observations (Skrutskie et al. 2006). The mean magnitude for Fundamental (FU) Cepheids was estimated by using single-epoch photometry and the light-curve template provided by Soszyński et al. (2005). The pulsation properties required to apply the template (epoch of maximum, optical amplitudes, periods) come from the General Catalog of Variable Stars<sup>4</sup> (GCVS; Samus et al. 2009), with the exception of a few objects for which we adopted the pulsation periods provided by Luck & Lambert (2011). The error on the mean NIR magnitudes was estimated as  $\sigma_{J,H,K_s}^2 = \sigma_{\text{phot}}^2 + \sigma_{\text{temp}}^2$ , where  $\sigma_{\text{phot}}$  is the intrinsic photometric error – typically of the order of 0.03 mag for the Cepheids in the 2MASS sample – and  $\sigma_{\text{temp}} = 0.03$  mag

<sup>4</sup> <http://www.sai.msu.su/gcvs/gcvs/index.htm>



is the uncertainty associated with the intrinsic scatter of the template.

We did not estimate the NIR mean magnitudes of classical Cepheids pulsating either in the first overtone (FO) or as mixed-mode pulsators (CEP(B)). Their mean magnitudes are the original single-epoch 2MASS measurements, because we still lack either the light-curve template for FOs or the epoch of maximum. This subsample is marked with an asterisk in the last column of Table 3.

In order to provide an estimate of the uncertainty affecting distance estimates based on NIR single-epoch data (FU and FOs), we associated to this photometric sample a cautionary total error of  $\sigma_{J,H,K_s} = \sqrt{\sigma_{\text{phot}}^2 + (A_{J,H,K_s}/2)^2}$ , where  $(A_{J,H,K_s}/2)$  is the semi-amplitude in the specific band. The NIR amplitudes were estimated by using empirical relations for the ratio between optical and NIR amplitudes. In particular, we adopted the  $A_{\text{NIR}}/A_I$  ratios provided by Soszyński et al. (2005) for FU Cepheids with  $\log P \leq 1.3$ :  $A_J/A_I = 0.63$ ,  $A_H/A_I = 0.50$ ,  $A_K/A_I = 0.49$  mag. We estimated the amplitude in the  $I$ -band  $A_I$  by using the optical ratios  $A_I = 0.62A_V$  and  $A_I = 0.42A_B$  according to the intrinsic parameters available in the GCVS.

For the FO pulsators we adopted the ratio between optical and NIR amplitudes for FU Cepheids with  $\log P \leq 1.2$  (see Klagyivik & Szabados 2009). This assumption relies on the theoretical and empirical evidence that FOs, once their period is fundamentalized, display pulsation properties very similar to FU Cepheids with periods shorter than  $\log P \leq 1.2$ .

We compared the above estimates with a dozen complete NIR FO light-curves available in the Laney sample and we found that in every case the observed ratios are quite similar to or lesser than the estimated ones. For double-mode and putative classical Cepheids we used instead the relations  $A_{\text{NIR}}/A_V$  provided by Soszyński et al. (2005) for classical Cepheids.

For the objects in common in more than one sample (SAAO, Monson & Pierce 2011, 2MASS) we adopted the most accurate mean magnitude values.

### 3.2. Distance determination

The individual distance moduli were estimated as the weighted mean of the three different distance moduli obtained by adopting the NIR ( $H$ ,  $J-H$ ;  $K$ ,  $J-K$ ;  $K$ ,  $H-K$ ) PW relations provided by Inno et al. (2013). The individual distance moduli are listed in Col. 9 of Tables 3 and 4 with their uncertainties. The Galactocentric distances listed in Col. 10 of Tables 3 and 4 were estimated assuming a solar Galactocentric distance of  $7.94 \pm 0.37 \pm 0.26$  kpc (Groenewegen et al. 2008; Matsunaga et al. 2013, and references therein). The final error on  $R_G$  accounts for errors affecting both the solar Galactocentric and heliocentric distances.

We tested that differences among individual distances based on single-epoch 2MASS photometry with those based either on SAAO or on Monson & Pierce (2011) NIR photometry are marginal (3% on average with a standard deviation of 7%). We also compared current individual distances based on NIR PW relations with individual distances estimated using two different flavors of the IRSB method and we found that the mean difference over the entire sample ranges from  $8 \pm 2\%$  (Groenewegen 2013,  $\sim 130$  stars in common) to  $4 \pm 2\%$  (Storm et al. 2011a,  $\sim 80$  stars in common). The mean difference between our distances and the distances from Luck & Lambert (2011) based on optical period-luminosity relations is of the

order of  $3 \pm 1\%$  ( $\sim 400$  stars in common). On the other hand, the typical dispersion between current and literature distances ranges from 17% (our-Luck) to 22% (our-Groenewegen). This suggests that the use of homogeneous NIR photometry and solid distance diagnostics have a major impact on the decrease of the intrinsic dispersion of Galactocentric distances.

## 4. The metallicity gradient

### 4.1. Spectroscopic data sets

We compared our new homogeneous estimates (current sample plus stars in Genovali et al. 2013, G13) with the iron abundances provided either by our group (Lemasle et al. 2007, 2008, LEM; Romaniello et al. 2008, ROM; Pedicelli et al. 2010, PED) or in the literature (Luck et al. 2011, LII; Luck & Lambert 2011, LIII; Sziládi et al. 2007, SZI; Yong et al. 2006, YON).

The increase in the number of Cepheids in common among the different data sets allowed us to better evaluate the possible occurrence of a systematic difference in the metallicity distribution. The difference in iron abundance among the different samples are the following:

$$\begin{aligned} \Delta[\text{Fe}/\text{H}](\text{LIII-ROM}) &= 0.11 \pm 0.11 \text{ (22)}, \\ \Delta[\text{Fe}/\text{H}](\text{LII-LEM}) &= 0.08 \pm 0.12 \text{ (51)}, \\ \Delta[\text{Fe}/\text{H}](\text{LIII-YON}) &= 0.34 \pm 0.20 \text{ (20)}, \\ \Delta[\text{Fe}/\text{H}](\text{LII-G13}) &= -0.05 \pm 0.11 \text{ (45)}, \\ \Delta[\text{Fe}/\text{H}](\text{LIII-G13}) &= 0.03 \pm 0.08 \text{ (33)}. \end{aligned}$$

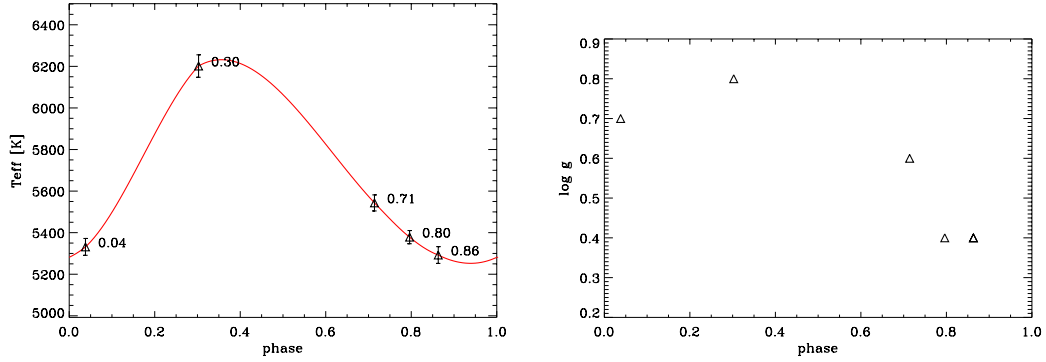
The numbers in parentheses give the number of objects in common among the different data sets. The difference with the double-mode Cepheids by Sziládi et al. (2007) was not estimated, since we only have one object in common.

The typical difference is on average smaller than 0.1 dex. Our results for CE Pup and HW Pup further support the systematic difference between iron abundances provided by Yong et al. (2006) and similar estimates available in the literature (Lemasle et al. 2008; Luck et al. 2011; Luck & Lambert 2011). In order to provide a homogeneous metallicity scale for a large sample of Galactic Cepheids, we applied the above differences to the quoted data sets. Column 7 in Table 4 lists the original iron abundances, while Col. 8 gives the rescaled iron abundance.

### 4.2. The iron abundance gradient

In this investigation we analyze the metallicity gradient using 63 homogeneous metallicity estimates based on single-epoch UVES spectra. Among them 33 were already presented in Genovali et al. (2013). We also include in the analysis new weighted mean abundances for eleven Cepheids observed from four to six times with UVES at random pulsational phases (V340 Ara, AV Sgr, VY Sgr, UZ Sct, Z Sct, V367 Sct, WZ Sgr, XX Sgr, KQ Sco, RY Sco, V500 Sco), collected either in observing run A (P81–P82, with the exception of V500 Sco) or in observing run B (P89, see Table 1). We confirm the previous findings by Andrievsky et al. (2005) and references therein that the iron abundance estimates, within the errors, are not phase-dependent. Moreover, we provide an independent estimate of the FEROS spectrum of the outer disk Cepheid CE Pup whose iron abundance was originally determined by Luck et al. (2011). A more detailed analysis of the multi-epoch spectra will be presented in a forthcoming paper.

The top panel of Fig. 4 shows the iron abundances based on UVES multi-epoch spectra of the observing run B (11 dark red circles), on UVES single-epoch spectra of the observing run A



**Fig. 3.** *Top:* effective temperature curve vs. pulsational phase for the Cepheid RY Sco as derived using the LDRs method (see text for details). The adopted spectra are the same as in Fig. 1. The  $T_{\text{eff}}$  estimates derived for each spectrum and its error are plotted as black triangles. The red line shows the spline fit. The numbers plotted on top of the individual measurements show the pulsation phase. *Bottom:* same as the top, for the surface gravity.

(30 red circles), and on the FEROS spectrum (light blue circles) as a function of the Galactocentric distances ( $R_G$ ). The blue circles display the iron abundances provided by [Genovali et al. \(2013\)](#) based on UVES single-epoch spectra of the observing run A (33 stars). Together with the current sample, we also included iron abundances for Galactic Cepheids estimated by our group using the same approach and similar data ([Lemasle et al. 2007, 2008](#); 39 objects, green circles; [Romaniello et al. 2008](#); 14 objects, yellow circles). The current data set covers a range in Galactocentric distances of more than 10 kpc ( $4 \lesssim R_G \lesssim 15$  kpc). We estimated the metallicity gradient (dashed line) and we found  $[\text{Fe}/\text{H}] = 0.49 \pm 0.03 - 0.051 \pm 0.003 R_G/\text{kpc}$ . The new slope and zero-point agree quite well with similar estimates available in the literature ([Luck & Lambert 2011](#); [Lemasle et al. 2013](#)). The spread in iron appears to be homogeneous over the entire Galactocentric range, but in the innermost disk regions it increases and becomes of the order of 0.5 dex. We also included Cepheid iron abundances available in the literature: [Yong et al. \(2006\)](#); [Sziládi et al. \(2007\)](#); [Luck & Lambert \(2011\)](#); [Luck et al. \(2011\)](#) (322 objects, black circles). The priority for objects in common among different data sets was given to the current sample, then to iron abundances obtained by our group, and finally to abundances available in the literature.

It is worth mentioning that we have been able, thanks to the current large and homogeneous data set of NIR mean magnitudes, to include in the analysis of the metallicity gradient 18 Cepheids for which the iron abundance was provided by [Luck & Lambert \(2011\)](#), but for which the individual distances were not available. We ended up with a sample of 450 Cepheids with a homogeneous metallicity scale and a homogeneous distance scale.

The metallicity gradient we found is  $[\text{Fe}/\text{H}] = 0.57 \pm 0.02 - 0.060 \pm 0.002 R_G/\text{kpc}$ , in very good agreement with previous results from [Luck & Lambert \(2011\)](#) based on a similar number of Cepheids. We note that to identify possible outliers, we performed a preliminary gradient estimate and we found  $[\text{Fe}/\text{H}] = 0.54 \pm 0.02 - 0.057 \pm 0.002 R_G/\text{kpc}$ . Subsequently, we neglected four Cepheids – BC Aql, HK Cas, EK Del, GP Per – with a gradient residual greater than  $3\sigma$ . Three out of the four neglected Cepheids are classified in the GCVS as candidate Cepheids (CEP), while HK Cas is very high on the Galactic plane and it has been classified as an Anomalous Cepheid by [Luck & Lambert \(2011\)](#).

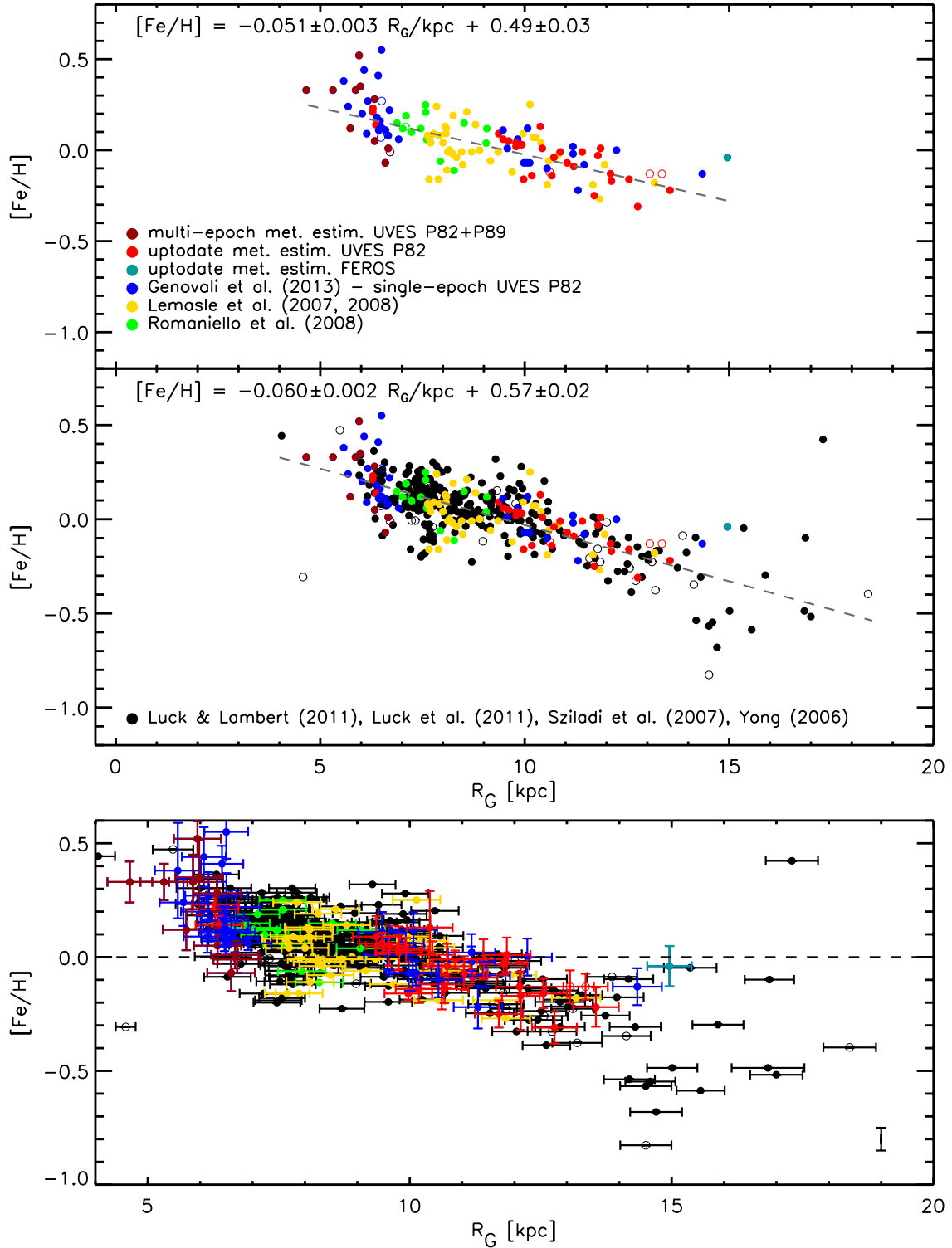
The new metallicity gradient still shows a large intrinsic dispersion around the solar circle and in the outer disk (Fig. 4) with the possible occurrence either of a change in the slope or of

a shoulder for  $7 \leq R_G \leq 10$  kpc, as suggested by [Twarog et al. \(1997\)](#); [Caputo et al. \(2001\)](#), and [Andrievsky et al. \(2004\)](#).

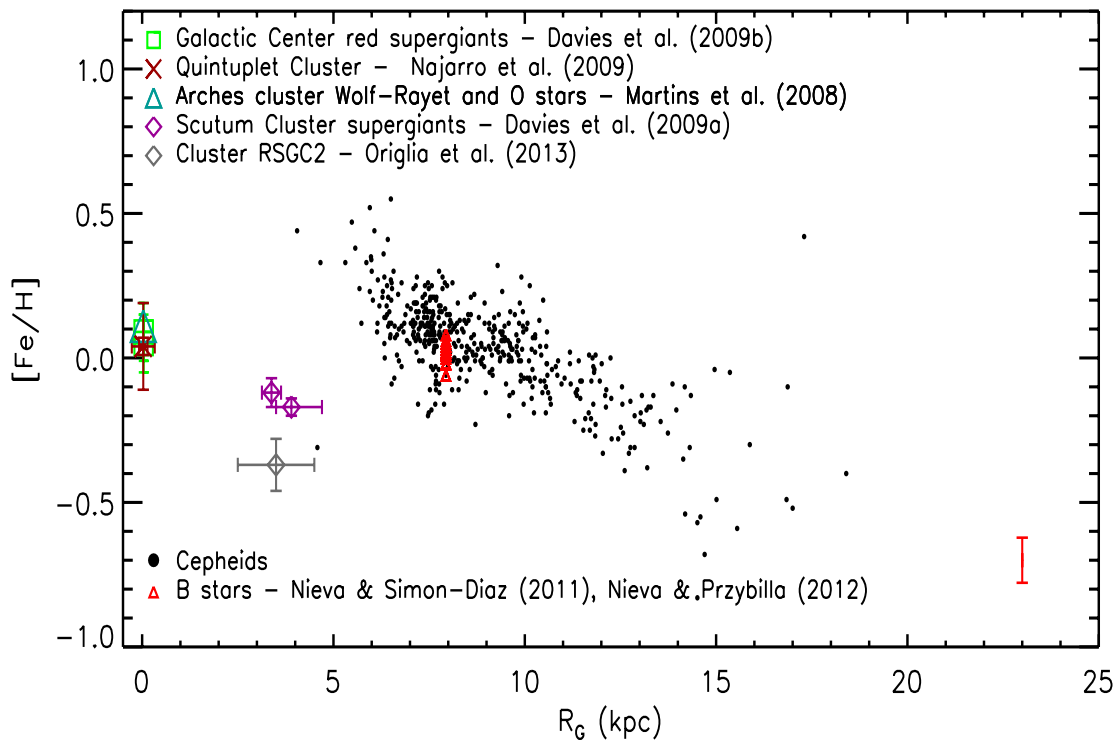
To further constrain the nature of the spread in iron along the metallicity gradient the referee suggested that we check its dependency on the distance from the Galactic plane. We selected the Cepheids in our sample with a distance above the Galactic plane smaller than 300 pc and we found that the gradient is quite similar:  $[\text{Fe}/\text{H}] = 0.49 \pm 0.03 - 0.052 \pm 0.004 R_G/\text{kpc}$ . We performed the same test by using the entire sample and the gradient is once again minimally affected, we found  $[\text{Fe}/\text{H}] = 0.53 \pm 0.02 - 0.055 \pm 0.002 R_G/\text{kpc}$ . The subsample located closer to the Galactic plane was also adopted to constrain the spread in iron of the outer disk ( $R_G \geq 13$  kpc). We found that the spread decreases from 0.17 dex (30 Cepheids) to 0.13 dex (9 Cepheids). This means that the difference decreases from 13% to 5% higher than the mean spread over the entire disk (0.11 dex).

It was also noted that the spread in iron abundance around the solar circle is larger than the spread in the region between 10 and 14 kpc and it was suggested that the difference might be caused by a different azimuthal distributions of the Cepheids in the two disk regions. To further constrain the dependence of the spread on the azimuthal distribution we estimated, following [Genovali et al. \(2013\)](#), the metallicity distribution of the four Galactic quadrants. We found that the  $\sigma$  of the four distributions attain very similar values ( $0.013 \pm 0.01$  dex), while the mean iron abundance increases by almost 0.2 dex when moving from quadrants I/II to quadrants III/IV (see Fig. 3 in [Genovali et al. 2013](#)). The reader interested in a more quantitative analysis of the variation of the spread along the metallicity gradient is referred to Sect. 6.

The iron abundances of the current investigation cover the outer disk  $R_G \geq 13$  kpc and together with iron abundances provided either by our group or available in the literature they provide a detailed sampling over a broad range of Galactocentric distances ( $4 \leq R_G \leq 19$  kpc). Data plotted in Fig. 4 display a steady increase in the metallicity dispersion when moving from the solar circle to the outer disk. It is interesting to note that Cepheids located in the outer disk also show larger distances from the Galactic plane ( $|z| \geq 400$  pc) when compared with inner disk and solar circle Cepheids (see Fig. 6). However, we did not find a clear correlation between distance from the Galactic plane and metallicity. To constrain the above difference on a more quantitative basis, we analyzed the Cepheid azimuthal distribution and we found, as expected ([Kraft & Schmidt 1963](#)), that they are on average  $\sim 38 \pm 13$  pc below the Galactic plane and their  $\sigma$  is  $\sim 270$  pc. However, the fraction of Cepheids



**Fig. 4.** *Top:* iron abundances of Galactic classical Cepheids vs. Galactocentric distance. Spectroscopic measurements based on different data sets are plotted with different colors. They include updated iron abundances based on current UVES spectra (30, red) and on multi-epoch UVES spectra (11, dark red); as well as updated iron abundance for CE Pup based on a FEROS spectrum (light blue) and iron abundances provided by our group: Genovali et al. (2013) (33, blue), Lemasle et al. (2007), Lemasle et al. (2008) (39, yellow), Romaniello et al. (2008) (14, green). Cepheids that according to the General Catalog of Variable Stars (Samus et al. 2009) are candidate classical Cepheids were plotted with open circles. The gray dashed line shows the metallicity gradient. *Middle:* same as the top, but the iron abundances include our measurements and those available in the literature: Luck et al. (2011), Luck & Lambert (2011), and Sziládi et al. (2007) (322, black). The gray dashed line shows the metallicity gradient based on the entire sample. *Bottom:* zoom of the top panel for Galactocentric distances ranging from 4 kpc to 20 kpc. The bars on individual Cepheids display the uncertainty both on iron abundance and on distance. The vertical black bar in the bottom right corner shows the mean uncertainty on Luck & Lambert (2011) and Romaniello et al. (2008) iron abundances.



**Fig. 5.** Comparison of the Cepheid (black dots) metallicity gradient with iron abundances of early B-type stars located either in the solar neighborhood or in the Orion star forming region (Nieva & Simón-Díaz 2011; Nieva & Przybilla 2012). The green square marks the iron abundance of the two red supergiants in the Galactic center measured by Davies et al. (2009a), the magenta diamonds the 26 red supergiants in the Scutum Clusters measured by Davies et al. (2009b), the gray diamond the three red supergiants in the cluster RSGC2 measured by Origlia et al. (2013), the red cross the two luminous blue variables (LBVs) in the Quintuplet cluster (Najarro et al. 2009), and the light-blue triangle three Wolf-Rayet and two O-type stars in the Arches cluster (Martins et al. 2008). The red vertical bar in the bottom right corner shows the mean uncertainty on iron abundances.

located at distances from the Galactic plane larger than  $1\sigma$  increases from 4% for  $R_G$  smaller than 10 kpc to 38% at larger Galactocentric distances.

It is worth mentioning that the evidence of an increase in the dispersion of the iron abundance in the outer disk is also supported by the fact that the use of homogeneous iron abundances has further decreased the intrinsic spread from 0.12 (see Fig. 2 of Genovali et al. 2013) to 0.10 dex (see Fig. 4) for  $R_G \sim 11$ –15 kpc.

## 5. Comparison between Cepheid and independent metallicity gradients

### 5.1. Young tracers

During the last few years several investigations have addressed the open problem concerning the age dependence of the metallicity gradient. This issue has been investigated not only from the empirical point of view (see, e.g., Maciel et al. 2003; Nordström et al. 2004; Henry et al. 2010; Yong et al. 2012) but also from the theoretical. In particular, there have been discussions regarding the role that different stellar tracers can play in constraining the chemical tagging not only in spatial distribution but also in time (Freeman & Bland-Hawthorn 2002).

To further constrain the age effect on the metallicity gradient we collected several abundance gradients based on different stellar tracers.

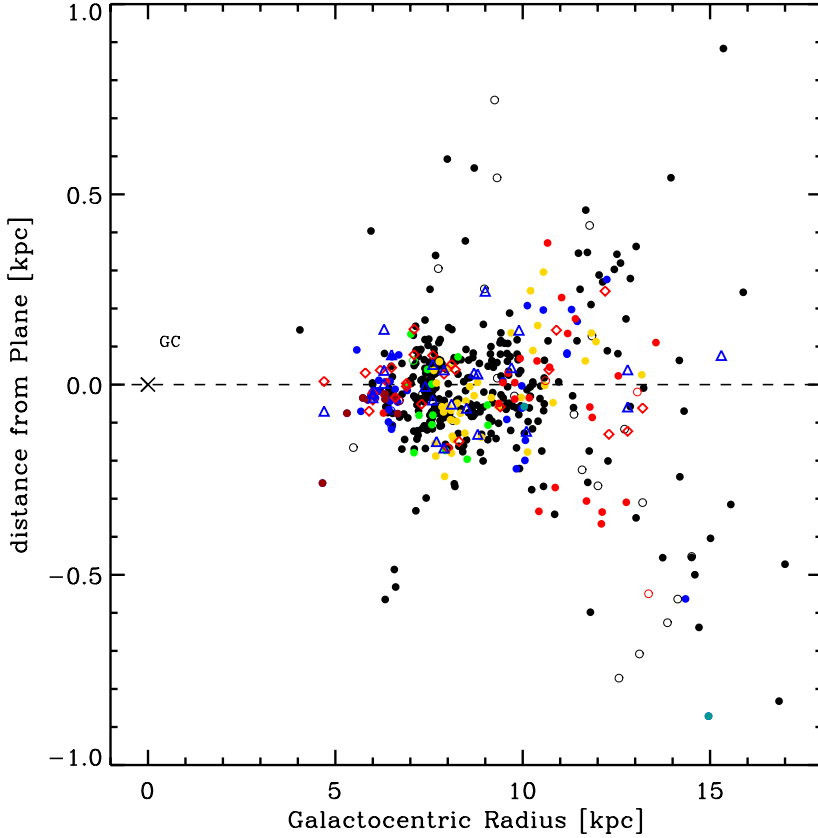
Figure 5 shows the comparison between the metallicity gradient based on Cepheids with the iron abundance of almost three dozen of early B-type stars (red triangles) located either

in the solar neighborhood (Nieva & Przybilla 2012) or in the nearby Orion star forming region (Nieva & Simón-Díaz 2011). The crucial advantage of this set of measurements is that they are based on high-resolution, high S/N spectra; they are homogenous; and they also account for non-LTE effects (Przybilla et al. 2011).

The comparison of the iron abundances further supports the evidence that early B-type stars and classical Cepheids display similar abundance in the solar neighborhood. The spread in iron of the B-type stars is narrower (see the red vertical error bar plotted in the right corner) than the Cepheids, but they also cover a narrow disk region. We note that the comparison appears even more compelling if we consider that B-type stars are the typical progenitors of classical Cepheids.

The above scenario concerning the iron abundance gradient of young stellar tracers shows a stark difference when compared with iron abundances of young stars (red supergiants, luminous blue variables, Wolf-Rayet and O-type stars) located either in the nuclear bulge or in the near end of the Galactic bar (Martins et al. 2008; Davies et al. 2009a,b; Najarro et al. 2009). The above spectroscopic measurements suggest either a solar or a subsolar iron abundance. This finding was reliably confirmed by Origlia et al. (2013) by using high-spectral resolution ( $R \sim 50\,000$ ) NIR spectra collected with GIANO at TNG. They found that the mean iron abundance of three RSGs located in the RSGC2 cluster are subsolar. This finding does not seem to be supported by recent chemical evolution models by Minchev et al. (2013), since they predict in the innermost Galactic regions present-day super-solar iron abundances.





**Fig. 6.** Distance from the Galactic plane vs. Galactocentric distance of Galactic Cepheids with accurate iron abundances. Symbols and colors are the same as in Fig. 4; the black cross marks the position of the Galactic center (GC).

The open clusters (OCs) have several advantages as stellar tracers of the Galactic thin disk. First, they typically host a sizeable sample of RGs; this means that multi-object spectrographs can provide very accurate measurements for both iron and  $\alpha$ -elements. Second, their distances can be evaluated with good precision by using the main sequence fitting. Finally, they trace a significant fraction of the Galactic disk (see the WEBDA website<sup>5</sup>) and their ages range from several hundred Myr to several Gyrs. The main drawback is that they are affected by high reddening and quite often by differential reddening. To fully exploit the advantages of using OCs to constrain the metallicity gradient, we selected a sample of 67 OCs for which spectroscopic measurements of iron abundances are available in the literature. To provide a homogeneous metallicity scale for OCs, the individual estimates were rescaled to the solar iron abundance we adopted in this investigation. For the OCs with multiple estimates of the iron abundance in the literature, we typically adopted the most recent measurement. Columns 4 and 5 in Table 5 give both the original and the rescaled iron abundance<sup>6</sup>, while Cols. 6 and 7 give the reference for the metallicity and for the age/distance.

In dealing with Galactocentric distances of OCs, the main source of uncertainty is the calibration of the adopted distance indicator.

Moreover and even more importantly, age estimates are tightly correlated with the adopted cluster distance, reddening, and metallicity. The cluster age also depends on the evolutionary framework (overshooting, mass loss, rotation, microphysics) adopted to compute evolutionary models and cluster isochrones (Bono et al. 2001e; Salaris & Cassisi 2008; Prada Moroni et al. 2012; Neilson et al. 2012b; Anderson et al. 2013).

<sup>5</sup> <http://webda.physics.muni.cz/>

<sup>6</sup> In a few cases we have not been able to rescale the iron abundance since the authors did not quote the adopted solar iron abundance.

To overcome this thorny problem and to limit their intrinsic dispersion in the metallicity gradient we decided to use only OC with homogeneous estimates of the five crucial parameters: age, distance, reddening, abundance, theoretical framework. In particular, we selected determinations provided by Salaris et al. (2004) and Friel (1995) (30 OCs), by the Carraro group (13 OCs), by BOCCE<sup>7</sup> (8 OCs), and by Friel & Janes (1993) (8 OCs). We adopted the Yong et al. (2012) values for two remaining OCs. For seven OCs selected by Cheng et al. (2012) we adopted the parameters given by WEBDA and for PWM4 the estimates provided by Yong et al. (2012). The Galactocentric distances are listed in Col. 3 in Table 5 and they were calculated using the same value of the Sun Galactocentric distance ( $R_G = 7.94$  kpc).

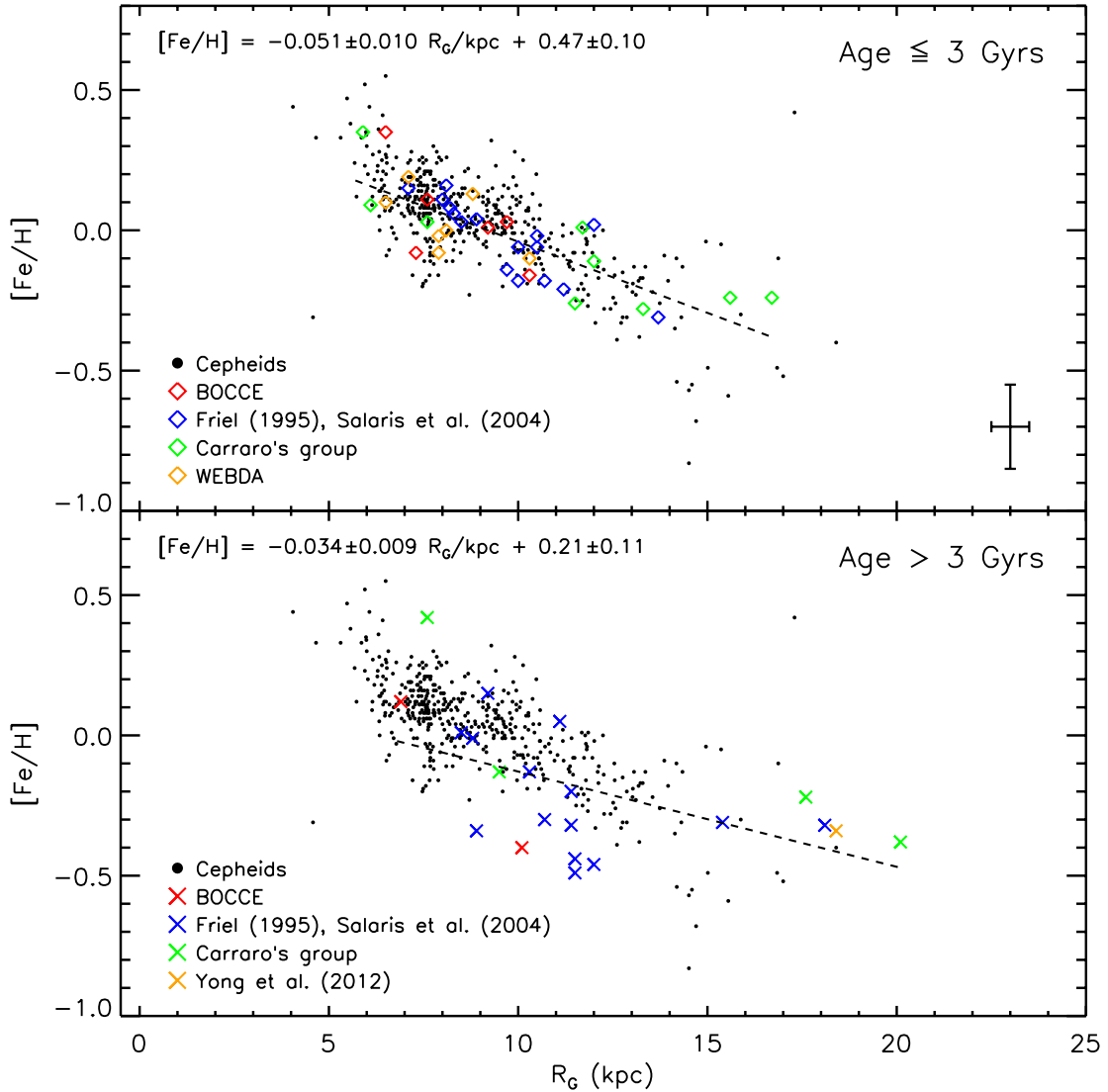
The top panel of Fig. 7 shows the comparison between Cepheids (black dots) and 44 OCs younger than 3 Gyr. Diamonds show the position of OCs and different data sets are marked with different colors (see also Table 5). Data plotted in this panel show that Cepheids and OCs younger than 3 Gyr are characterized by similar trends when moving from the inner to the outer disk. The same outcome applies, within the errors, to the intrinsic dispersion.

We found a metallicity gradient for the young OCs in our sample of  $[\text{Fe}/\text{H}] = 0.47 \pm 0.10 - 0.051 \pm 0.010 R_G/\text{kpc}$  (see the top panel of Fig. 5), in which both the slope and the zero-point attain values very similar to the Cepheid metallicity gradient (see Fig. 4).

## 5.2. Intermediate-age tracers

The bottom panel of Fig. 7 shows the same comparison as the top panel, but for OCs (23) with ages ranging from 3.6 Gyr to 9 Gyr. Data plotted in this panel show two distinctive features; i) old

<sup>7</sup> <http://www.bo.astro.it/~angela/bocce.html>



**Fig. 7.** *Top:* comparison of the Cepheid (black dots) metallicity gradient with iron abundances for open clusters younger than 3 Gyr. The color coding refers to different subsamples: BOCCE project (red); cluster ages from Salaris et al. (2004) and distances from Friel (1995) (blue); Carraro et al. (green); WEBDA (yellow). See Table 5 for individual values and references. The vertical and horizontal black error bars in the bottom right corner show the mean uncertainty on Galactocentric distances and iron abundances for OCs in the above subsamples. The dashed line shows the metallicity gradient based on the selected open clusters. *Bottom:* same as the top, but for cluster ages older than 3 Gyr. The yellow cross marks the position of the subsample from Yong et al. (2012). The dashed line shows the metallicity gradient based on the selected open clusters.

OCs display a clear flattening in iron abundance for  $R_G \geq 15$  kpc and ii) the old OCs for Galactocentric distances between the solar circle and 12 kpc seem to show a dichotomic distribution. The difference is of the order of several tenths of dex, i.e., larger than possible uncertainties affecting individual iron abundances. We also checked the position of the seven OCs that are, at fixed Galactocentric distance more metal-poor and we found that five out of the seven cover a very narrow range in Galactic latitude ( $y \sim 3.5$  kpc). Data plotted in the above figure support the evidence that the metallicity gradient depends on age for ages older than  $\sim 3$  Gyr. We could also speculate that there are a dozen OCs distributed along a metal-poor plateau with an almost constant iron abundance ( $[\text{Fe}/\text{H}] \sim -0.4$ ) and Galactocentric distances ranging from 9 kpc to 21 kpc.

We estimated the metallicity gradient of the older OCs and we found of  $[\text{Fe}/\text{H}] = 0.21 \pm 0.11 - 0.034 \pm 0.009 R_G/\text{kpc}$  (see the bottom panel of Fig. 5). The slope and the zero-point are

significantly shallower than for Cepheids and younger open clusters and agree quite well with similar estimates available in the literature for old OCs (Carraro et al. 2007b; Yong et al. 2012). However, our sample of OCs covers a range in age of five Gyr and the sample is modest. More solid constraints call for larger samples of OCs and a wider disk coverage.

However, data plotted in the bottom panel of Fig. 7 show that the Cepheid iron abundances in the inner disk are more metal-rich than thin disk old OCs. Moreover, the Cepheids display a well-defined iron gradient when moving from the inner to the outer disk ( $5 \leq R_G \leq 18$  kpc). However, the above evidence relies on stellar populations with significantly different ages. The Cepheids and the supergiants of the nuclear bulge and of the Bar have ages ranging from a few Myr to a few hundred Myr.

The above findings indicate that younger tracers appear to be still in situ, i.e., in the same regions where they formed, while

the intermediate-age tracers appear to be affected both by radial gas flows and by radial migration, as suggested by chemical evolution models (Portinari & Chiosi 2000; Curir et al. 2012; Minchev et al. 2013). However, current data do not allow us to constrain the timescale within which the metallicity gradient becomes shallower.

## 6. The fine structure of the metallicity gradient

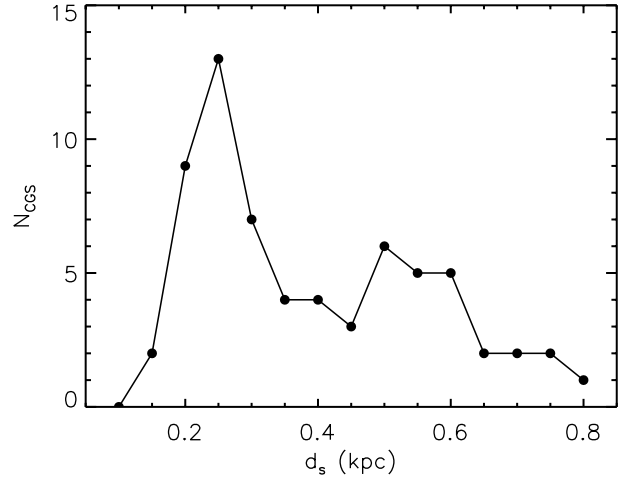
We are facing the evidence that the intrinsic dispersion of the iron metallicity gradient is, at fixed Galactocentric distance, systematically larger than the expected standard deviation (see the error bar in the right corner of the bottom panel of Fig. 4). This circumstantial evidence stimulated several investigations aimed at constraining the physical reasons for such a broad distribution. On the basis of a large Cepheid data set Luck et al. (2006) suggested that the large dispersion in iron abundance for Galactocentric distances of  $R_G \sim 9\text{--}11$  kpc was caused by a metallicity island located at  $l = 130^\circ$ . However, the detection of a well-defined region characterized by a higher iron abundance was not supported in a subsequent analysis by Luck & Lambert (2011) by using a larger Cepheid sample. The evidence of a clumpy metallicity distribution across the Galactic disk was also brought forward by Lemasle et al. (2008) and by Pedicelli et al. (2009) by using similar samples of Galactic Cepheids. However, the evidence was partially hampered by the sample size and by the lack of a homogeneous metallicity scale.

### 6.1. Identification of Cepheid groups

To further constrain the above preliminary evidence we decided to follow a different approach. We performed a new search for Cepheids groups (CGs) across the Galactic disk. The search in 3D space follows a method originally suggested by Battinelli (1991) and applied to Galactic Cepheids by Ivanov (2008, hereafter I08). He adopted  $J$ ,  $H$ ,  $K$  2MASS photometry for 345 Galactic Cepheids and identified 18 CGs. The current approach when compared with I08 has several advantages: i) we are dealing with a Cepheid sample that is 30% larger and they cover more than 15 kpc across the disk; ii) individual Cepheid distances are independent of reddening corrections; and iii) 56% of NIR Cepheid mean magnitudes are based on multi-epoch light curves.

We ranked the entire Cepheid sample and arbitrarily selected the first one as a pivot and estimated its closest neighborhood by using their rectangular coordinates  $x$ ,  $y$ , and  $z$ . Then, we selected the second Cepheid as a pivot, but we removed the first one from the list. In the next step, we selected the third Cepheid in our list as a pivot, but we removed the first and the second one from the list. This process is iterated until we reach the last but one Cepheid in our list. Thus, we are left with a set of  $N-1$  pair distances that provide, by definition, a path connecting the entire Cepheid sample, what (Battinelli 1991) called ‘‘Path Linkage Criterion’’. The two main positive features of the above algorithm are that a region with a high concentration of short pair distances is also a region in 3D space with a high concentration of Cepheids. Moreover, the use of relative distances on a common path provides solid detections of filamentary groups (Battinelli 1996).

Once we have the set of pair distances, we need to define (on the basis of our Cepheid sample) a characteristic distance called the search distance ( $d_S$ ) that will allow us to identify candidate Cepheid groups. In particular, we define a candidate Cepheid group if  $m$  Cepheids (with  $m \geq 6$ ) have a distance



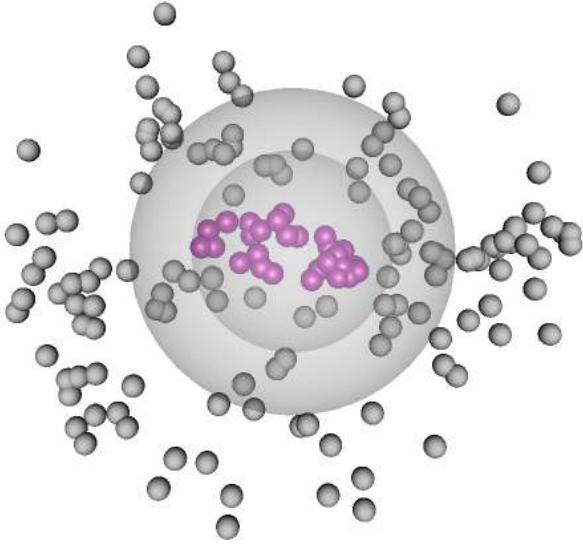
**Fig. 8.** Number of candidate Cepheid groups as a function of the search distance (see text for details).

$d < d_S$ , where  $d_S$  is an arbitrary distance in kpc. We adopted  $d_S$  distances ranging from 0.1 kpc to 0.8 kpc with a step in distance of 0.05 kpc. Figure 8 shows the number of independent CGs we detected as a function of the searching distance. The distribution of the candidate CGs we found is similar to the distribution found by I08. However, the current peak of the distribution is slightly smaller (13 vs. 18) and takes place at smaller  $d_S$  distances (0.25 vs. 0.40 kpc). Moreover, the number of candidate CGs decreases quite rapidly for  $d_S$  distances larger than  $\sim 0.6$  kpc while I08 detected CGs at  $d_S$  distances larger than 1 kpc (see Fig. 3 in I08). The difference might be explained with the difference in sample size and in the adopted Cepheid distances.

Once we have defined the optimal search distance for our Cepheid sample we need to define a criterion to constrain how significant the density of the individual candidate CG is when compared with the average stellar density of its neighborhood. In particular, we define a bonafide CG only the candidate CGs whose density ( $\rho_{CG}$ ) is four times larger than the density of a spherical layer ( $\rho_{sl}$ ) centered on the center of mass of the CG. The outer radius of the spherical layer ( $R_{sl}$ ) was fixed in such a way that the volume of the spherical layer is three times larger than the volume of the CG. In particular,  $V_{sl} = 3V_{CG} = 4\pi(R_{sl} - R_{CG})^3/3$  where  $V_{CG}$  is the volume of the candidate CGs estimated by using a Monte Carlo method and by assuming for each Cepheid in the group a radius equal to the adopted search distance ( $d_S$ ). The radius of the candidate CG was defined as  $R_{CG} = 1.1 \times \delta$ , where  $\delta$  is the distance of the two most distant Cepheids. We note that  $R_{CG}$  is also by construction the inner radius of the spherical layer adopted to estimate the difference in density between the candidate CG and its stellar neighborhood.

Figure 9 shows a 3D graphical view of the approach we adopted to estimate the density of the candidate CGs and the density of the spherical layer. The members of the candidate Cepheid group are plotted as magenta spheres, while the inner light gray sphere defines  $V_{CG}$ , i.e., the volume of the sphere (with radius equal to  $R_{CG}$ ) adopted to estimate the density of the candidate CG ( $\rho_{CG}$ ). The dark gray sphere defines  $V_{sl}$ , i.e., the volume of the spherical layer of outer radius  $R_{sl}$  and inner radius  $R_{CG}$  adopted to estimate the average density of the stellar vicinity ( $\rho_{sl}$ ).

In order to fix the cutoff density for the identification of CGs, we performed a series of numerical experiments in which we randomly distributed the same number of Cepheids across the



**Fig. 9.** 3D plot of our approach for selecting candidate CGs. The members of a generic CG are displayed with magenta spheres and the surrounding Cepheids with gray spheres. The dark gray inner area shows the sphere including the members of the CG (the radius  $R_{CG}$ ). The light gray outer area shows the spherical layer with a volume three times larger than the volume of the selected CG. Candidate CGs have a Cepheid density that is 3.5 larger than the average stellar density of its neighborhood.

Galactic disk and we found that their densities are systematically smaller than four times the densities of the spherical layers. By adopting this conservative selection criterion we ended up with ten candidate CGs. The overdensities of the selected CGs range from 4.1 to 45.7 when compared with their stellar neighborhood. The coordinates and the Galactocentric distances of the newly identified Cepheids are listed in Cols. 1 to 5 of Table 6 together with their diameters and the number of members. The smaller groups have on average 6–7 members and have sizes of the order of half a kpc, while the largest ones have 20–50 members and sizes between 1.2 kpc and 1.9 kpc. The above dimensions are similar to the typical size of giant molecular clouds (see Fig. 3 in Bolatto et al. 2008 and Table 1 in Murray 2011) and to the typical size of giant star complexes and superassociations (Elmegreen & Elmegreen 1983; Efremov 1995).

To further constrain the spatial distribution of the newly identified candidate CGs, the top panel of Fig. 10 shows their projection (filled circles) onto the Galactic plane. The members of the individual candidate CGs are plotted in yellow and confined by ellipses. Each group is marked by an increasing Roman number according to the Galactocentric radius. In order to find a correlation between the location of candidate CGs and the spiral arms, we also plotted a simplified model of the disk spiral structure. We used the logarithmic model presented by Vallée (2002) with four arms and a pitch angle of 12 degrees. The logarithmic parameter  $r_0 = 2.58$  was fixed in such a way that the Perseus arm overlaps with the fiducial points of the model provided by Cordes & Lazio (2002). We adopted this empirical calibration because Xu et al. (2013) found that this disk model fits quite well the parallax data of 30 masers associated with star forming regions in the Perseus and Sagittarius arms.

The true location of the spiral arms is not well defined, since it depends on the adopted tracers whose distance is quite often poorly known. However, data plotted in the top panel of Fig. 10

indicate a correlation between candidate Cepheid groups and star formation regions associated with the spiral arms.

## 6.2. Residuals of the metallicity gradient

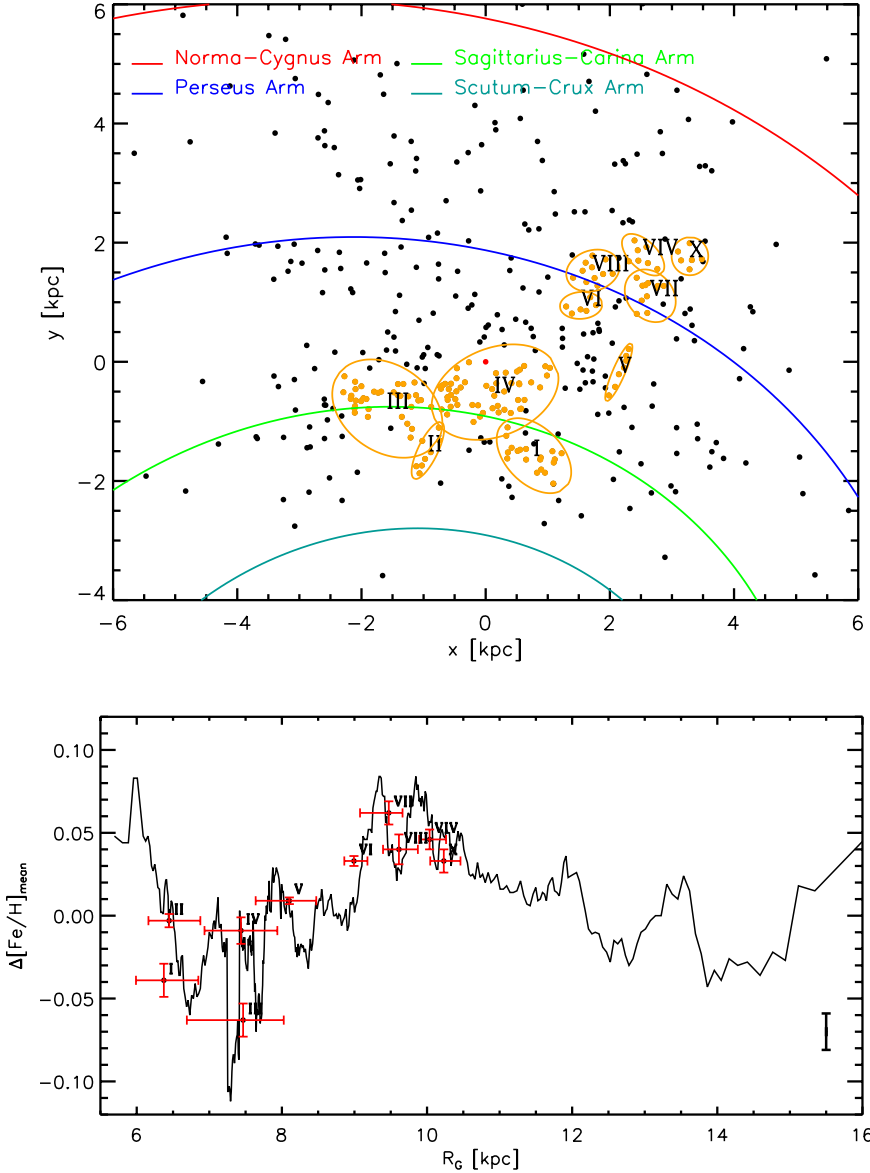
To further investigate the physical connection of the individual members of the candidate CGs, we analyzed the residuals of the metallicity gradient. We estimated for each Cepheid in our sample the difference between its iron abundance and the iron abundance of the metallicity gradient at the same Galactocentric distance. To avoid spurious fluctuations in the mean iron abundance, we ranked all the Cepheids as a function of the Galactocentric distance ( $R_G$ ) and estimated the running average by using the first 20 objects in the list. The mean  $R_G$  and the mean residual ( $\Delta[\text{Fe}/\text{H}]$ ) of the bin were estimated as the mean over the individual Galactocentric distances and residual abundances of the same 20 objects. We estimated the same quantities by moving one object in the ranked list until we accounted for the last 20 Cepheids in the sample with the largest distances. The running average is plotted as a black line in the bottom panel of Fig. 10. The error on the mean residual for individual bins is of the order of a few hundredths of dex. In order to provide robust constraints on the possible uncertainties introduced by the adopted number of Cepheids per bin and by the number of stepping stars, we performed a series of Monte Carlo simulations. The estimated mean dispersion of the above simulations is plotted as a vertical black line.

Interestingly enough, the residuals display local minima and maxima that are significantly larger than the intrinsic dispersion. The occurrence of the above chemical inhomogeneities is well defined for Galactocentric distances smaller than 11 kpc. Unfortunately, the current sample does not allow us to reach firm conclusions concerning the outer disk. To constrain the nature of the secondary features in the residuals, we overplotted the position of the ten candidate CGs in the bottom panel of Fig. 10 (red dots). We adopted the mean Galactocentric distance and the mean iron abundance of the individual CGs listed in Cols. 5 and 14 in Table 6 and subtracted the iron abundance of the metallicity gradient at the same  $R_G$ . The red vertical lines display the standard deviation of the iron abundances, while the horizontal red lines display the inner and the outer edge of the individual CGs (Cols. 6 and 7 in Table 6).

Data plotted in this figure show that the residuals in iron abundance appear to be tightly correlated with the mean residual abundance of the candidate CGs. This finding further supports the evidence that a significant fraction of the intrinsic dispersion of the metallicity gradient is caused by the presence of Cepheid groups across the Galactic disk with mean metallicities that are either more metal-rich or more metal-poor than expected according to a linear mean metallicity gradient. The mean periods and their intrinsic dispersions listed in Cols. 10 and 11 in Table 6 seem to suggest that the candidate CGs with negative iron residuals have, on average, slightly longer periods and larger intrinsic dispersions when compared with the candidate CGs showing a positive iron residual. However, this evidence could be caused by an observational bias, and indeed the former candidate CGs have higher Cepheid densities (see Cols. 9 and 13 in Table 6) than the latter ones. The pulsation and evolutionary properties of the candidate CGs will be discussed in a forthcoming paper.

The above empirical evidence also has implications concerning the chemical enrichment of the Galactic disk. During the last few years it has been suggested that iron and oxygen abundances show a break in the abundance gradient associated





**Fig. 10.** *Top:* projection onto the Galactic plane of isolated Cepheids (black dots) and Cepheids members of candidate CGs (yellow dots). The ellipses mark the edges of individual CGs. They are also labeled with the identification number given in Table 6. The red dot shows the position of the Sun. The colored lines show a logarithmic model of the spiral arms (Vallée 2002; Cordes & Lazio 2002, see text for details). The names of the spiral arms are labeled. *Bottom:* running average of Cepheid metallicity residuals vs. Galactocentric radius (black line). The red dots mark the mean metallicity of the candidate CGs once the metallicity gradient has been subtracted. The red vertical lines display the intrinsic dispersion in iron of candidate CGs. The red horizontal lines show the inner and outer Galactocentric distance of individual candidate CGs (see Cols. 6 and 7 in Table 6).

with the corotation resonance of the spiral pattern (see, e.g., Acharova et al. 2010). This evidence applies not only to external spiral galaxies (Scarano et al. 2011; Scarano & Lépine 2013), but also to our Galaxy (Lépine et al. 2011). In particular, it has been suggested that the breaks in iron,  $\alpha$ -elements, and barium abundance gradients of Cepheid and open cluster are caused by the corotation resonance located at  $R_G \sim 9.0$ – $9.5$  kpc (Lépine et al. 2013). The occurrence of a discontinuity at the above Galactocentric distance is further supported by the presence of a well-defined local minimum in the Galactic rotation curve (see Figs. 1, 3, and 5 in Sofue et al. 2009). On the basis of the above preliminary evidence it has been suggested that the Galaxy is experiencing a bimodal chemical evolution, since the kinematics of the gas has opposite directions at the corotation resonance of the spiral pattern.

However, current iron abundances for Galactic Cepheids do not show a break, a jump, or a change in the slope for  $R_G \sim 9.0$ – $9.5$  kpc. Moreover and even more importantly, the positive iron residual located at the above Galactocentric distance appears to be associated with the five candidate CGs that are located across the Perseus arm (see the solid blue line in the top panel of Fig. 10). We note that the association between

the candidate CGs and the Perseus arm requires a more detailed analysis, since we adopted a qualitative model of the Galactic logarithmic spiral arms (Vallée 2005). In passing, we note that current findings, once confirmed by independent stellar tracers, support the suggestion brought forward by Sofue et al. (2009) and by Sofue (2013) that the dip in the rotation curve  $R_G \sim 9.0$ – $9.5$  is caused by a massive ring associated with the Perseus arm.

## 7. Luminosity amplitudes and metallicity dependence

During the last few years the dependence of the luminosity amplitude on metallicity has been investigated both from the theoretical point of view (Bono et al. 2000b) and the observational (Klagyivik & Szabados 2009; Pedicelli et al. 2010; Klagyivik et al. 2013). In particular, Szabados & Klagyivik (2012), by using a large sample (327) of Galactic Cepheids with accurate pulsation parameters and spectroscopic metal abundances, found evidence that the luminosity and the radial velocity amplitudes slightly decrease with increasing iron abundance. However, no firm conclusion has been reached since

Pedicelli et al. (2010), by using a similar data set, did not find a clear dependence on metallicity. More recently, Klagyivik et al. (2013) by using short-period ( $\log P \leq 1.02$ ) Cepheids found that the  $R_{21}$  and the  $R_{31}$  Fourier amplitude ratios decrease for increasing iron abundance.

To further constrain the behavior of this interesting diagnostic we took advantage of the current sample of Galactic Cepheids with homogeneous spectroscopic abundances. We limited our sample to fundamental Cepheids for which accurate  $V$ -band amplitudes are available<sup>8</sup> and we ended up with a sample of 351 Cepheids. However, the period distribution of Galactic Cepheids shows a short tail in the long-period range when compared with Magellanic Cloud (MC) Cepheids (Gascoigne 1974; Bono et al. 2010; Inno et al. 2013; Genovali et al. 2013). To overcome possible biases in constraining the metallicity dependence, we took advantage of the MC Cepheids for which were available spectroscopic iron abundances (Luck & Lambert 1992; Luck et al. 1998; Romaniello et al. 2008) and  $V$ -band amplitudes (SMC and LMC field Cepheids: OGLE III (Soszyński et al. 2008; Soszyński et al. 2010), ASAS (Karczmarek et al. 2011, 2012), as well as data provided by van Genderen (1983); Freedman et al. (1985); Caldwell et al. (1986, 2001); van Genderen & Nitihardjo (1989). For cluster Cepheids we adopted data provided by Sebo & Wood (1995) [NGC 1850] and by Welch et al. (1991); Welch & Stetson (1993) [NGC 1866].

We ended up with a sample of 58 Large Magellanic Cloud (LMC) and 19 Small Magellanic Cloud (SMC) Cepheids. We note that in the first sample 19 Cepheids belonging to the cluster NGC 1866 and 7 Cepheids belonging to the cluster NGC 1850 have also been included. The metallicities and the pulsation parameters for the Magellanic Cepheids are listed in Table 7. The top left panel of Fig. 11 shows the Bailey diagram ( $V$ -band luminosity amplitude vs. logarithmic period) for the entire sample (428 stars). The center of the Hertzsprung progression at  $\log P \leq 1.02$  is quite evident. The reader interested in a more detailed discussion concerning the nature of the Hertzsprung progression and its metallicity dependence is referred to Bono et al. (2000a,b).

In order to constrain the dependence of the luminosity amplitude on the metallicity we split the entire sample into metal-poor ( $[\text{Fe}/\text{H}] \leq 0.03$ , red circles) and metal-rich ( $[\text{Fe}/\text{H}] > 0.03$ , green circles). To avoid spurious fluctuations in the mean  $A_V$  amplitude, we ranked all the Cepheids as a function of the logarithmic period and estimated the running average by using the first 25 objects in the list. The mean  $\log P$  and the mean  $A_V$  of the bin were estimated as the mean over the individual periods and amplitudes of the same 25 objects. We estimated the same quantities by moving one object in the ranked list until we accounted for the 25 Cepheids with the longest periods. The running averages for the metal-poor and the metal-rich samples are plotted as red and green lines in the bottom left panel of Fig. 11. The error on the mean  $A_V$  for individual bins is of the order of a few hundredths of mag. In order to provide robust constraints on the possible uncertainties introduced by the adopted number of Cepheids per bin and by the number of stepping stars, we performed a series of Monte Carlo simulations. The estimated mean dispersions of the above

simulations are plotted as vertical green and red lines. We also found that we can exclude a metallicity dependence of the two subsamples at the 98% confidence level. The two running averages plotted in the bottom panel display a strong similarity in the short-period ( $\log P \leq 1.02$ ) range, but the difference increases at longer periods. We performed the same analysis by splitting the sample in short- and long-period Cepheids and we found that the metallicity dependence in the former group can be excluded at the 94% level, while in the latter group at the 70% level.

To further constrain the dependence of the  $V$ -band amplitude on metallicity, we performed the same analysis, but the entire sample was split into metal-poor ( $[\text{Fe}/\text{H}] \leq -0.10$ ), metal-intermediate ( $-0.10 \leq [\text{Fe}/\text{H}] \leq +0.10$ ), and metal-rich ( $[\text{Fe}/\text{H}] \geq +0.10$ ). The three different subsamples are plotted as red, black, and green circles in the top right panel of Fig. 11, while the three running averages and their mean dispersions are plotted in the bottom right panel of the same figure. The outcome concerning the metallicity dependence is quite similar to the above analysis. We found that the metallicity dependence between the metal-poor and the metal-intermediate subsamples can be excluded at the 90% confidence level, while the dependence between the metal-poor and the metal-rich subsample at the 80% level. We also split the sample in short- and long-period and we found that the dependence can be excluded at the 93% and at the 90% level between metal-poor and metal-intermediate Cepheids and at the 90% and at the 77% level between metal-poor and metal-rich Cepheids.

The above findings indicate that the luminosity amplitude of Galactic and MC Cepheids does not display a solid trend with metal abundance. However, the current analysis should be cautiously treated for two different reasons: i) the Galactic sample is still dominated by Cepheids at solar iron abundance, since the sample of more metal-poor Cepheids located in the outer disk ( $R_G \geq 13$  kpc) is quite limited and ii) the spectroscopic abundances for MC Cepheids are dominated by brighter (long-period) Cepheids. Firm conclusions concerning the metallicity dependence require larger samples of spectroscopic abundances to further constrain the difference in pulsation amplitude and in period distribution.

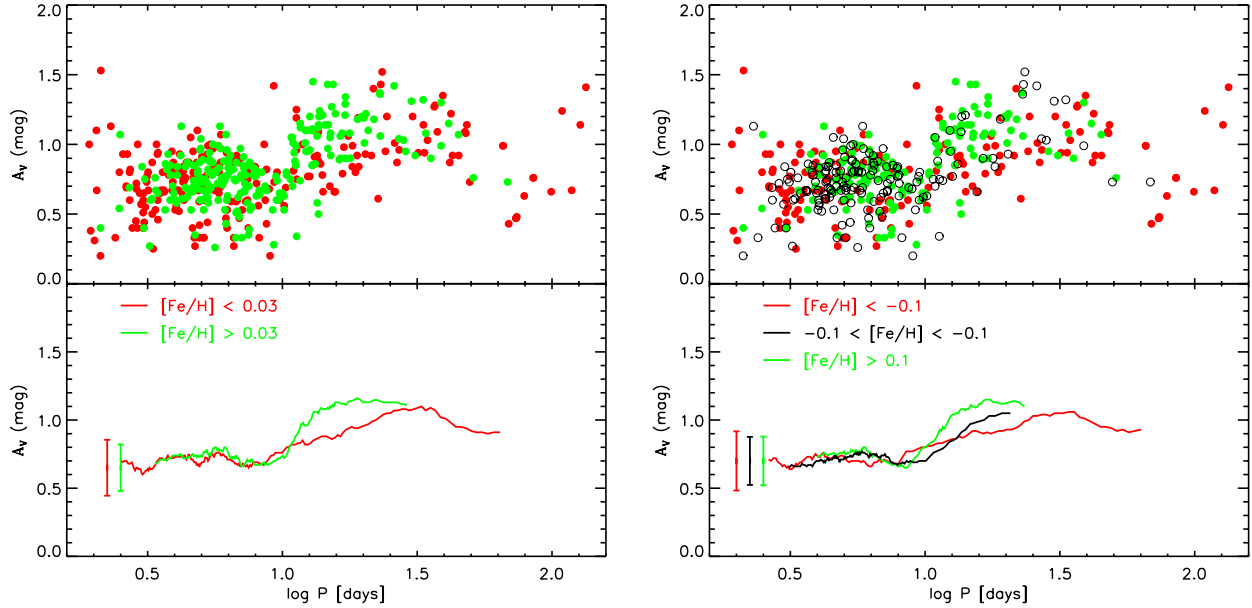
## 8. Discussion and conclusions

We performed accurate new measurements of iron abundances for 42 Galactic Cepheids using high-resolution, high-S/N UVES, NARVAL, and FEROS spectra. The iron abundance, for eleven Cepheids located in the inner disk, is based on multi-epoch spectra (from four to six) and their intrinsic uncertainty is smaller when compared with other Cepheids at super-solar iron content. The current sample was complemented with Cepheid iron abundances based on high-resolution spectra provided either by our group (Lemasle et al. 2007, 2008; Romaniello et al. 2008; Genovali et al. 2013) or available in the literature (Luck et al. 2011; Luck & Lambert 2011). We ended up with a sample of 450 Cepheids. To improve the accuracy on the metallicity distribution across the disk, we estimated homogeneous and reddening-free distances by using NIR PW relations for the entire sample.

The main findings of the current iron abundance analysis are given in more detail in the following.

- We found that the metallicity gradient, based on current spectroscopic measurements, is linear with a slope of  $-0.051 \pm 0.003$  dex/kpc, in agreement with recent studies

<sup>8</sup> For a small sample of Cepheids the  $V$ -band luminosity amplitude was not available in the literature. For these objects the  $V$ -band amplitude was estimated using the amplitude relations  $A_V = A_I/0.622$  for  $\log P < 1.02$  and  $A_V = A_I/0.606$  for  $\log P > 1.02$  provided by Klagyivik & Szabados (2009).



**Fig. 11.** Visual amplitudes vs. logarithmic period for Galactic and Magellanic Cepheids. Different colors indicate different metallicity ranges. *Top left:* the Cepheid sample was divided into two subsamples: supersolar (green circles) and subsolar (red) metallicity. *Bottom left:* running mean of the luminosity amplitudes plotted in the *top panel*: the color coding is the same as the *top panel*: the vertical bars display the intrinsic error of the running mean due to bin size and number of stepping stars (see text for more details). *Top right:* same as the *top left panel*, but the Cepheid sample was divided into three subsamples: supersolar (green), solar (empty black circles), and subsolar (red) metallicity. *Bottom right:* same as the *bottom left panel*, but for the three different metallicity bins adopted in the *top panel*.

by Luck et al. (2011) and Luck & Lambert (2011). The metallicity gradient based both on our iron abundances and on those from the literature shows a similar slope:  $-0.060 \pm 0.002$  dex/kpc. Current estimates agree quite well with the chemical evolution model for the thin disk recently provided by Minchev et al. (2013). In particular, they found that the iron gradient is  $-0.061$  dex/kpc for Galactocentric distances ranging from 5 kpc to 12 kpc and  $-0.057$  dex/kpc for Galactocentric distances ranging from 6 kpc to 11 kpc. The predicted slopes become marginally shallower if they account for stellar radial migrations.

- We estimated the metallicity gradient by selecting the Cepheids in our sample with a distance above the Galactic plane smaller than 300 pc and we found that it is, within the errors, quite similar:  $-0.052 \pm 0.004$  dex/kpc. The same outcome applies to the gradient based on the entire sample, and we found:  $-0.055 \pm 0.002$  dex/kpc. We also found that the spread in iron in the outer disk ( $R_G \geq 13$  kpc) decreases by more than a factor of two (0.13 vs. 0.17 dex) if we adopt the subsample located closer to the Galactic plane.
- We also confirm that classical Cepheids in the inner disk ( $R_G \sim 5.5\text{--}6.0$  kpc), just beyond the position of the Galactic bar corotation resonance (Gerhard et al. 2011), attain super-solar ( $[\text{Fe}/\text{H}] \sim 0.4$ ) iron abundances. This result supports similar findings by G13 and by Andrievsky et al. (2002); Pedicelli et al. (2010); Luck & Lambert (2011). There is preliminary evidence that the iron abundance in the innermost Galactic regions (nuclear bulge, Galactic bar) is more metal-poor than predicted by chemical evolution models (Minchev et al. 2013). Recent spectroscopic iron abundances of young stars (red supergiants, luminous blue variables, Wolf-Rayet, O-type stars) indicate either solar or subsolar abundances (Davies et al. 2009a,b; Origlia et al. 2013). On the other hand, chemical evolution models suggest in the same regions iron abundances larger than  $[\text{Fe}/\text{H}] \sim 0.8$  (Minchev et al. 2013). The above evidence indicates that

objects located inside the corotation resonance of the bar experienced a different chemical enrichment history than the Cepheids located just beyond this limit.

- The new homogeneous Cepheid metallicity distribution is characterized by a smaller intrinsic dispersion when compared with similar estimates available in the literature. We found evidence of a steady increase in the abundance dispersion when moving in the outer disk ( $R_G > 14$  kpc). Current data do not allow us to constrain whether this effect is the aftermath of outward stellar migrators as recently suggested by Minchev et al. (2012) or the consequence of the infall of the Sagittarius dwarf galaxy producing a flared outer disk as suggested by Purcell et al. (2011).
- To investigate the fine structure of the metallicity in the disk, we searched for Cepheids groups following the approach suggested by Ivanov (2008). We found ten candidate Cepheids groups, i.e., physical aggregations of stars whose mean residual metallicity agrees quite well with the trend of the metallicity residuals as a function of the Galactocentric distance. The presence of the CGs appears to be the main culprit of the fluctuations in the metallicity residuals and of the azimuthal effects on the radial gradient. This suggests that members of CGs experienced a very similar chemical enrichment history. Most of the CGs are located close to spiral arms (Sagittarius-Carina and Perseus arms) according to a simple logarithmic spiral model provided by Vallée (2005). The above findings indicate that the occurrence of CGs with sizes ranging from OB association/young cluster to star complexes/superassociations appear to be largely responsible for the intrinsic spread of the iron metallicity gradient. Moreover, the association of the metallicity residuals with candidate CGs supports the results by Sofue (2013) concerning the association of a local minimum in the Galactic rotational curve at  $R_G \sim 9.5$  kpc with the Perseus arm.



- We also found that the mean periods of the Cepheids hosted in candidate CGs with negative iron residuals have, on average, slightly longer periods and larger intrinsic dispersions when compared with the candidate CGs showing a positive iron residual, thus suggesting a common star formation episode within each candidate CG. The evidence of possible abundance inhomogeneities in the Galactic disk dates back to (Efremov 1995, and references therein) who suggested that the different star complexes might have different star formation histories and different interactions with the intergalactic medium. It is clear that the abundance information (iron and  $\alpha$ -elements) will provide a new spin to the analysis of their evolutionary and pulsation properties.
- To constrain the impact of age on the iron abundance gradient, we compared the Cepheid iron gradient with those based on OCs. Spectroscopic metallicities and homogeneous distances and ages were collected for OCs spanning a large range in age. The OC gradient based on clusters younger than 3 Gyr agrees quite well with the Cepheid gradient.
- The comparison between Cepheids and OCs older than 3 Gyr is more complex. We found that old OCs display a clear flattening in iron abundance for  $R_G \geq 15$  kpc. This result supports similar findings available in the literature e.g., Carraro et al. (2007b), Bragaglia et al. (2008), Magrini et al. (2009, 2010), Jacobson et al. (2011a,b), Yong et al. (2012). Moreover, old OCs located between the solar circle and  $R_G \sim 12$  kpc seem to show a dichotomic distribution. The difference is of the order of several tenths of dex and might be due to a selection bias affecting the azimuthal distribution. However, the comparison of Cepheid iron abundances with similar abundances for old OCs further supports the evidence that the metallicity gradient depends on age for ages larger than  $\sim 3$  Gyr.
- We investigate the possible occurrence of a metallicity effect on the pulsational amplitude by using a large sample of fundamental Galactic and Magellanic Cepheids (Luck & Lambert 1992; Luck et al. 1998; Romaniello et al. 2008) with accurate iron abundances. The comparison of low, medium, and high metallicity subsamples indicates that luminosity amplitudes are, within current uncertainties, independent of iron abundance.

Classical Cepheids appear to be solid young stellar tracers to constrain the recent chemical enrichment of the Galactic thin disk. The current sample of Galactic Cepheids is smaller when compared with similar tracers (OB stars, HII regions, red clump stars, open clusters). However, their distances, ages, and abundances can be estimated with certainty. They are ubiquitous in young star forming regions and the recent identification of classical Cepheids both in the nuclear bulge and in the Galactic bar (Matsunaga et al. 2011, 2013) will provide the opportunity to use the same stellar tracer to constrain the change in iron abundance across the corotation resonance. This also means there is the opportunity to constrain whether the high star formation rate of the innermost Galactic regions is driven by a disk instability that is dragging material from the inner disk into these regions (Freeman et al. 2013; Ness et al. 2013a,b).

Classical Cepheids are also excellent tracers for constraining the speed of the spiral arm pattern by fitting a kinematic model to the observed Cepheid kinematics (Fernández et al. 2001; Lépine et al. 2001). The Cepheid kinematics is time consuming, since a proper coverage of the radial velocity curves does require spectroscopic time series data. The use of template radial velocity curves significantly decreases the number of

measurements required for an accurate estimate of the center of mass radial velocity (Metzger et al. 1998). However, we still lack accurate radial velocity curve templates covering the entire period range.

The current observational scenario appears to be even more appealing in the outer disk, since we are still facing a “Cepheid desert” for Galactocentric distances larger than  $\sim 18$  kpc. New identification and characterization of Cepheids at least in the first and in the second quadrant are urgently needed to properly trace the outskirts of the Galactic disk.

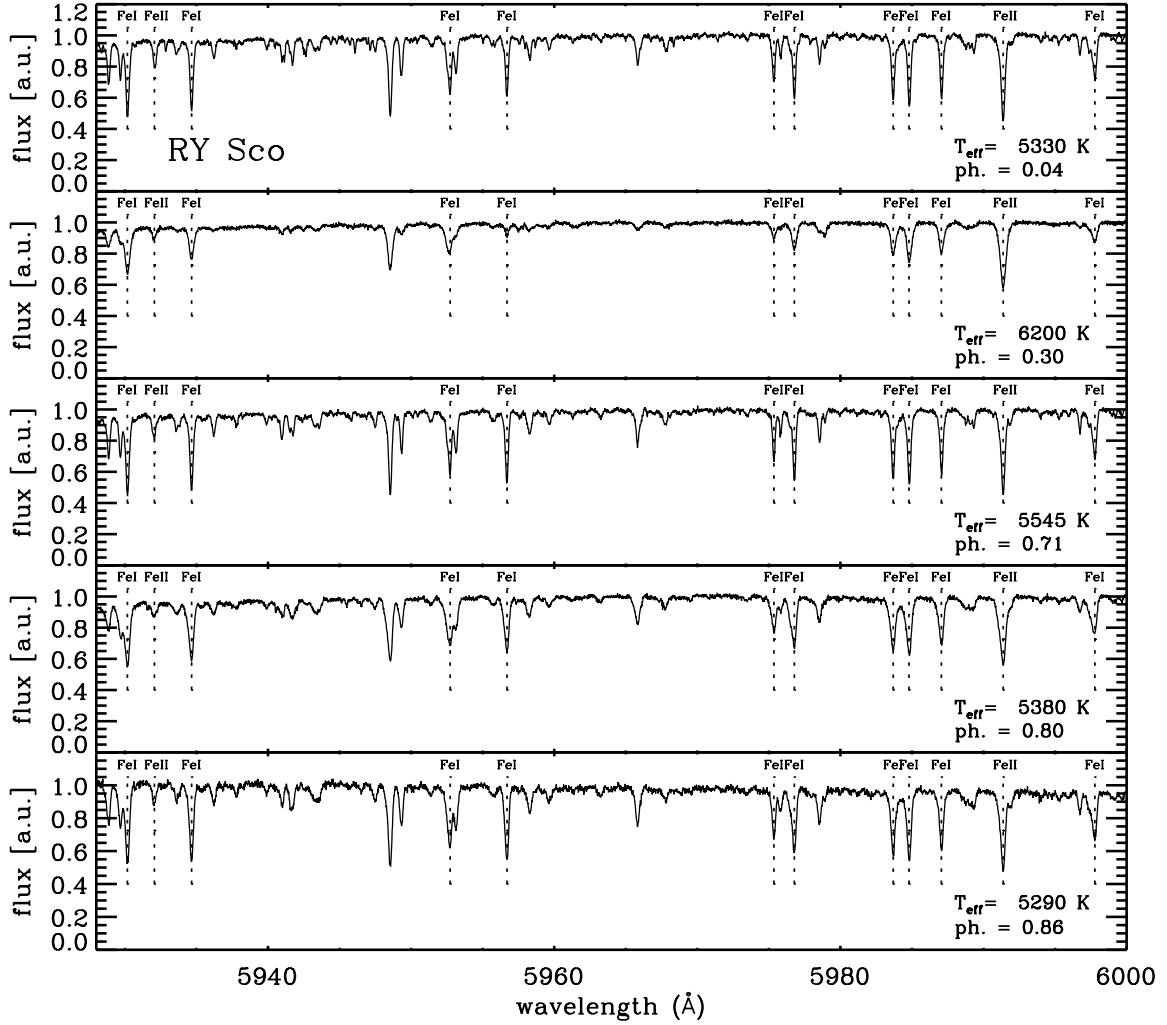
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**Fig. 1.** High-resolution ( $R \sim 38\,000$ ) UVES spectra of solar metallicity Galactic Cepheid RY Sco ( $[\text{Fe}/\text{H}] = 0.01 \pm 0.06$ ). From top to bottom the spectra were plotted for increasing pulsational phase (see the corresponding  $T_{\text{eff}}$  curve in Fig. 3). The S/N of this sample is around 100 in the spectral range  $\lambda \sim 5650\text{--}7500 \text{ \AA}$ . The vertical dashed lines display selected Fe I ( $\lambda\lambda 5930.17, 5934.66, 5952.73, 5956.7, 5975.35, 5976.78, 5983.69, 5984.79, 5987.05, 5997.78 \text{ \AA}$ ) and Fe II ( $\lambda\lambda 5932.06, 5991.37 \text{ \AA}$ ) lines included in our abundance analysis (see Table 1 and Romaniello et al. 2008).

**Table 1.** Intrinsic parameters and abundances for the current sample of classical Cepheids based on individual spectra.

| Name     | Date         | MJD       | $ET$<br>(s) | $S/N$ | $T_{\text{eff}}$<br>K | $\log g$ | $v_t$<br>(km s <sup>-1</sup> ) | Fe I         | $N$ | Fe II        | $N$ | Spect. |
|----------|--------------|-----------|-------------|-------|-----------------------|----------|--------------------------------|--------------|-----|--------------|-----|--------|
| V340 Ara | 2012-Jul.-29 | 56137.137 | 120         | 99    | 5210 ± 49             | 0.30     | 5.0                            | 0.28 ± 0.27  | 23  | 0.27 ± 0.11  | 2   | UVES   |
| V340 Ara | 2008-Aug.-30 | 54708.065 | 300         | 241   | 5210 ± 88             | 0.00     | 3.0                            | 0.53 ± 0.15  | 53  | 0.53 ± 0.11  | 4   | UVES   |
| V340 Ara | 2008-Aug.-31 | 54709.079 | 300         | 264   | 5130 ± 96             | 0.40     | 3.0                            | 0.42 ± 0.22  | 26  | 0.65 ± 0.24  | 3   | UVES   |
| V340 Ara | 2012-Jul.-30 | 56138.094 | 120         | 122   | 5610 ± 68             | 0.70     | 4.4                            | 0.30 ± 0.20  | 41  | 0.33 ± 0.10  | 2   | UVES   |
| V340 Ara | 2012-Jul.-31 | 56139.185 | 120         | 114   | 6060 ± 65             | 0.80     | 5.2                            | 0.24 ± 0.13  | 51  | 0.22 ± 0.01  | 2   | UVES   |
| V340 Ara | 2012-Aug.-13 | 56152.054 | 121         | 69    | 4820 ± 53             | 1.00     | 4.4                            | 0.20 ± 0.23  | 15  | 0.30 ± 0.29  | 2   | UVES   |
| AS Aur   | 2009-Jan.-14 | 54845.136 | 500         | 94    | 5800 ± 86             | 1.10     | 2.6                            | 0.01 ± 0.14  | 74  | -0.01 ± 0.10 | 8   | UVES   |
| KN Cen   | 2009-Jan.-31 | 54862.355 | 80          | 153   | 5130 ± 68             | 0.01     | 3.2                            | 0.36 ± 0.28  | 14  | 0.59 ± 0.13  | 3   | UVES   |
| MZ Cen   | 2008-Apr.-28 | 54584.280 | 800         | 217   | 5520 ± 55             | 0.90     | 3.6                            | 0.27 ± 0.14  | 45  | 0.26 ± 0.14  | 4   | UVES   |
| OO Cen   | 2008-Apr.-29 | 54585.060 | 1500        | 288   | 5950 ± 65             | 1.00     | 3.7                            | 0.19 ± 0.12  | 30  | 0.20 ± 0.07  | 4   | UVES   |
| TX Cen   | 2009-Jan.-31 | 54862.363 | 200         | 152   | 5380 ± 87             | 0.60     | 3.8                            | 0.43 ± 0.16  | 78  | 0.45 ± 0.20  | 7   | UVES   |
| V339 Cen | 2008-Apr.-28 | 54584.304 | 60          | 183   | 5210 ± 54             | 0.40     | 3.2                            | 0.06 ± 0.14  | 39  | 0.06 ± 0.03  | 3   | UVES   |
| VW Cen   | 2009-Jan.-31 | 54862.359 | 200         | 144   | 5190 ± 65             | 0.30     | 4.4                            | 0.40 ± 0.10  | 43  | 0.44 ± 0.13  | 2   | UVES   |
| AO CMa   | 2009-Jan.-08 | 54839.053 | 900         | 120   | 5855 ± 57             | 1.30     | 2.6                            | 0.00 ± 0.07  | 75  | 0.03 ± 0.11  | 5   | UVES   |
| RW CMa   | 2009-Jan.-08 | 54839.138 | 500         | 198   | 6050 ± 63             | 1.20     | 3.0                            | -0.07 ± 0.11 | 83  | -0.06 ± 0.11 | 5   | UVES   |
| SS CMa   | 2009-Jan.-08 | 54839.066 | 80          | 93    | 5700 ± 54             | 0.60     | 2.6                            | 0.06 ± 0.05  | 57  | 0.07 ± 0.10  | 5   | UVES   |
| TV CMa   | 2009-Jan.-16 | 54847.246 | 200         | 149   | 5570 ± 38             | 1.10     | 3.0                            | 0.00 ± 0.11  | 89  | 0.01 ± 0.09  | 6   | UVES   |
| TV CMa   | 2007-Nov.-03 | 54407.238 | 2700        | 101   | 5850 ± 126            | 1.4      | 2.6                            | 0.01 ± 0.09  | 128 | 0.06 ± 0.19  | 23  | NARVAL |
| TW CMa   | 2009-Jan.-08 | 54839.077 | 80          | 63    | 6135 ± 109            | 1.20     | 2.5                            | 0.04 ± 0.10  | 38  | 0.07 ± 0.30  | 4   | UVES   |
| AA Gem   | 2009-Jan.-15 | 54846.149 | 80          | 84    | 5540 ± 104            | 0.60     | 3.0                            | -0.08 ± 0.06 | 74  | -0.08 ± 0.13 | 5   | UVES   |
| AD Gem   | 2009-Jan.-15 | 54846.221 | 80          | 109   | 6200 ± 122            | 1.60     | 2.2                            | -0.17 ± 0.14 | 70  | -0.13 ± 0.07 | 7   | UVES   |
| BB Gem   | 2009-Jan.-15 | 54846.187 | 500         | 160   | 7000 ± 253            | 1.90     | 2.8                            | -0.08 ± 0.13 | 70  | -0.09 ± 0.04 | 9   | UVES   |
| BW Gem   | 2009-Jan.-14 | 54845.122 | 900         | 141   | 5850 ± 65             | 1.60     | 2.2                            | -0.22 ± 0.12 | 99  | -0.21 ± 0.15 | 6   | UVES   |
| DX Gem   | 2009-Jan.-15 | 54846.196 | 200         | 121   | 6200 ± 92             | 1.60     | 2.8                            | -0.01 ± 0.11 | 72  | -0.01 ± 0.15 | 6   | UVES   |
| RZ Gem   | 2009-Jan.-14 | 54845.094 | 200         | 207   | 7000 ± 170            | 1.60     | 3.4                            | -0.13 ± 0.11 | 44  | -0.16 ± 0.03 | 5   | UVES   |
| BE Mon   | 2009-Jan.-15 | 54846.201 | 200         | 136   | 5770 ± 58             | 1.50     | 2.9                            | 0.05 ± 0.12  | 78  | 0.05 ± 0.13  | 5   | UVES   |
| CV Mon   | 2009-Jan.-15 | 54846.182 | 200         | 152   | 5540 ± 58             | 0.60     | 2.6                            | 0.09 ± 0.10  | 52  | 0.11 ± 0.21  | 2   | UVES   |
| FT Mon   | 2009-Jan.-14 | 54845.104 | 1000        | 85    | 5810 ± 92             | 1.20     | 2.7                            | -0.13 ± 0.11 | 61  | -0.14 ± 0.12 | 8   | UVES   |
| SV Mon   | 2009-Jan.-14 | 54845.119 | 30          | 143   | 5090 ± 58             | 0.10     | 2.5                            | 0.10 ± 0.09  | 54  | 0.17 ± 0.15  | 8   | UVES   |
| TW Mon   | 2008-Nov.-26 | 54796.347 | 1000        | 144   | 5990 ± 105            | 1.30     | 2.7                            | -0.13 ± 0.08 | 75  | -0.13 ± 0.16 | 6   | UVES   |
| TX Mon   | 2008-Nov.-28 | 54798.345 | 200         | 109   | 6180 ± 62             | 1.40     | 3.2                            | -0.03 ± 0.15 | 76  | -0.03 ± 0.05 | 4   | UVES   |
| TY Mon   | 2009-Jan.-15 | 54846.139 | 500         | 134   | 6320 ± 73             | 1.50     | 2.3                            | 0.01 ± 0.11  | 85  | 0.03 ± 0.12  | 6   | UVES   |
| TZ Mon   | 2009-Jan.-16 | 54847.237 | 200         | 127   | 5625 ± 41             | 1.20     | 2.9                            | -0.02 ± 0.08 | 94  | -0.01 ± 0.12 | 6   | UVES   |
| V465 Mon | 2009-Jan.-16 | 54847.241 | 200         | 144   | 6250 ± 56             | 1.50     | 2.8                            | -0.07 ± 0.11 | 107 | -0.07 ± 0.10 | 6   | UVES   |
| V495 Mon | 2009-Jan.-15 | 54846.167 | 1000        | 126   | 5590 ± 57             | 1.20     | 3.0                            | -0.14 ± 0.09 | 73  | -0.11 ± 0.10 | 4   | UVES   |
| V508 Mon | 2009-Jan.-16 | 54847.232 | 200         | 135   | 6140 ± 95             | 1.70     | 2.7                            | -0.06 ± 0.15 | 118 | -0.03 ± 0.13 | 7   | UVES   |
| V510 Mon | 2009-Jan.-15 | 54846.153 | 1000        | 125   | 5505 ± 52             | 0.90     | 3.4                            | -0.15 ± 0.11 | 80  | -0.17 ± 0.08 | 3   | UVES   |
| XX Mon   | 2008-Nov.-28 | 54798.335 | 500         | 93    | 5590 ± 47             | 1.20     | 2.8                            | 0.00 ± 0.09  | 55  | 0.02 ± 0.14  | 2   | UVES   |
| GU Nor   | 2008-Jul.-20 | 54667.205 | 300         | 258   | 6240 ± 43             | 1.40     | 3.2                            | 0.08 ± 0.11  | 80  | 0.08 ± 0.07  | 7   | UVES   |
| IQ Nor   | 2008-Apr.-28 | 54584.299 | 150         | 265   | 5950 ± 87             | 0.70     | 4.0                            | 0.19 ± 0.13  | 63  | 0.23 ± 0.09  | 7   | UVES   |
| QZ Nor   | 2009-Feb.-01 | 54863.366 | 30          | 100   | 5740 ± 46             | 1.10     | 2.8                            | 0.18 ± 0.12  | 81  | 0.19 ± 0.12  | 3   | UVES   |
| QZ Nor   | 2009-Apr.-02 | 54923.345 | 30          | 100   | 5790 ± 53             | 1.00     | 2.8                            | 0.20 ± 0.12  | 86  | 0.24 ± 0.09  | 2   | UVES   |
| RS Nor   | 2009-Feb.-01 | 54863.361 | 200         | 230   | 6140 ± 63             | 1.20     | 3.2                            | 0.17 ± 0.12  | 82  | 0.19 ± 0.12  | 5   | UVES   |
| SY Nor   | 2008-Aug.-30 | 54708.061 | 150         | 170   | 5550 ± 64             | 0.70     | 3.7                            | 0.26 ± 0.14  | 46  | 0.28 ± 0.15  | 5   | UVES   |
| SY Nor   | 2008-Aug.-31 | 54709.075 | 150         | 205   | 5675 ± 55             | 1.00     | 3.6                            | 0.20 ± 0.12  | 58  | 0.19 ± 0.13  | 4   | UVES   |
| TW Nor   | 2008-Jul.-19 | 54666.127 | 800         | 216   | 5090 ± 73             | 0.30     | 3.5                            | 0.28 ± 0.20  | 69  | 0.27 ± 0.12  | 7   | UVES   |
| V340 Nor | 2009-Feb.-11 | 54873.376 | 30          | 169   | 5685 ± 77             | 0.60     | 3.4                            | 0.07 ± 0.10  | 47  | 0.08 ± 0.11  | 4   | UVES   |
| CS Ori   | 2009-Jan.-14 | 54845.085 | 500         | 128   | 6390 ± 162            | 1.20     | 2.0                            | -0.27 ± 0.08 | 68  | -0.22 ± 0.09 | 6   | UVES   |
| GQ Ori   | 2009-Jan.-14 | 54845.082 | 30          | 100   | 5050 ± 104            | 2.80     | 1.2                            | 0.19 ± 0.12  | 92  | 0.22 ± 0.12  | 14  | UVES   |
| RS Ori   | 2009-Jan.-14 | 54845.100 | 30          | 149   | 6165 ± 57             | 1.00     | 2.6                            | 0.11 ± 0.13  | 71  | 0.11 ± 0.12  | 5   | UVES   |
| AQ Pup   | 2009-Jan.-08 | 54839.075 | 30          | 50    | 5030 ± 96             | 0.10     | 4.4                            | -0.07 ± 0.14 | 14  | 0.08 ± 0.05  | 2   | UVES   |
| BC Pup   | 2009-Jan.-08 | 54839.147 | 2000        | 81    | 5705 ± 121            | 1.40     | 3.2                            | -0.31 ± 0.09 | 57  | -0.32 ± 0.11 | 3   | UVES   |
| BM Pup   | 2009-Jan.-08 | 54839.086 | 200         | 80    | 5526 ± 84             | 0.80     | 2.7                            | -0.07 ± 0.11 | 61  | -0.06 ± 0.11 | 7   | UVES   |
| BN Pup   | 2009-Jan.-08 | 54839.109 | 80          | 117   | 5330 ± 54             | 0.50     | 2.6                            | 0.03 ± 0.06  | 69  | 0.05 ± 0.13  | 4   | UVES   |
| CE Pup   | 2010-Mar.-31 | 55286.057 | 6300        | 248   | 5770 ± 123            | 0.50     | 4.0                            | -0.04 ± 0.11 | 67  | -0.03 ± 0.15 | 3   | FEROS  |
| CK Pup   | 2009-Jan.-08 | 54839.113 | 2000        | 141   | 6235 ± 62             | 1.20     | 2.4                            | -0.15 ± 0.11 | 72  | -0.14 ± 0.12 | 4   | UVES   |
| CK Pup   | 2009-Jan.-08 | 54839.173 | 2000        | 156   | 6200 ± 108            | 0.80     | 2.3                            | -0.11 ± 0.11 | 78  | -0.13 ± 0.11 | 11  | UVES   |
| HW Pup   | 2008-Nov.-22 | 54792.249 | 900         | 123   | 5200 ± 61             | 0.40     | 2.6                            | -0.24 ± 0.10 | 70  | -0.16 ± 0.17 | 3   | UVES   |
| LS Pup   | 2009-Jan.-08 | 54839.081 | 200         | 97    | 5235 ± 115            | 0.40     | 3.6                            | -0.12 ± 0.11 | 18  | -0.13 ± 0.00 | 1   | UVES   |
| VW Pup   | 2009-Jan.-01 | 54832.331 | 500         | 142   | 5600 ± 78             | 1.20     | 3.1                            | -0.14 ± 0.07 | 50  | -0.16 ± 0.13 | 4   | UVES   |
| VZ Pup   | 2009-Jan.-08 | 54839.096 | 80          | 123   | 6480 ± 65             | 1.00     | 3.1                            | 0.01 ± 0.05  | 27  | -0.05 ± 0.06 | 2   | UVES   |
| WW Pup   | 2009-Jan.-08 | 54839.091 | 200         | 119   | 5500 ± 104            | 1.20     | 3.2                            | 0.13 ± 0.16  | 18  | 0.13 ± 0.00  | 1   | UVES   |
| WY Pup   | 2009-Jan.-08 | 54839.100 | 200         | 102   | 6020 ± 76             | 1.60     | 3.2                            | -0.10 ± 0.10 | 49  | -0.09 ± 0.12 | 6   | UVES   |
| WZ Pup   | 2009-Jan.-08 | 54839.104 | 200         | 113   | 5660 ± 41             | 1.00     | 2.7                            | -0.07 ± 0.07 | 72  | -0.07 ± 0.09 | 7   | UVES   |
| X Pup    | 2009-Jan.-08 | 54839.070 | 30          | 69    | 5070 ± 115            | 0.10     | 4.8                            | 0.00 ± 0.09  | 15  | 0.09 ± 0.16  | 2   | UVES   |
| KQ Sco   | 2012-Jul.-31 | 56139.021 | 100         | 87    | 5030 ± 40             | 0.10     | 4.8                            | 0.26 ± 0.15  | 32  | 0.00 ± 0.00  | 0   | UVES   |
| KQ Sco   | 2009-Feb.-11 | 54873.379 | 80          | 150   | 4905 ± 80             | 0.10     | 4.6                            | 0.51 ± 0.08  | 51  | 0.63 ± 0.27  | 4   | UVES   |
| KQ Sco   | 2012-Aug.-13 | 56152.097 | 100         | 100   | 4915 ± 53             | 0.30     | 3.6                            | 0.30 ± 0.21  | 16  | 0.35 ± 0.00  | 1   | UVES   |
| KQ Sco   | 2012-Aug.-24 | 56163.004 | 100         | 85    | 4840 ± 62             | 0.10     | 5.2                            | 0.22 ± 0.27  | 20  | 0.63 ± 0.00  | 1   | UVES   |
| KQ Sco   | 2012-Aug.-27 | 56166.004 | 100         | 97    | 4930 ± 53             | 0.20     | 4.8                            | 0.21 ± 0.28  | 15  | 0.39 ± 0.00  | 1   | UVES   |
| RY Sco   | 2012-Aug.-01 | 56140.187 | 20          | 116   | 5545 ± 40             | 0.60     | 3.6                            | 0.02 ± 0.14  | 74  | 0.06 ± 0.01  | 2   | UVES   |
| RY Sco   | 2008-May-13  | 54599.412 | 20          | 136   | 5290 ± 40             | 0.40     | 3.7                            | 0.06 ± 0.09  | 34  | 0.06 ± 0.02  | 5   | UVES   |
| RY Sco   | 2012-Aug.-13 | 56152.143 | 20          | 116   | 6200 ± 54             | 0.80     | 5.2                            | 0.01 ± 0.15  | 75  | 0.01 ± 0.03  | 3   | UVES   |
| RY Sco   | 2012-Aug.-23 | 56162.170 | 20          | 108   | 5380 ± 38             | 0.40     | 3.8                            | 0.00 ± 0.14  | 66  | -0.03 ± 0.05 | 2   | UVES   |
| RY Sco   | 2012-Aug.-28 | 56167.085 | 20          | 111   | 5330 ± 31             | 0.70     | 4.8                            | -0.05 ± 0.12 | 45  | -0.03 ± 0.11 | 2   | UVES   |

**Notes.** From left to right the columns give the Cepheid name, the date of acquisition and the modified Julian Day of the spectrum, the exposure time, maximum S/N of the spectrum, the estimated intrinsic parameters ( $T_{\text{eff}}$ ,  $\log g$ ,  $v_t$ ). Columns 9 and 10 list the Fe I abundance and its standard deviation together with the number of Fe I lines measured. Columns 11 and 12 list the Fe II abundance and its standard deviation together with the number of Fe II lines measured. The last column gives the name of the adopted spectrograph.

Table 1. continued.

| Name      | Date         | MJD       | ET<br>(s) | S/N | $T_{\text{eff}}$<br>K | log $g$ | $v_t$<br>(km s <sup>-1</sup> ) | Fe I         | $N$ | Fe II        | $N$ | Spect. |
|-----------|--------------|-----------|-----------|-----|-----------------------|---------|--------------------------------|--------------|-----|--------------|-----|--------|
| V470 Sco  | 2008-Aug.-30 | 54708.073 | 800       | 380 | 5730 ± 33             | 0.80    | 4.4                            | 0.16 ± 0.10  | 66  | 0.16 ± 0.08  | 4   | UVES   |
| V500 Sco  | 2012-Aug.-01 | 56140.191 | 46        | 126 | 5980 ± 27             | 1.10    | 4.6                            | -0.09 ± 0.16 | 86  | 0.00 ± 0.05  | 3   | UVES   |
| V500 Sco  | 2012-Aug.-13 | 56152.092 | 45        | 99  | 5330 ± 26             | 0.60    | 3.2                            | -0.04 ± 0.12 | 67  | 0.10 ± 0.20  | 3   | UVES   |
| V500 Sco  | 2012-Aug.-23 | 56162.998 | 45        | 101 | 5280 ± 31             | 0.40    | 3.8                            | -0.02 ± 0.17 | 53  | -0.04 ± 0.17 | 3   | UVES   |
| V500 Sco  | 2012-Aug.-28 | 56167.077 | 45        | 152 | 6020 ± 35             | 1.10    | 4.0                            | -0.11 ± 0.16 | 97  | -0.11 ± 0.08 | 5   | UVES   |
| EV Sct    | 2008-Aug.-30 | 54708.086 | 300       | 224 | 6025 ± 65             | 1.50    | 2.5                            | 0.10 ± 0.15  | 57  | 0.09 ± 0.08  | 3   | UVES   |
| RU Sct    | 2009-Mar.-16 | 54906.414 | 120       | 205 | 5190 ± 35             | 0.10    | 2.9                            | 0.15 ± 0.12  | 95  | 0.16 ± 0.05  | 7   | UVES   |
| RU Sct    | 2009-Apr.-02 | 54923.375 | 80        | 216 | 5495 ± 48             | 0.30    | 3.0                            | 0.09 ± 0.10  | 45  | 0.09 ± 0.09  | 5   | UVES   |
| RU Sct    | 2007-Oct.-31 | 54404.777 | 2000      | 208 | 6450 ± 142            | 0.7     | 3.7                            | -0.07 ± 0.10 | 74  | -0.06 ± 0.14 | 15  | NARVAL |
| UZ Sct    | 2012-Jul.-29 | 56137.160 | 360       | 105 | 4850 ± 55             | 0.60    | 4.0                            | 0.26 ± 0.20  | 17  | 0.29 ± 0.16  | 4   | UVES   |
| UZ Sct    | 2009-Mar.-16 | 54906.400 | 700       | 273 | 5470 ± 76             | 0.80    | 2.8                            | 0.36 ± 0.19  | 34  | 0.36 ± 0.12  | 5   | UVES   |
| UZ Sct    | 2009-Apr.-02 | 54923.366 | 500       | 249 | 5060 ± 76             | 0.20    | 2.9                            | 0.45 ± 0.08  | 63  | 0.43 ± 0.15  | 7   | UVES   |
| UZ Sct    | 2012-Aug.-13 | 56152.064 | 360       | 70  | 4850 ± 49             | 0.80    | 4.4                            | 0.25 ± 0.28  | 8   | 0.00 ± 0.00  | 0   | UVES   |
| UZ Sct    | 2012-Aug.-21 | 56160.167 | 360       | 117 | 5370 ± 76             | 0.60    | 3.2                            | 0.34 ± 0.23  | 47  | 0.37 ± 0.11  | 2   | UVES   |
| UZ Sct    | 2012-Sep.-05 | 56175.049 | 360       | 116 | 5320 ± 85             | 0.60    | 3.2                            | 0.31 ± 0.21  | 36  | 0.34 ± 0.00  | 2   | UVES   |
| V367 Sct  | 2012-Jul.-29 | 56137.147 | 360       | 98  | 5670 ± 56             | 1.00    | 3.8                            | 0.08 ± 0.18  | 72  | 0.14 ± 0.08  | 3   | UVES   |
| V367 Sct  | 2008-Aug.-31 | 54709.128 | 800       | 255 | 5740 ± 51             | 1.30    | 3.4                            | -0.05 ± 0.13 | 56  | -0.04 ± 0.04 | 4   | UVES   |
| V367 Sct  | 2012-Sep.-05 | 56175.105 | 360       | 82  | 5930 ± 64             | 1.20    | 4.2                            | 0.15 ± 0.15  | 50  | 0.14 ± 0.07  | 3   | UVES   |
| V367 Sct  | 2012-Sep.-14 | 56184.000 | 360       | 123 | 6200 ± 91             | 1.00    | 3.4                            | 0.04 ± 0.15  | 84  | 0.03 ± 0.08  | 4   | UVES   |
| X Sct     | 2007-Nov.-01 | 54405.762 | 2400      | 128 | 6300 ± 138            | 1.2     | 2.7                            | 0.05 ± 0.16  | 82  | 0.16 ± 0.26  | 23  | NARVAL |
| X Sct     | 2008-Aug.-31 | 54709.122 | 300       | 231 | 5830 ± 83             | 1.10    | 2.5                            | 0.11 ± 0.12  | 72  | 0.14 ± 0.15  | 9   | UVES   |
| Z Sct     | 2012-Jul.-29 | 56137.123 | 100       | 111 | 5130 ± 70             | 0.20    | 4.6                            | 0.10 ± 0.16  | 20  | 0.00 ± 0.00  | 0   | UVES   |
| Z Sct     | 2008-Jul.-31 | 54678.090 | 150       | 185 | 5005 ± 78             | 0.05    | 3.8                            | 0.18 ± 0.14  | 41  | 0.18 ± 0.12  | 3   | UVES   |
| Z Sct     | 2012-Aug.-13 | 56152.073 | 101       | 96  | 5650 ± 61             | 0.90    | 5.2                            | 0.09 ± 0.14  | 49  | 0.11 ± 0.02  | 2   | UVES   |
| Z Sct     | 2012-Aug.-20 | 56159.186 | 100       | 103 | 5160 ± 64             | 0.20    | 3.4                            | 0.21 ± 0.22  | 45  | 0.27 ± 0.08  | 2   | UVES   |
| Z Sct     | 2012-Sep.-05 | 56175.038 | 100       | 89  | 5005 ± 68             | 0.40    | 4.6                            | 0.00 ± 0.30  | 25  | 0.00 ± 0.00  | 0   | UVES   |
| AA Ser    | 2008-Aug.-30 | 54708.040 | 1500      | 231 | 4830 ± 80             | 0.20    | 3.2                            | 0.38 ± 0.20  | 24  | 0.37 ± 0.00  | 1   | UVES   |
| CR Ser    | 2008-Aug.-31 | 54709.116 | 300       | 122 | 5500 ± 48             | 0.80    | 3.3                            | 0.13 ± 0.11  | 53  | 0.11 ± 0.11  | 5   | UVES   |
| AV Sgr    | 2012-Jul.-28 | 56136.169 | 361       | 87  | 5070 ± 56             | 0.20    | 3.6                            | 0.37 ± 0.21  | 29  | 0.43 ± 0.21  | 2   | UVES   |
| AV Sgr    | 2012-Jul.-28 | 56136.192 | 1440      | 173 | 5080 ± 51             | 0.10    | 3.4                            | 0.43 ± 0.23  | 31  | 0.45 ± 0.20  | 2   | UVES   |
| AV Sgr    | 2009-Apr.-02 | 54923.348 | 500       | 233 | 5060 ± 50             | 0.10    | 4.5                            | 0.35 ± 0.30  | 16  | 0.61 ± 0.20  | 2   | UVES   |
| AV Sgr    | 2012-Aug.-13 | 56152.082 | 361       | 62  | 5020 ± 58             | 0.30    | 3.6                            | 0.29 ± 0.23  | 24  | 0.58 ± 0.25  | 2   | UVES   |
| AV Sgr    | 2012-Aug.-29 | 56168.049 | 360       | 75  | 5020 ± 49             | 0.40    | 3.6                            | 0.30 ± 0.22  | 19  | 0.35 ± 0.00  | 1   | UVES   |
| AY Sgr    | 2008-May-13  | 54599.398 | 300       | 195 | 5760 ± 52             | 0.90    | 3.0                            | 0.11 ± 0.14  | 58  | 0.11 ± 0.07  | 5   | UVES   |
| V1954 Sgr | 2008-May-13  | 54599.389 | 300       | 158 | 6120 ± 33             | 1.10    | 3.5                            | 0.25 ± 0.13  | 61  | 0.22 ± 0.17  | 4   | UVES   |
| V773 Sgr  | 2008-Jul.-22 | 54669.207 | 1500      | 264 | 6195 ± 39             | 1.00    | 3.4                            | 0.11 ± 0.07  | 58  | 0.10 ± 0.11  | 8   | UVES   |
| VY Sgr    | 2012-Aug.-21 | 56160.179 | 360       | 76  | 4900 ± 46             | 0.20    | 4.6                            | 0.27 ± 0.25  | 14  | 0.56 ± 0.00  | 1   | UVES   |
| VY Sgr    | 2009-Apr.-02 | 54923.356 | 500       | 231 | 5100 ± 84             | 0.40    | 2.6                            | 0.37 ± 0.19  | 30  | 0.49 ± 0.21  | 6   | UVES   |
| VY Sgr    | 2012-Aug.-23 | 56162.162 | 360       | 83  | 5230 ± 91             | 0.10    | 5.2                            | 0.32 ± 0.27  | 17  | 0.30 ± 0.00  | 1   | UVES   |
| VY Sgr    | 2012-Aug.-29 | 56168.062 | 360       | 81  | 5470 ± 77             | 0.60    | 3.4                            | 0.32 ± 0.19  | 51  | 0.31 ± 0.05  | 2   | UVES   |
| WZ Sgr    | 2012-Jul.-24 | 56132.190 | 20        | 134 | 5990 ± 72             | 0.90    | 5.6                            | 0.19 ± 0.11  | 56  | 0.18 ± 0.11  | 2   | UVES   |
| WZ Sgr    | 2008-May-13  | 54599.395 | 20        | 101 | 5115 ± 65             | 0.05    | 4.6                            | 0.36 ± 0.10  | 42  | 0.32 ± 0.14  | 2   | UVES   |
| WZ Sgr    | 2012-Jul.-28 | 56136.213 | 80        | 267 | 5500 ± 70             | 0.50    | 3.5                            | 0.24 ± 0.16  | 48  | 0.24 ± 0.01  | 2   | UVES   |
| WZ Sgr    | 2012-Aug.-13 | 56152.044 | 20        | 87  | 5200 ± 56             | 0.20    | 5.0                            | 0.25 ± 0.26  | 28  | 0.29 ± 0.14  | 2   | UVES   |
| WZ Sgr    | 2012-Aug.-20 | 56159.125 | 20        | 129 | 5335 ± 58             | 0.30    | 3.2                            | 0.34 ± 0.18  | 44  | 0.37 ± 0.06  | 2   | UVES   |
| XX Sgr    | 2012-May-07  | 56054.234 | 45        | 121 | 5840 ± 49             | 1.20    | 3.4                            | -0.02 ± 0.14 | 100 | -0.01 ± 0.13 | 5   | UVES   |
| XX Sgr    | 2008-May-13  | 54599.404 | 60        | 184 | 6340 ± 84             | 1.40    | 3.6                            | -0.03 ± 0.12 | 59  | -0.09 ± 0.08 | 4   | UVES   |
| XX Sgr    | 2012-Jul.-28 | 56136.223 | 180       | 257 | 6200 ± 40             | 1.00    | 3.4                            | -0.05 ± 0.12 | 101 | -0.05 ± 0.05 | 6   | UVES   |
| XX Sgr    | 2012-Aug.-13 | 56152.047 | 46        | 84  | 5520 ± 48             | 0.80    | 3.0                            | 0.05 ± 0.08  | 43  | 0.05 ± 0.03  | 3   | UVES   |
| XX Sgr    | 2012-Aug.-20 | 56159.128 | 45        | 95  | 5525 ± 55             | 0.90    | 3.6                            | -0.01 ± 0.18 | 64  | -0.03 ± 0.15 | 4   | UVES   |
| EZ Vel    | 2008-Oct.-20 | 54759.348 | 1000      | 89  | 4735 ± 75             | 0.10    | 3.9                            | -0.17 ± 0.15 | 23  | -0.10 ± 0.00 | 1   | UVES   |



**Table 3.** Mean NIR magnitudes, mean distances and mean iron abundances for the current sample of classical Cepheids.

| Name     | Type   | $\log(P)$<br>[days] | $\langle J \rangle$<br>mag | $\langle H \rangle$<br>mag | $\langle K \rangle$<br>mag | $[\text{Fe}/\text{H}]_{\text{lit}}$ | $[\text{Fe}/\text{H}]$ | $N_S$ | $\mu^d$<br>mag   | $R_G^e$<br>(pc) | Notes          | Ref. <sup>f</sup> |
|----------|--------|---------------------|----------------------------|----------------------------|----------------------------|-------------------------------------|------------------------|-------|------------------|-----------------|----------------|-------------------|
| V340 Ara | DCEP   | 1.3183              | 7.302                      | 6.754                      | 6.534                      | 0.40                                | $0.33 \pm 0.09$        | 6     | $12.99 \pm 0.05$ | $4657 \pm 427$  | b <sup>†</sup> | PED               |
| AO Cma   | DCEP   | 0.7646              | 9.154                      | 8.595                      | 8.366                      | -0.04                               | $0.01 \pm 0.06$        | 1     | $12.95 \pm 0.05$ | $10430 \pm 433$ | b <sup>†</sup> | LEM               |
| TW Cma   | DCEP   | 0.8448              | 7.567                      | 7.178                      | 7.008                      | -0.51                               | $0.04 \pm 0.09$        | 1     | $12.02 \pm 0.05$ | $9788 \pm 445$  | a              | LEM               |
| AD Gem   | DCEP   | 0.5784              | 8.448                      | 8.151                      | 8.027                      | -0.19                               | $-0.14 \pm 0.06$       | 1     | $12.24 \pm 0.05$ | $10662 \pm 455$ | a              | LEM               |
| BB Gem   | DCEP   | 0.3633              | 9.696                      | 9.335                      | 9.215                      | -0.10                               | $-0.09 \pm 0.04$       | 1     | $12.66 \pm 0.07$ | $11199 \pm 460$ | c              | LIII              |
| DX Gem   | DCEPS  | 0.4966              | 8.759                      | 8.336                      | 8.207                      | -0.04                               | $-0.01 \pm 0.09$       | 1     | $12.78 \pm 0.09$ | $11407 \pm 473$ | c*             | LIII              |
| RZ Gem   | DCEP   | 0.7427              | 7.600                      | 7.165                      | 6.950                      | -0.44                               | $-0.16 \pm 0.03$       | 1     | $11.56 \pm 0.05$ | $9973 \pm 454$  | a              | LEM               |
| BE Mon   | DCEP   | 0.4322              | 8.256                      | 7.854                      | 7.676                      | -0.07                               | $0.05 \pm 0.09$        | 1     | $11.28 \pm 0.05$ | $9609 \pm 452$  | a              | LEM               |
| CV Mon   | DCEP   | 0.7307              | 7.314                      | 6.781                      | 6.529                      | -0.10                               | $0.09 \pm 0.09$        | 1     | $11.00 \pm 0.05$ | $9362 \pm 452$  | a              | LEM               |
| TW Mon   | CEP    | 0.8511              | 9.709                      | 9.137                      | 8.904                      | -0.15                               | $-0.13 \pm 0.07$       | 1     | $13.76 \pm 0.05$ | $13059 \pm 457$ | b <sup>†</sup> | LEM               |
| TX Mon   | DCEP   | 0.9396              | 8.569                      | 8.114                      | 7.922                      | -0.12                               | $-0.03 \pm 0.05$       | 1     | $13.19 \pm 0.05$ | $11790 \pm 452$ | a <sup>†</sup> | LEM               |
| V465 Mon | DCEP   | 0.4335              | 8.751                      | 8.440                      | 8.315                      | 0.02                                | $-0.07 \pm 0.07$       | 1     | $12.75 \pm 0.05$ | $11037 \pm 450$ | a              | LIII              |
| V495 Mon | DCEP   | 0.6124              | 9.827                      | 9.351                      | 9.185                      | -0.17                               | $-0.13 \pm 0.07$       | 1     | $13.35 \pm 0.05$ | $12098 \pm 453$ | a <sup>†</sup> | LEM               |
| V508 Mon | DCEP   | 0.6163              | 8.627                      | 8.277                      | 8.136                      | -0.25                               | $-0.04 \pm 0.10$       | 1     | $12.42 \pm 0.05$ | $10714 \pm 452$ | a              | LEM               |
| V510 Mon | DCEP   | 0.8637              | 9.507                      | 8.898                      | 8.648                      | -0.12                               | $-0.16 \pm 0.06$       | 1     | $13.51 \pm 0.05$ | $12550 \pm 456$ | b <sup>†</sup> | LEM               |
| XX Mon   | DCEP   | 0.7369              | 9.402                      | 8.903                      | 8.699                      | -0.18                               | $-0.10 \pm 0.08$       | 1     | $13.25 \pm 0.05$ | $11854 \pm 451$ | b <sup>†</sup> | LEM               |
| QZ Nor   | DCEPS  | 0.5782              | 7.085                      | 6.748                      | 6.614                      | 0.19                                | $0.21 \pm 0.06$        | 2     | $11.53 \pm 0.05$ | $6283 \pm 447$  | b              | G13               |
| SY Nor   | DCEP   | 1.1019              | 6.638                      | 6.091                      | 5.864                      | 0.34                                | $0.23 \pm 0.07$        | 2     | $11.59 \pm 0.05$ | $6286 \pm 446$  | b <sup>†</sup> | LIII              |
| CS Ori   | DCEP   | 0.5899              | 9.331                      | 8.954                      | 8.790                      | -0.19                               | $-0.25 \pm 0.06$       | 1     | $12.96 \pm 0.05$ | $11701 \pm 458$ | a              | LEM               |
| AQ Pup   | DCEP   | 1.4786              | 6.033                      | 5.495                      | 5.283                      | -0.26                               | $0.06 \pm 0.05$        | 1     | $12.29 \pm 0.05$ | $9472 \pm 436$  | b              | LEM               |
| BC Pup   | DCEP   | 0.5495              | 11.015                     | 10.475                     | 10.247                     | -0.23                               | $-0.31 \pm 0.07$       | 1     | $14.12 \pm 0.05$ | $12763 \pm 426$ | b <sup>†</sup> | LII               |
| BN Pup   | DCEP   | 1.1359              | 7.563                      | 7.090                      | 6.910                      | -0.03                               | $0.03 \pm 0.05$        | 1     | $12.83 \pm 0.05$ | $9930 \pm 428$  | b              | LEM               |
| CE Pup   | DCEP   | 1.6949              | 8.402                      | 7.816                      | 7.581                      | -0.04                               | $-0.04 \pm 0.09$       | 1     | $15.27 \pm 0.07$ | $14958 \pm 422$ | c              | LII               |
| CK Pup   | CEP    | 0.8703              | 10.273                     | 9.703                      | 9.456                      | -0.12                               | $-0.13 \pm 0.06$       | 2     | $14.37 \pm 0.05$ | $13357 \pm 423$ | b <sup>†</sup> | G13               |
| HW Pup   | DCEP   | 1.1289              | 9.468                      | 8.914                      | 8.716                      | -0.28                               | $-0.22 \pm 0.09$       | 1     | $14.55 \pm 0.07$ | $13554 \pm 436$ | c              | LEM               |
| LS Pup   | CEP    | 1.1506              | 8.030                      | 7.531                      | 7.341                      | -0.15                               | $-0.12 \pm 0.11$       | 1     | $13.29 \pm 0.05$ | $10610 \pm 423$ | b              | ROM               |
| VW Pup   | DCEP   | 0.6320              | 9.008                      | 8.514                      | 8.360                      | -0.19                               | $-0.14 \pm 0.06$       | 1     | $12.58 \pm 0.07$ | $10175 \pm 443$ | c              | LII               |
| VZ Pup   | DCEP   | 1.3649              | 7.309                      | 6.842                      | 6.657                      | -0.37                               | $-0.01 \pm 0.04$       | 1     | $13.35 \pm 0.05$ | $10867 \pm 425$ | b              | LEM               |
| WW Pup   | DCEP   | 0.7417              | 8.653                      | 8.274                      | 8.131                      | -0.18                               | $0.13 \pm 0.16$        | 1     | $12.82 \pm 0.05$ | $10382 \pm 436$ | b <sup>†</sup> | LII               |
| X Pup    | DCEP   | 1.4143              | 6.117                      | 5.614                      | 5.418                      | 0.05                                | $0.02 \pm 0.08$        | 1     | $12.24 \pm 0.05$ | $9788 \pm 441$  | b              | ROM               |
| KQ Sco   | DCEP   | 1.4577              | 5.945                      | 5.229                      | 4.924                      | 0.22                                | $0.52 \pm 0.08$        | 5     | $11.67 \pm 0.05$ | $5948 \pm 451$  | b              | ROM               |
| RY Sco   | DCEP   | 1.3078              | 4.930                      | 4.379                      | 4.134                      | 0.09                                | $0.01 \pm 0.06$        | 5     | $10.54 \pm 0.05$ | $6663 \pm 453$  | b              | LII               |
| V500 Sco | DCEP   | 0.9693              | 6.041                      | 5.532                      | 5.330                      | 0.01                                | $-0.07 \pm 0.08$       | 4     | $10.65 \pm 0.05$ | $6590 \pm 453$  | b              | LII               |
| RU Sct   | DCEP   | 1.2945              | 5.891                      | 5.287                      | 5.034                      | 0.11                                | $0.14 \pm 0.04$        | 2     | $11.35 \pm 0.05$ | $6361 \pm 449$  | a              | LIII              |
| UZ Sct   | DCEP   | 1.1686              | 7.405                      | 6.749                      | 6.461                      | 0.35                                | $0.33 \pm 0.08$        | 6     | $12.29 \pm 0.05$ | $5309 \pm 448$  | a <sup>†</sup> | PED               |
| V367 Sct | CEP(B) | 0.7989              | 7.605                      | 6.955                      | 6.651                      | -0.01                               | $0.05 \pm 0.08$        | 4     | $11.23 \pm 0.05$ | $6332 \pm 451$  | b              | LII               |
| Z Sct    | DCEP   | 1.1106              | 6.949                      | 6.477                      | 6.263                      | 0.33                                | $0.12 \pm 0.09$        | 5     | $12.08 \pm 0.05$ | $5733 \pm 445$  | a              | LIII              |
| AV Sgr   | DCEP   | 1.1879              | 6.878                      | 6.089                      | 5.730                      | 0.27                                | $0.35 \pm 0.17$        | 5     | $11.49 \pm 0.05$ | $5980 \pm 454$  | b <sup>†</sup> | PED               |
| VY Sgr   | DCEP   | 1.1322              | 7.156                      | 6.385                      | 6.042                      | 0.35                                | $0.33 \pm 0.12$        | 5     | $11.63 \pm 0.05$ | $5862 \pm 453$  | b <sup>†</sup> | PED               |
| WZ Sgr   | DCEP   | 1.3394              | 5.255                      | 4.752                      | 4.536                      | 0.19                                | $0.28 \pm 0.08$        | 5     | $11.10 \pm 0.05$ | $6326 \pm 453$  | a              | LII               |
| XX Sgr   | CEP    | 0.8078              | 6.436                      | 5.967                      | 5.747                      | 0.10                                | $-0.01 \pm 0.06$       | 5     | $10.55 \pm 0.07$ | $6706 \pm 453$  | c              | LII               |
| EZ Vel   | DCEP   | 1.5383              | 8.884                      | 8.203                      | 7.914                      | -0.01                               | $-0.17 \pm 0.15$       | 1     | $14.97 \pm 0.07$ | $12119 \pm 358$ | c              | LEM               |

**Notes.** From left to right the columns give the target name; the variable type (from GCVS); the logarithmic period; the mean magnitudes in  $J$ ,  $H$ , and  $K$  bands. Columns 7 and 8 give the iron abundance available in the literature rescaled to our solar abundance, and the current iron abundance. Column 9 gives the number of spectra used to estimate the mean iron abundance. Columns 10 and 11 list the true distance modulus and the Galactocentric distance. The last two columns give the notes on the NIR photometry and distances for individual objects and the references. **a)** Mean magnitudes provided by [Monson & Pierce \(2011\)](#) transformed into the 2MASS photometric system using the zero-points given in their Table 1. **b)** Mean magnitudes provided by [Laney & Stobie \(1992\)](#) and by Laney (priv. comm.) transformed into the 2MASS photometric system using the zero-points provided by [Koen et al. \(2007\)](#). The objects marked with a <sup>†</sup> (Laney, priv. comm.) do not have a complete coverage of the light-curve (the number of phase points ranges from 4 to 14). **c)** Mean magnitudes based on single-epoch measurements from the 2MASS catalog and the NIR template light curves provided by [Soszyński et al. \(2005\)](#). An asterisk indicates the use of single-epoch photometry in the distance determination (see Sect. 3 for details). For these stars the magnitudes listed in Cols. 4–6 are the single-epoch measurements retrieved from the 2MASS catalog. **d)** The weighted mean of the three true distance moduli. The errors account for uncertainties affecting the mean magnitudes and for the intrinsic dispersion of the adopted NIR PW relations. **e)** The weighted mean Galactocentric distances were estimated assuming  $R_G = 7.94 \pm 0.37 \pm 0.26$  kpc ([Groenewegen et al. 2008](#)). The errors account for uncertainties affecting both the solar Galactocentric distance and the heliocentric distances. **f)** References for the iron estimate given in Col. 7. The priority was given, in the following order, to evaluations from our group (G13: [Genovali et al. 2013](#); PED: [Pedicelli et al. \(2010\)](#); LEM: [Lemasle et al. \(2007, 2008\)](#); ROM: [Romaniello et al. \(2008\)](#)) and from the literature: LII: [Luck et al. \(2011\)](#); LIII: [Luck & Lambert \(2011\)](#).

**Table 4.** Galactic Cepheids for which the iron abundance was available in the literature.

| Name       | Type     | $\log(P)$<br>[days] | $\langle J \rangle$<br>mag | $\langle H \rangle$<br>mag | $\langle K \rangle$<br>mag | [Fe/H] <sub>lit</sub> | [Fe/H] | $\mu^d$<br>mag | $R_G^e$<br>(pc) | Notes          | Ref. <sup>f</sup> |
|------------|----------|---------------------|----------------------------|----------------------------|----------------------------|-----------------------|--------|----------------|-----------------|----------------|-------------------|
| T Ant      | DCEP     | 0.7707              | 7.914                      | 7.602                      | 7.494                      | -0.20                 | -0.23  | 12.35 ± 0.05   | 8706 ± 427      | b              | LIII              |
| BC Aql     | CEP      | 0.4632              | 11.634                     | 11.283                     | 11.180                     | -0.28                 | -0.31  | 14.97 ± 0.07   | 4578 ± 190      | c              | LIII              |
| EV Aql     | CEP      | 1.5885              | 8.990                      | 8.369                      | 8.162                      | 0.06                  | 0.03   | 15.48 ± 0.07   | 9249 ± 287      | c              | LIII              |
| FF Aql     | DCEPS    | 0.6504              | 4.030                      | 3.741                      | 3.525                      | 0.04                  | 0.10   | 8.71 ± 0.37    | 7592 ± 455      | c*             | LII               |
| FM Aql     | DCEP     | 0.7863              | 5.657                      | 5.210                      | 5.007                      | 0.24                  | 0.21   | 9.76 ± 0.05    | 7326 ± 450      | a              | LIII              |
| FN Aql     | DCEPS    | 0.9769              | 5.940                      | 5.485                      | 5.291                      | -0.06                 | -0.09  | 11.47 ± 0.05   | 6520 ± 445      | a              | LIII              |
| KL Aql     | DCEP     | 0.7859              | 8.488                      | 8.114                      | 7.979                      | 0.33                  | 0.30   | 12.82 ± 0.07   | 6573 ± 403      | c              | LIII              |
| SZ Aql     | DCEP     | 1.2340              | 5.836                      | 5.337                      | 5.121                      | 0.18                  | 0.24   | 11.33 ± 0.05   | 6527 ± 447      | a              | LII               |
| TT Aql     | DCEP     | 1.1384              | 4.634                      | 4.174                      | 3.998                      | 0.22                  | 0.19   | 9.94 ± 0.05    | 7176 ± 451      | a              | LIII              |
| U Aql      | DCEP     | 0.8466              | 4.400                      | 4.002                      | 3.844                      | 0.17                  | 0.14   | 8.86 ± 0.05    | 7448 ± 451      | b              | LIII              |
| V1162 Aql  | DCEPS    | 0.7305              | 6.133                      | 5.813                      | 5.663                      | 0.01                  | 0.07   | 11.11 ± 0.05   | 6609 ± 450      | a              | LII               |
| V1344 Aql  | DCEP     | 0.8738              | 5.177                      | 4.732                      | 4.536                      | 0.15                  | 0.12   | 9.59 ± 0.05    | 7317 ± 451      | a              | LIII              |
| V1359 Aql  | DCEPS:   | 0.5719              | 6.505                      | 5.824                      | 5.612                      | 0.28                  | 0.25   | 10.20 ± 0.07   | 7148 ± 450      | c*             | LIII              |
| V336 Aql   | DCEP     | 0.8635              | 7.149                      | 6.688                      | 6.484                      | 0.18                  | 0.15   | 11.48 ± 0.05   | 6399 ± 446      | a              | LIII              |
| V493 Aql   | DCEP     | 0.4753              | 8.464                      | 8.001                      | 7.817                      | 0.03                  | 0.00   | 11.52 ± 0.07   | 6344 ± 447      | c              | LIII              |
| V496 Aql   | DCEPS    | 0.8330              | 5.564                      | 5.136                      | 4.966                      | 0.05                  | 0.11   | 10.68 ± 0.05   | 6775 ± 450      | b              | LII               |
| V526 Aql   | CEP      | 0.6244              | 9.609                      | 9.174                      | 8.981                      | 0.50                  | 0.47   | 13.20 ± 0.07   | 5481 ± 386      | c              | LIII              |
| V600 Aql   | DCEP     | 0.8596              | 6.960                      | 6.447                      | 6.206                      | 0.03                  | 0.09   | 11.13 ± 0.05   | 6827 ± 446      | a              | LII               |
| V733 Aql   | DCEP     | 0.7909              | 8.333                      | 7.936                      | 7.851                      | 0.08                  | 0.14   | 12.72 ± 0.07   | 6329 ± 410      | c              | LII               |
| V916 Aql   | DCEP     | 1.1284              | 7.367                      | 6.764                      | 6.515                      | 0.39                  | 0.36   | 12.28 ± 0.05   | 6311 ± 428      | a              | LIII              |
| $\eta$ Aql | DCEP     | 0.8559              | 2.388                      | 2.062                      | 1.945                      | 0.08                  | 0.14   | 7.07 ± 0.05    | 7750 ± 452      | b              | LII               |
| AN Aur     | DCEP     | 1.0124              | 7.927                      | 7.446                      | 7.237                      | -0.10                 | -0.13  | 12.72 ± 0.05   | 11 355 ± 458    | a              | LIII              |
| CO Aur     | CEP(B)   | 0.2514              | 6.314                      | 6.004                      | 5.873                      | -0.01                 | -0.04  | 8.97 ± 0.13    | 8557 ± 453      | c*             | LIII              |
| CY Aur     | DCEP     | 1.1414              | 8.586                      | 7.958                      | 7.709                      | -0.12                 | -0.15  | 13.49 ± 0.05   | 12 755 ± 463    | a              | LIII              |
| ER Aur     | DCEP     | 1.1958              | 9.062                      | 8.601                      | 8.410                      | -0.27                 | -0.30  | 14.54 ± 0.05   | 15 884 ± 486    | a              | LIII              |
| EW Aur     | DCEP     | 0.4248              | 11.232                     | 10.755                     | 10.592                     | -0.54                 | -0.57  | 14.13 ± 0.06   | 14 506 ± 490    | c              | LIII              |
| FF Aur     | DCEP     | 0.3264              | 11.661                     | 11.070                     | 10.907                     | -0.51                 | -0.54  | 14.02 ± 0.06   | 14 192 ± 486    | c              | LIII              |
| GT Aur     | DCEP     | 0.6439              | 10.407                     | 10.083                     | 9.978                      | -0.02                 | -0.05  | 14.40 ± 0.07   | 15 355 ± 502    | c              | LIII              |
| GV Aur     | DCEP     | 0.7210              | 9.493                      | 9.011                      | 8.811                      | -0.21                 | -0.24  | 13.32 ± 0.07   | 12 513 ± 473    | c              | LIII              |
| IN Aur     | DCEP     | 0.6912              | 10.458                     | 9.904                      | 9.693                      | -0.28                 | -0.31  | 14.04 ± 0.06   | 14 305 ± 488    | c              | LIII              |
| RT Aur     | DCEP     | 0.5715              | 4.222                      | 3.987                      | 3.881                      | 0.13                  | 0.10   | 8.13 ± 0.05    | 8356 ± 452      | a              | LIII              |
| RX Aur     | DCEP     | 1.0654              | 5.726                      | 5.357                      | 5.212                      | 0.10                  | 0.07   | 10.99 ± 0.05   | 9480 ± 453      | a              | LIII              |
| V335 Aur   | DCEP     | 0.5331              | 9.863                      | 9.398                      | 9.195                      | -0.30                 | -0.33  | 13.08 ± 0.05   | 12 037 ± 461    | a              | LIII              |
| V637 Aur   | DCEPS    | 0.8949              | 8.519                      | 8.142                      | 7.955                      | -0.15                 | -0.18  | 13.91 ± 0.09   | 13 955 ± 510    | c*             | LIII              |
| AB Cam     | DCEP     | 0.7625              | 9.418                      | 8.936                      | 8.746                      | -0.08                 | -0.11  | 13.40 ± 0.06   | 12 132 ± 458    | c              | LIII              |
| AC Cam     | DCEP     | 0.6188              | 9.325                      | 8.752                      | 8.499                      | -0.13                 | -0.16  | 12.56 ± 0.06   | 10 675 ± 451    | c              | LIII              |
| AD Cam     | DCEP     | 1.0516              | 8.988                      | 8.363                      | 8.109                      | -0.25                 | -0.28  | 13.59 ± 0.07   | 12 444 ± 460    | c              | LIII              |
| AM Cam     | CEP      | 0.6018              | 10.179                     | 9.517                      | 9.313                      | -0.13                 | -0.16  | 13.28 ± 0.07   | 11 785 ± 456    | c              | LIII              |
| CK Cam     | DCEP     | 0.5172              | 0.000                      | 0.000                      | 0.000                      | 0.07                  | 0.04   | 8.93 ± 0.13    | 8486 ± 453      | c              | LIII              |
| LO Cam     | DCEP     | 1.1017              | 0.000                      | 0.000                      | 0.000                      | -0.05                 | -0.08  | 13.03 ± 0.23   | 11 487 ± 587    | c              | LIII              |
| MN Cam     | DCEP     | 0.9138              | 8.219                      | 7.609                      | 7.348                      | 0.01                  | -0.02  | 12.37 ± 0.07   | 10 578 ± 454    | c              | LIII              |
| MQ Cam     | DCEP     | 0.8195              | 9.255                      | 8.586                      | 8.310                      | -0.11                 | -0.14  | 12.96 ± 0.06   | 11 447 ± 457    | c              | LIII              |
| OX Cam     | DCEP     | 0.7050              | 7.329                      | 6.740                      | 6.478                      | -0.01                 | -0.04  | 10.82 ± 0.06   | 9152 ± 451      | c              | LIII              |
| PV Cam     | DCEPS:   | 0.4900              | 9.749                      | 9.341                      | 9.170                      | -0.17                 | -0.20  | 13.71 ± 0.08   | 12 872 ± 476    | c*             | LIII              |
| QS Cam     | DCEP     | 0.7093              | 9.373                      | 8.804                      | 8.622                      | -0.22                 | -0.25  | 13.03 ± 0.07   | 11 530 ± 458    | c              | LIII              |
| RW Cam     | DCEP     | 1.2152              | 5.817                      | 5.289                      | 5.077                      | 0.11                  | 0.08   | 11.21 ± 0.05   | 9414 ± 451      | a              | LIII              |
| RX Cam     | DCEP     | 0.8983              | 5.161                      | 4.726                      | 4.540                      | 0.11                  | 0.08   | 9.69 ± 0.05    | 8668 ± 451      | a              | LIII              |
| TV Cam     | DCEP     | 0.7239              | 9.345                      | 8.822                      | 8.653                      | 0.04                  | 0.01   | 13.16 ± 0.07   | 11 682 ± 457    | c              | LIII              |
| V359 Cam   | DCEP     | 0.8195              | 9.557                      | 9.078                      | 8.864                      | -0.16                 | -0.19  | 13.70 ± 0.06   | 13 026 ± 469    | c              | LIII              |
| CN Car     | DCEP     | 0.6931              | 8.345                      | 7.848                      | 7.704                      | 0.21                  | 0.18   | 12.14 ± 0.07   | 7761 ± 426      | c              | LIII              |
| CY Car     | DCEP     | 0.6300              | 7.949                      | 7.565                      | 7.430                      | 0.11                  | 0.08   | 11.74 ± 0.07   | 7496 ± 434      | c              | LIII              |
| DY Car     | DCEP     | 0.6697              | 9.160                      | 8.729                      | 8.563                      | 0.07                  | 0.04   | 12.96 ± 0.07   | 7635 ± 396      | c              | LIII              |
| ER Car     | DCEP     | 0.8875              | 5.360                      | 5.020                      | 4.899                      | 0.15                  | 0.12   | 10.12 ± 0.05   | 7641 ± 448      | b <sup>†</sup> | LIII              |
| EY Car     | DCEP     | 0.4588              | 8.352                      | 7.953                      | 7.808                      | -0.17                 | -0.18  | 11.53 ± 0.07   | 7563 ± 437      | c              | SZI               |
| FI Car     | DCEP     | 1.1290              | 8.350                      | 7.797                      | 7.502                      | 0.31                  | 0.28   | 13.28 ± 0.07   | 7845 ± 380      | c              | LIII              |
| FR Car     | DCEP     | 1.0301              | 7.470                      | 7.012                      | 6.835                      | 0.11                  | 0.08   | 12.41 ± 0.05   | 7410 ± 417      | b              | LIII              |
| GH Car     | DCEPS    | 0.7578              | 7.188                      | 6.872                      | 6.668                      | 0.22                  | 0.19   | 12.18 ± 0.09   | 7416 ± 424      | c*             | LIII              |
| GX Car     | DCEP     | 0.8571              | 7.197                      | 6.763                      | 6.555                      | 0.14                  | 0.11   | 11.55 ± 0.07   | 7791 ± 437      | c              | LIII              |
| GZ Car     | DCEPS(B) | 0.6190              | 8.126                      | 7.698                      | 7.528                      | -0.07                 | -0.08  | 11.75 ± 0.11   | 7681 ± 433      | c*             | SZI               |
| HQ Car     | DCEP     | 1.1483              | 10.791                     | 10.348                     | 10.185                     | -0.41                 | -0.10  | 16.18 ± 0.07   | 16 865 ± 471    | c              | YON               |
| HW Car     | DCEP     | 0.9638              | 7.239                      | 6.814                      | 6.663                      | 0.09                  | 0.06   | 12.06 ± 0.07   | 7567 ± 427      | c              | LIII              |
| IO Car     | CEP      | 1.1337              | 8.649                      | 8.133                      | 7.940                      | 0.13                  | 0.10   | 13.82 ± 0.08   | 8134 ± 343      | c              | LIII              |
| IT Car     | DCEP     | 0.8770              | 6.309                      | 5.924                      | 5.779                      | 0.14                  | 0.11   | 10.92 ± 0.05   | 7517 ± 444      | b <sup>†</sup> | LIII              |
| SX Car     | DCEP     | 0.6866              | 7.222                      | 6.853                      | 6.752                      | 0.05                  | 0.02   | 11.29 ± 0.07   | 7619 ± 440      | c              | LIII              |
| UW Car     | DCEP     | 0.7280              | 7.356                      | 6.947                      | 6.760                      | 0.09                  | 0.06   | 11.36 ± 0.07   | 7652 ± 439      | c              | LIII              |
| UY Car     | DCEP     | 0.7438              | 7.248                      | 6.887                      | 6.821                      | 0.13                  | 0.10   | 11.57 ± 0.07   | 7589 ± 436      | c              | LIII              |
| UZ Car     | DCEP     | 0.7164              | 7.646                      | 7.257                      | 7.110                      | 0.13                  | 0.10   | 11.70 ± 0.07   | 7583 ± 434      | c              | LIII              |
| V701 Car   | CEP(B)   | 0.6117              | 8.321                      | 7.799                      | 7.568                      | -0.11                 | -0.12  | 11.66 ± 0.16   | 7769 ± 435      | c*             | SZI               |
| WW Car     | DCEP     | 0.6699              | 7.723                      | 7.338                      | 7.186                      | 0.00                  | -0.03  | 11.62 ± 0.07   | 7551 ± 435      | c              | LIII              |
| XX Car     | DCEP     | 1.1963              | 7.176                      | 6.745                      | 6.566                      | 0.20                  | 0.17   | 12.72 ± 0.05   | 7423 ± 406      | b              | LIII              |
| XY Car     | DCEP     | 1.0946              | 6.915                      | 6.419                      | 6.227                      | 0.07                  | 0.04   | 11.99 ± 0.05   | 7402 ± 429      | b              | LIII              |
| XZ Car     | DCEP     | 1.2214              | 6.251                      | 5.759                      | 5.572                      | 0.19                  | 0.16   | 11.76 ± 0.05   | 7463 ± 433      | b              | LIII              |
| Y Car      | DCEP(B)  | 0.5611              | 6.802                      | 6.573                      | 6.477                      | -0.05                 | -0.06  | 10.69 ± 0.19   | 7682 ± 445      | c*             | SZI               |

**Notes.** From left to right the columns give the same quantities as in Table 3. Column 7 gives the original iron estimate available in the literature, while Col. 8 gives the iron abundance rescaled to current metallicity scale. In Col. 2 the GCVS classification type is listed. We note that V556 Cas and V1397 Cyg are misclassified in the GCVS since they have been identified as classical Cepheids by [Wils & Greaves \(2004\)](#). Moreover, their nature was confirmed by [Luck & Lambert \(2011\)](#) on the basis of spectroscopic evidence. The acronym SZI refers to [Sziládi et al. \(2007\)](#) and YON to [Yong et al. \(2006\)](#).

Table 4. continued.

| Name      | Type   | $\log(P)$<br>[days] | $\langle J \rangle$<br>mag | $\langle H \rangle$<br>mag | $\langle K \rangle$<br>mag | [Fe/H] <sub>lit</sub> | [Fe/H] | $\mu^d$<br>mag | $R_G^c$<br>(pc) | Notes          | Ref. <sup>f</sup> |
|-----------|--------|---------------------|----------------------------|----------------------------|----------------------------|-----------------------|--------|----------------|-----------------|----------------|-------------------|
| YZ Car    | DCEP   | 1.2592              | 6.432                      | 5.985                      | 5.800                      | 0.00                  | -0.03  | 12.15 ± 0.05   | 7668 ± 425      | b              | LIII              |
| AP Cas    | DCEP   | 0.8355              | 8.788                      | 8.189                      | 7.982                      | 0.05                  | 0.02   | 12.79 ± 0.07   | 10269 ± 440     | c              | LIII              |
| AS Cas    | CEP(B) | 0.4802              | 9.404                      | 8.837                      | 8.622                      | 0.02                  | -0.01  | 12.25 ± 0.15   | 9662 ± 458      | c*             | LIII              |
| AW Cas    | DCEP   | 0.6313              | 8.774                      | 8.206                      | 7.919                      | 0.03                  | 0.00   | 12.01 ± 0.07   | 9637 ± 445      | c              | LIII              |
| AY Cas    | DCEP   | 0.4581              | 9.055                      | 8.545                      | 8.315                      | 0.02                  | -0.01  | 11.90 ± 0.07   | 9602 ± 446      | c              | LIII              |
| BF Cas    | DCEP   | 0.5599              | 9.568                      | 9.032                      | 8.840                      | -0.05                 | -0.08  | 12.77 ± 0.06   | 10142 ± 436     | c              | LIII              |
| BP Cas    | DCEP   | 0.7975              | 7.842                      | 7.275                      | 7.042                      | 0.09                  | 0.06   | 11.72 ± 0.07   | 9392 ± 446      | c              | LIII              |
| BV Cas    | DCEP   | 0.7324              | 9.015                      | 8.394                      | 8.072                      | 0.02                  | -0.01  | 12.44 ± 0.07   | 10113 ± 445     | c              | LIII              |
| BY Cas    | DCEPS  | 0.5083              | 7.637                      | 7.199                      | 7.035                      | 0.12                  | 0.09   | 11.61 ± 0.12   | 9420 ± 453      | c*             | LIII              |
| CD Cas    | DCEP   | 0.8921              | 7.631                      | 7.090                      | 6.860                      | 0.13                  | 0.10   | 11.88 ± 0.05   | 9216 ± 441      | a              | LIII              |
| CF Cas    | DCEP   | 0.6880              | 8.590                      | 8.126                      | 7.900                      | 0.02                  | -0.01  | 12.29 ± 0.05   | 9579 ± 437      | a              | LIII              |
| CG Cas    | DCEP   | 0.6400              | 8.903                      | 8.299                      | 8.109                      | 0.09                  | 0.06   | 12.26 ± 0.07   | 9557 ± 440      | c              | LIII              |
| CH Cas    | DCEP   | 1.1786              | 7.331                      | 6.686                      | 6.385                      | 0.17                  | 0.23   | 12.25 ± 0.05   | 9405 ± 436      | a              | LII               |
| CT Cas    | DCEP   | 0.5810              | 9.455                      | 8.810                      | 8.600                      | -0.05                 | -0.08  | 12.51 ± 0.07   | 9892 ± 439      | c              | LIII              |
| CY Cas    | DCEP   | 1.1577              | 7.861                      | 7.174                      | 6.903                      | 0.06                  | 0.12   | 12.69 ± 0.05   | 9849 ± 432      | a              | LII               |
| CZ Cas    | DCEP   | 0.7532              | 8.622                      | 8.124                      | 7.855                      | 0.07                  | 0.04   | 12.42 ± 0.07   | 9621 ± 437      | c              | LIII              |
| DD Cas    | DCEP   | 0.9918              | 7.526                      | 7.067                      | 6.887                      | 0.10                  | 0.16   | 12.33 ± 0.05   | 9623 ± 437      | a              | LII               |
| DF Cas    | DCEP   | 0.5835              | 8.488                      | 8.036                      | 7.879                      | 0.13                  | 0.19   | 11.97 ± 0.07   | 9873 ± 449      | c              | LII               |
| DL Cas    | DCEP   | 0.9031              | 6.550                      | 6.101                      | 5.892                      | -0.01                 | 0.05   | 11.03 ± 0.05   | 8859 ± 447      | a              | LII               |
| DW Cas    | DCEP   | 0.6988              | 8.195                      | 7.671                      | 7.420                      | 0.06                  | 0.03   | 11.79 ± 0.07   | 9103 ± 442      | c              | LIII              |
| EX Cas    | DCEP   | 0.6340              | 9.556                      | 8.944                      | 8.742                      | -0.07                 | -0.10  | 12.86 ± 0.07   | 10202 ± 435     | c              | LIII              |
| FM Cas    | DCEP   | 0.7641              | 7.128                      | 6.747                      | 6.581                      | -0.09                 | -0.03  | 11.33 ± 0.05   | 8942 ± 445      | a              | LII               |
| FO Cas    | DCEP   | 0.8324              | 11.136                     | 10.529                     | 10.267                     | -0.56                 | -0.59  | 15.02 ± 0.06   | 15552 ± 459     | c              | LIII              |
| FW Cas    | DCEP   | 0.7950              | 9.408                      | 8.716                      | 8.393                      | -0.09                 | -0.12  | 12.92 ± 0.07   | 10460 ± 440     | c              | LIII              |
| GL Cas    | DCEP   | 0.6029              | 9.778                      | 9.432                      | 9.216                      | 0.03                  | 0.00   | 13.42 ± 0.07   | 11773 ± 449     | c              | LIII              |
| GM Cas    | DCEP   | 0.8733              | 7.823                      | 7.135                      | 6.870                      | -0.10                 | -0.13  | 11.70 ± 0.06   | 9596 ± 449      | c              | LIII              |
| GO Cas    | DCEP   | 0.5104              | 9.718                      | 9.160                      | 8.898                      | 0.12                  | 0.09   | 12.61 ± 0.06   | 10575 ± 449     | c              | LIII              |
| HK Cas    | DCEP   | 0.3979              | 12.016                     | 11.831                     | 11.668                     | 0.45                  | 0.42   | 15.34 ± 0.07   | 17296 ± 498     | c              | LIII              |
| IO Cas    | DCEP   | 0.7485              | 11.082                     | 10.612                     | 10.503                     | -0.49                 | -0.52  | 15.16 ± 0.07   | 16998 ± 499     | c              | LIII              |
| KK Cas    | DCEP   | 0.9134              | 8.632                      | 7.998                      | 7.774                      | 0.13                  | 0.10   | 12.80 ± 0.07   | 10043 ± 434     | c              | LIII              |
| LT Cas    | DCEP   | 0.7712              | 9.733                      | 9.264                      | 9.074                      | -0.36                 | -0.39  | 13.77 ± 0.06   | 12609 ± 454     | c              | LIII              |
| NP Cas    | DCEP   | 0.7903              | 9.584                      | 8.876                      | 8.550                      | 0.01                  | -0.02  | 13.05 ± 0.07   | 10572 ± 436     | c              | LIII              |
| NY Cas    | DCEPS  | 0.4507              | 11.398                     | 10.985                     | 10.850                     | -0.46                 | -0.49  | 15.27 ± 0.12   | 16839 ± 693     | c*             | LIII              |
| OP Cas    | DCEP   | 0.7414              | 8.778                      | 8.207                      | 7.966                      | 0.14                  | 0.11   | 12.45 ± 0.07   | 9945 ± 441      | c              | LIII              |
| OZ Cas    | DCEP   | 0.7059              | 8.491                      | 7.482                      | 7.074                      | 0.06                  | 0.03   | 11.01 ± 0.06   | 8962 ± 448      | c              | LIII              |
| PW Cas    | DCEP   | 0.6021              | 10.246                     | 9.679                      | 9.483                      | -0.06                 | -0.09  | 13.53 ± 0.07   | 10959 ± 425     | c              | LIII              |
| RS Cas    | DCEP   | 0.7991              | 6.769                      | 6.225                      | 5.968                      | 0.18                  | 0.15   | 10.66 ± 0.05   | 8589 ± 447      | a              | LIII              |
| RW Cas    | DCEP   | 1.1701              | 6.829                      | 6.366                      | 6.175                      | 0.22                  | 0.28   | 12.21 ± 0.05   | 9914 ± 444      | a              | LII               |
| RY Cas    | DCEP   | 1.0841              | 7.062                      | 6.549                      | 6.311                      | 0.26                  | 0.32   | 11.99 ± 0.05   | 9288 ± 440      | a              | LII               |
| SU Cas    | DCEPS  | 0.2899              | 4.483                      | 4.210                      | 4.114                      | 0.06                  | 0.12   | 8.10 ± 0.05    | 8229 ± 451      | b              | LII               |
| SW Cas    | DCEP   | 0.7357              | 7.400                      | 6.983                      | 6.801                      | -0.03                 | 0.03   | 11.42 ± 0.05   | 8774 ± 443      | a              | LII               |
| SY Cas    | DCEP   | 0.6097              | 7.816                      | 7.449                      | 7.287                      | 0.04                  | 0.10   | 11.53 ± 0.05   | 9068 ± 444      | a              | LII               |
| SZ Cas    | DCEPS  | 1.1346              | 6.814                      | 6.217                      | 6.007                      | 0.07                  | 0.04   | 12.61 ± 0.10   | 10557 ± 457     | c*             | LIII              |
| TU Cas    | CEP(B) | 0.3303              | 6.681                      | 6.441                      | 6.331                      | 0.03                  | 0.09   | 9.76 ± 0.25    | 8398 ± 453      | c*             | LII               |
| UZ Cas    | DCEP   | 0.6294              | 9.155                      | 8.679                      | 8.522                      | -0.05                 | -0.08  | 12.75 ± 0.06   | 10408 ± 442     | c              | LIII              |
| V1017 Cas | DCEP   | 0.6665              | 9.766                      | 9.289                      | 9.100                      | -0.18                 | -0.21  | 13.43 ± 0.06   | 11725 ± 447     | c              | LIII              |
| V1019 Cas | DCEPS  | 0.5587              | 8.390                      | 7.813                      | 7.566                      | 0.07                  | 0.04   | 12.17 ± 0.07   | 9312 ± 438      | c*             | LIII              |
| V1020 Cas | DCEP   | 0.6758              | 9.286                      | 8.569                      | 8.276                      | 0.15                  | 0.12   | 12.40 ± 0.07   | 9580 ± 437      | c              | LIII              |
| V1100 Cas | DCEP   | 0.6730              | 8.991                      | 8.351                      | 8.088                      | 0.02                  | -0.01  | 12.28 ± 0.07   | 9899 ± 444      | c              | LIII              |
| V1154 Cas | DCEP   | 0.3249              | 8.933                      | 8.554                      | 8.453                      | -0.06                 | -0.09  | 11.76 ± 0.07   | 9508 ± 447      | c              | LIII              |
| V1206 Cas | DCEP   | 0.6758              | 9.419                      | 8.871                      | 8.655                      | -0.16                 | -0.19  | 12.95 ± 0.06   | 10239 ± 432     | c              | LIII              |
| V342 Cas  | DCEP   | 0.5933              | 9.010                      | 8.510                      | 8.327                      | 0.03                  | 0.00   | 12.40 ± 0.06   | 9355 ± 433      | c              | LIII              |
| V379 Cas  | DCEPS  | 0.6340              | 6.816                      | 6.362                      | 6.217                      | 0.06                  | 0.12   | 11.23 ± 0.09   | 8950 ± 447      | c*             | LII               |
| V395 Cas  | DCEP   | 0.6061              | 8.446                      | 8.001                      | 7.874                      | 0.02                  | -0.01  | 12.06 ± 0.07   | 9849 ± 447      | c              | LIII              |
| V407 Cas  | DCEP   | 0.6613              | 9.404                      | 8.890                      | 8.673                      | 0.11                  | 0.08   | 12.95 ± 0.07   | 10270 ± 433     | c              | LIII              |
| V556 Cas  | RR:    | 0.7803              | 8.883                      | 8.292                      | 7.984                      | -0.01                 | -0.04  | 12.54 ± 0.29   | 10201 ± 549     | c*             | LIII              |
| V636 Cas  | DCEPS  | 0.9231              | 4.899                      | 4.158                      | 4.059                      | 0.07                  | 0.13   | 9.83 ± 0.29    | 8533 ± 458      | c*             | LII               |
| VV Cas    | DCEP   | 0.7929              | 8.316                      | 7.880                      | 7.697                      | -0.04                 | -0.07  | 12.49 ± 0.05   | 10260 ± 443     | a              | LIII              |
| VW Cas    | DCEP   | 0.7777              | 8.343                      | 7.844                      | 7.675                      | 0.19                  | 0.16   | 12.38 ± 0.07   | 9947 ± 443      | c              | LIII              |
| XY Cas    | DCEP   | 0.6534              | 7.735                      | 7.336                      | 7.156                      | 0.10                  | 0.07   | 11.51 ± 0.05   | 9178 ± 445      | a              | LIII              |
| AY Cen    | DCEP   | 0.7251              | 6.808                      | 6.431                      | 6.249                      | 0.08                  | 0.05   | 10.86 ± 0.07   | 7496 ± 444      | c              | LIII              |
| AZ Cen    | DCEPS  | 0.5066              | 7.222                      | 6.944                      | 6.831                      | 0.09                  | 0.06   | 11.55 ± 0.05   | 7392 ± 437      | b              | LIII              |
| BB Cen    | DCEPS  | 0.6018              | 7.922                      | 7.539                      | 7.369                      | 0.22                  | 0.19   | 12.31 ± 0.13   | 7140 ± 421      | c*             | LIII              |
| BK Cen    | CEP(B) | 0.5016              | 8.339                      | 7.947                      | 7.772                      | 0.07                  | 0.06   | 11.62 ± 0.16   | 7268 ± 437      | c*             | SZI               |
| KK Cen    | DCEP   | 1.0857              | 8.713                      | 8.117                      | 7.955                      | 0.24                  | 0.21   | 13.62 ± 0.07   | 7526 ± 349      | c              | LIII              |
| QY Cen    | DCEP   | 1.2493              | 7.374                      | 6.596                      | 6.242                      | 0.24                  | 0.21   | 12.22 ± 0.07   | 6427 ± 429      | c              | LIII              |
| UZ Cen    | CEP(B) | 0.5230              | 7.335                      | 6.957                      | 6.767                      | -0.19                 | -0.20  | 10.69 ± 0.16   | 7465 ± 446      | c*             | SZI               |
| V1048 Cen | CEP(B) | -0.0351             | 9.113                      | 8.799                      | 8.719                      | -0.18                 | -0.19  | 10.88 ± 0.08   | 7493 ± 444      | c*             | SZI               |
| V1210 Cen | CEP(B) | 0.6352              | 7.603                      | 7.173                      | 6.968                      | -0.02                 | -0.03  | 11.23 ± 0.06   | 6775 ± 445      | c*             | SZI               |
| V378 Cen  | DCEPS  | 0.8102              | 6.328                      | 5.909                      | 5.743                      | 0.08                  | 0.05   | 11.38 ± 0.05   | 6993 ± 441      | b <sup>†</sup> | LIII              |
| V381 Cen  | CEP    | 0.7058              | 6.143                      | 5.822                      | 5.703                      | 0.02                  | -0.01  | 10.33 ± 0.05   | 7235 ± 449      | b <sup>†</sup> | LIII              |
| v419 Cen  | DCEPS  | 0.7409              | 6.706                      | 6.461                      | 6.273                      | 0.14                  | 0.11   | 11.79 ± 0.09   | 7392 ± 433      | c*             | LIII              |
| V496 Cen  | DCEP   | 0.6458              | 7.424                      | 6.977                      | 6.784                      | 0.09                  | 0.06   | 11.07 ± 0.07   | 7145 ± 444      | c              | LIII              |
| V659 Cen  | DCEP   | 0.7499              | 5.177                      | 4.907                      | 4.651                      | 0.09                  | 0.06   | 9.38 ± 0.07    | 7504 ± 451      | c              | LIII              |
| V737 Cen  | DCEP   | 0.8492              | 4.951                      | 4.573                      | 4.432                      | 0.14                  | 0.11   | 9.48 ± 0.05    | 7403 ± 451      | b <sup>†</sup> | LIII              |
| AK Cep    | DCEP   | 0.8593              | 8.400                      | 7.896                      | 7.703                      | 0.05                  | 0.02   | 12.66 ± 0.05   | 9420 ± 426      | a              | LIII              |
| CN Cep    | DCEP   | 0.9778              | 8.329                      | 7.641                      | 7.333                      | 0.06                  | 0.03   | 12.49 ± 0.05   | 9649 ± 434      | a              | LIII              |
| CP Cep    | DCEP   | 1.2519              | 7.335                      | 6.724                      | 6.476                      | -0.01                 | 0.05   | 12.64 ± 0.05   | 9175 ± 423      | a              | LII               |
| CR Cep    | DCEP   | 0.7947              | 6.641                      | 6.097                      | 5.873                      | -0.06                 | -0.00  | 10.57 ± 0.05   | 8424 ± 447      | a              | LII               |
| DR Cep    | DCEP   | 1.2803              | 9.471                      | 8.851                      | 8.695                      | -0.14                 | -0.17  | 15.00 ± 0.07   | 13289 ± 389     | c              | LIII              |

Table 4. continued.

| Name      | Type   | log( <i>P</i> )<br>[days] | $\langle J \rangle$<br>mag | $\langle H \rangle$<br>mag | $\langle K \rangle$<br>mag | [Fe/H] <sub>lit</sub> | [Fe/H] | $\mu^d$<br>mag | $R_G^c$<br>(pc) | Notes          | Ref. <sup>f</sup> |
|-----------|--------|---------------------------|----------------------------|----------------------------|----------------------------|-----------------------|--------|----------------|-----------------|----------------|-------------------|
| IR Cep    | DCEP   | 0.3251                    | 5.907                      | 5.593                      | 5.454                      | 0.05                  | 0.11   | 9.58 ± 0.09    | 8169 ± 450      | c              | LII               |
| IY Cep    | CEP    | 0.7526                    | 9.871                      | 9.123                      | 8.843                      | 0.11                  | 0.08   | 13.21 ± 0.06   | 9777 ± 412      | c              | LIII              |
| MU Cep    | CEP    | 0.5761                    | 9.370                      | 8.783                      | 8.632                      | 0.18                  | 0.15   | 12.60 ± 0.07   | 9321 ± 428      | c              | LIII              |
| V901 Cep  | DCEP   | 0.9542                    | 8.022                      | 7.351                      | 7.073                      | 0.04                  | 0.01   | 12.18 ± 0.07   | 9138 ± 436      | c              | LIII              |
| V911 Cep  | DCEP   | 0.6312                    | 8.854                      | 8.220                      | 7.977                      | -0.02                 | -0.05  | 12.04 ± 0.07   | 9076 ± 437      | c              | LIII              |
| δCep      | DCEP   | 0.7297                    | 2.700                      | 2.397                      | 2.306                      | 0.12                  | 0.09   | 7.04 ± 0.05    | 8010 ± 452      | b              | LIII              |
| AV Cir    | DCEP   | 0.4864                    | 5.582                      | 5.236                      | 5.093                      | 0.17                  | 0.14   | 9.68 ± 0.05    | 7371 ± 450      | b <sup>†</sup> | LIII              |
| AX Cir    | DCEP   | 0.7221                    | 4.299                      | 3.879                      | 3.780                      | -0.01                 | -0.04  | 8.41 ± 0.17    | 7603 ± 452      | c              | LIII              |
| BP Cir    | CEP    | 0.3799                    | 5.918                      | 5.612                      | 5.483                      | 0.02                  | -0.01  | 9.74 ± 0.05    | 7326 ± 450      | b <sup>†</sup> | LIII              |
| VZ Cma    | DCEPS  | 0.4950                    | 7.221                      | 6.806                      | 6.605                      | -0.06                 | -0.00  | 11.13 ± 0.10   | 8903 ± 449      | c*             | LII               |
| XZ Cma    | CEP    | 0.4082                    | 10.970                     | 10.558                     | 10.390                     | -0.57                 | -0.26  | 13.92 ± 0.07   | 12 567 ± 447    | c              | YON               |
| AD Cru    | DCEP   | 0.8060                    | 8.198                      | 7.661                      | 7.387                      | 0.11                  | 0.08   | 12.10 ± 0.07   | 7075 ± 427      | c              | LIII              |
| AG Cru    | DCEP   | 0.5840                    | 6.674                      | 6.353                      | 6.230                      | 0.08                  | 0.05   | 10.44 ± 0.05   | 7371 ± 447      | b              | LIII              |
| BG Cru    | DCEPS  | 0.5241                    | 4.237                      | 3.975                      | 3.878                      | -0.08                 | -0.11  | 8.68 ± 0.05    | 7678 ± 451      | b              | LIII              |
| R Cru     | DCEP   | 0.7654                    | 5.260                      | 4.931                      | 4.810                      | 0.13                  | 0.10   | 9.63 ± 0.05    | 7559 ± 450      | b <sup>†</sup> | LIII              |
| S Cru     | DCEP   | 0.6712                    | 5.086                      | 4.755                      | 4.632                      | 0.11                  | 0.08   | 9.13 ± 0.05    | 7593 ± 451      | b              | LIII              |
| T Cru     | DCEP   | 0.8282                    | 4.941                      | 4.541                      | 4.407                      | 0.14                  | 0.11   | 9.37 ± 0.05    | 7599 ± 450      | b <sup>†</sup> | LIII              |
| VW Cru    | DCEP   | 0.7214                    | 6.805                      | 6.261                      | 6.051                      | 0.19                  | 0.16   | 10.51 ± 0.07   | 7370 ± 447      | c              | LIII              |
| X Cru     | DCEP   | 0.7938                    | 6.521                      | 6.125                      | 5.935                      | 0.15                  | 0.12   | 10.76 ± 0.07   | 7283 ± 446      | c              | LIII              |
| BZ Cyg    | DCEP   | 1.0061                    | 6.758                      | 6.147                      | 5.864                      | 0.19                  | 0.25   | 11.19 ± 0.05   | 7971 ± 441      | a              | LII               |
| CD Cyg    | DCEP   | 1.2323                    | 6.347                      | 5.842                      | 5.647                      | 0.15                  | 0.12   | 11.86 ± 0.05   | 7513 ± 431      | a              | LIII              |
| DT Cyg    | DCEPS  | 0.3978                    | 4.638                      | 4.390                      | 4.374                      | 0.10                  | 0.16   | 8.80 ± 0.18    | 7827 ± 451      | c*             | LII               |
| EP Cyg    | DCEP   | 0.6323                    | 10.112                     | 9.687                      | 9.483                      | -0.06                 | -0.09  | 13.73 ± 0.05   | 7674 ± 339      | a              | LIII              |
| EU Cyg    | CEP    | 1.1758                    | 10.177                     | 9.679                      | 9.456                      | -0.20                 | -0.23  | 15.47 ± 0.06   | 11 847 ± 314    | c              | LIII              |
| EX Cyg    | DCEP   | 0.6858                    | 9.665                      | 9.023                      | 8.752                      | 0.25                  | 0.22   | 12.98 ± 0.06   | 7391 ± 393      | c              | LIII              |
| EZ Cyg    | DCEP   | 1.0667                    | 8.190                      | 7.667                      | 7.460                      | 0.28                  | 0.25   | 13.10 ± 0.05   | 7389 ± 386      | a              | LIII              |
| GH Cyg    | DCEP   | 0.8931                    | 7.251                      | 6.799                      | 6.577                      | 0.21                  | 0.18   | 11.67 ± 0.05   | 7351 ± 435      | a              | LIII              |
| GI Cyg    | DCEP   | 0.7621                    | 8.756                      | 8.225                      | 7.985                      | 0.27                  | 0.24   | 12.57 ± 0.07   | 7494 ± 412      | c              | LIII              |
| GL Cyg    | CEP    | 0.5277                    | 11.173                     | 10.633                     | 10.481                     | 0.05                  | 0.02   | 14.32 ± 0.07   | 9314 ± 320      | c              | LIII              |
| IY Cyg    | CEP    | 1.3375                    | 9.523                      | 8.637                      | 8.328                      | -0.09                 | -0.12  | 14.54 ± 0.06   | 8976 ± 283      | c              | LIII              |
| KX Cyg    | DCEP   | 1.3020                    | 6.867                      | 5.995                      | 5.589                      | 0.21                  | 0.18   | 11.64 ± 0.05   | 7804 ± 435      | a              | LIII              |
| MW Cyg    | DCEP   | 0.7749                    | 6.688                      | 6.206                      | 5.984                      | 0.09                  | 0.15   | 10.66 ± 0.05   | 7605 ± 445      | a              | LII               |
| SU Cyg    | DCEP   | 0.5850                    | 5.629                      | 5.390                      | 5.268                      | -0.03                 | 0.03   | 9.55 ± 0.05    | 7629 ± 450      | a              | LII               |
| SZ Cyg    | DCEP   | 1.1793                    | 6.517                      | 5.957                      | 5.709                      | 0.09                  | 0.15   | 11.67 ± 0.05   | 8023 ± 435      | a              | LII               |
| TX Cyg    | DCEP   | 1.1676                    | 5.326                      | 4.630                      | 4.307                      | 0.20                  | 0.26   | 10.08 ± 0.05   | 7905 ± 448      | a              | LII               |
| V1020 Cyg | DCEP   | 0.6920                    | 9.697                      | 8.958                      | 8.655                      | 0.29                  | 0.26   | 12.81 ± 0.07   | 7473 ± 402      | c              | LIII              |
| V1025 Cyg | DCEP   | 0.8427                    | 9.534                      | 8.849                      | 8.562                      | 0.23                  | 0.20   | 13.28 ± 0.06   | 7518 ± 376      | c              | LIII              |
| V1033 Cyg | CEP    | 0.6935                    | 9.503                      | 8.918                      | 8.673                      | 0.12                  | 0.09   | 12.99 ± 0.07   | 7559 ± 394      | c              | LIII              |
| V1046 Cyg | CEP    | 0.6941                    | 8.978                      | 8.257                      | 8.012                      | 0.23                  | 0.20   | 12.22 ± 0.06   | 7679 ± 423      | c              | LIII              |
| V1154 Cyg | CEP    | 0.6925                    | 7.457                      | 7.094                      | 6.964                      | -0.10                 | -0.04  | 11.51 ± 0.07   | 7746 ± 437      | c              | LII               |
| V1334 Cyg | DCEPS  | 0.5228                    | 5.170                      | 4.664                      | 4.460                      | 0.03                  | 0.09   | 9.00 ± 0.13    | 7895 ± 450      | c*             | LII               |
| V1364 Cyg | DCEP   | 1.1132                    | 9.104                      | 8.351                      | 8.055                      | 0.29                  | 0.26   | 13.62 ± 0.05   | 8109 ± 356      | a              | LIII              |
| V1397 Cyg | IS:    | 0.6665                    | 9.127                      | 8.507                      | 8.262                      | 0.01                  | -0.02  | 12.46 ± 0.27   | 8874 ± 459      | c*             | LIII              |
| V1726 Cyg | DCEPS  | 0.6269                    | 7.181                      | 6.836                      | 6.699                      | -0.02                 | 0.04   | 11.78 ± 0.07   | 8352 ± 435      | c*             | LII               |
| V347 Cyg  | DCEP   | 0.9413                    | 8.874                      | 8.237                      | 7.969                      | 0.25                  | 0.22   | 13.06 ± 0.07   | 8679 ± 402      | c              | LIII              |
| V356 Cyg  | DCEP   | 0.7039                    | 9.802                      | 9.271                      | 9.046                      | 0.17                  | 0.14   | 13.45 ± 0.07   | 9203 ± 390      | c              | LIII              |
| V386 Cyg  | DCEP   | 0.7208                    | 6.363                      | 5.806                      | 5.524                      | 0.11                  | 0.17   | 9.93 ± 0.05    | 7923 ± 448      | a              | LII               |
| V396 Cyg  | DCEP   | 1.5218                    | 6.072                      | 5.053                      | 4.588                      | 0.11                  | 0.08   | 11.23 ± 0.05   | 7799 ± 440      | a              | LIII              |
| V402 Cyg  | DCEP   | 0.6400                    | 7.799                      | 7.411                      | 7.247                      | 0.02                  | 0.08   | 11.57 ± 0.05   | 7638 ± 436      | a              | LII               |
| V438 Cyg  | DCEP   | 1.0496                    | 6.780                      | 6.074                      | 5.723                      | 0.33                  | 0.30   | 11.08 ± 0.05   | 7755 ± 442      | a              | LIII              |
| V459 Cyg  | DCEP   | 0.8604                    | 7.600                      | 7.071                      | 6.847                      | 0.09                  | 0.06   | 11.77 ± 0.05   | 8273 ± 435      | a              | LIII              |
| V492 Cyg  | DCEP   | 0.8797                    | 8.750                      | 8.145                      | 7.859                      | 0.24                  | 0.21   | 12.76 ± 0.07   | 7688 ± 405      | c              | LIII              |
| V495 Cyg  | DCEP   | 0.8276                    | 7.110                      | 6.539                      | 6.252                      | 0.24                  | 0.21   | 11.00 ± 0.05   | 7632 ± 443      | a              | LIII              |
| V514 Cyg  | DCEP   | 0.7075                    | 7.647                      | 7.011                      | 6.702                      | 0.18                  | 0.15   | 10.99 ± 0.05   | 7957 ± 443      | a              | LIII              |
| V520 Cyg  | DCEP   | 0.6074                    | 8.229                      | 7.755                      | 7.590                      | 0.08                  | 0.05   | 11.74 ± 0.07   | 8153 ± 435      | c              | LIII              |
| V532 Cyg  | DCEPS  | 0.5164                    | 6.863                      | 6.393                      | 6.250                      | -0.04                 | 0.02   | 10.85 ± 0.10   | 8049 ± 444      | c*             | LII               |
| V538 Cyg  | DCEP   | 0.7867                    | 7.791                      | 7.306                      | 7.099                      | 0.05                  | 0.02   | 11.82 ± 0.05   | 8473 ± 435      | a              | LIII              |
| V547 Cyg  | DCEP   | 0.7942                    | 10.065                     | 9.530                      | 9.316                      | 0.15                  | 0.12   | 14.02 ± 0.06   | 8468 ± 328      | c              | LIII              |
| V609 Cyg  | DCEP   | 1.4924                    | 6.815                      | 6.122                      | 5.783                      | 0.22                  | 0.19   | 12.65 ± 0.05   | 8949 ± 420      | a              | LIII              |
| V621 Cyg  | DCEP   | 0.7682                    | 9.367                      | 8.735                      | 8.540                      | 0.12                  | 0.09   | 13.10 ± 0.07   | 9156 ± 407      | c              | LIII              |
| V924 Cyg  | DCEPS  | 0.7460                    | 8.963                      | 8.654                      | 8.511                      | -0.09                 | -0.03  | 14.03 ± 0.08   | 7987 ± 321      | c*             | LII               |
| VX Cyg    | DCEP   | 1.3039                    | 6.694                      | 6.078                      | 5.840                      | 0.09                  | 0.15   | 12.19 ± 0.05   | 8037 ± 426      | a              | LII               |
| VY Cyg    | DCEP   | 0.8953                    | 6.999                      | 6.548                      | 6.337                      | 0.00                  | 0.06   | 11.45 ± 0.05   | 7937 ± 438      | a              | LII               |
| VZ Cyg    | DCEP   | 0.6870                    | 7.186                      | 6.852                      | 6.699                      | 0.05                  | 0.11   | 11.23 ± 0.05   | 8174 ± 441      | a              | LII               |
| X Cyg     | DCEP   | 1.2145                    | 4.417                      | 3.969                      | 3.815                      | 0.10                  | 0.16   | 10.04 ± 0.05   | 7772 ± 448      | b              | LII               |
| EK Del    | CEP    | 0.3111                    | 11.292                     | 10.953                     | 10.887                     | -1.54                 | -1.57  | 14.20 ± 0.07   | 6867 ± 292      | c              | LIII              |
| W Gem     | DCEP   | 0.8984                    | 5.117                      | 4.768                      | 4.633                      | 0.02                  | -0.01  | 9.87 ± 0.05    | 8843 ± 452      | a              | LIII              |
| BB Her    | DCEP   | 0.8755                    | 8.076                      | 7.675                      | 7.538                      | 0.26                  | 0.23   | 12.66 ± 0.06   | 5950 ± 418      | c              | LIII              |
| BG Lac    | DCEP   | 0.7269                    | 7.009                      | 6.649                      | 6.473                      | 0.07                  | 0.04   | 11.11 ± 0.05   | 8191 ± 443      | a              | LIII              |
| DF Lac    | DCEP   | 0.6512                    | 9.429                      | 9.054                      | 8.848                      | 0.04                  | 0.01   | 13.20 ± 0.07   | 9834 ± 415      | c              | LIII              |
| FQ Lac    | CEP:   | 1.0518                    | 11.234                     | 10.278                     | 9.630                      | -0.20                 | -0.23  | 14.64 ± 0.07   | 13 114 ± 413    | c              | LIII              |
| RR Lac    | DCEP   | 0.8073                    | 6.967                      | 6.620                      | 6.468                      | 0.04                  | 0.01   | 11.40 ± 0.05   | 8647 ± 442      | a              | LIII              |
| V Lac     | DCEP   | 0.6975                    | 7.034                      | 6.667                      | 6.531                      | 0.06                  | 0.03   | 11.08 ± 0.05   | 8552 ± 444      | a              | LIII              |
| V411 Lac  | DCEPS  | 0.4639                    | 6.309                      | 6.033                      | 5.929                      | 0.02                  | -0.01  | 10.51 ± 0.07   | 8279 ± 447      | c*             | LIII              |
| X Lac     | DCEPS  | 0.7360                    | 6.492                      | 6.139                      | 5.969                      | 0.08                  | 0.05   | 11.40 ± 0.05   | 8676 ± 442      | a              | LIII              |
| Y Lac     | DCEP   | 0.6359                    | 7.612                      | 7.310                      | 7.180                      | 0.03                  | 0.00   | 11.58 ± 0.05   | 8500 ± 439      | a              | LIII              |
| Z Lac     | DCEP   | 1.0369                    | 6.210                      | 5.804                      | 5.630                      | 0.10                  | 0.07   | 11.27 ± 0.05   | 8603 ± 443      | a              | LIII              |
| V473 Lyr  | DCEPS: | 0.1734                    | 5.470                      | 4.700                      | 4.549                      | -0.06                 | -0.09  | 7.86 ± 0.18    | 7764 ± 452      | c*             | LIII              |
| AA Mon    | DCEP   | 0.5953                    | 9.729                      | 9.199                      | 8.953                      | -0.09                 | -0.12  | 12.97 ± 0.05   | 11 330 ± 450    | a <sup>†</sup> | LIII              |
| AC Mon    | DCEP   | 0.9039                    | 7.577                      | 7.066                      | 6.849                      | -0.03                 | -0.06  | 11.94 ± 0.05   | 9895 ± 448      | a              | LIII              |



Table 4. continued.

| Name     | Type   | $\log(P)$<br>[days] | $\langle J \rangle$<br>mag | $\langle H \rangle$<br>mag | $\langle K \rangle$<br>mag | [Fe/H] <sub>lit</sub> | [Fe/H] | $\mu^d$<br>mag | $R_G^e$<br>(pc) | Notes          | Ref. <sup>f</sup> |
|----------|--------|---------------------|----------------------------|----------------------------|----------------------------|-----------------------|--------|----------------|-----------------|----------------|-------------------|
| CS Mon   | CEP    | 0.8281              | 8.634                      | 8.160                      | 7.949                      | -0.08                 | -0.11  | 12.82 ± 0.07   | 11 367 ± 461    | c              | LIII              |
| CU Mon   | DCEP   | 0.6728              | 10.595                     | 10.007                     | 9.762                      | -0.23                 | -0.26  | 14.00 ± 0.05   | 13 735 ± 461    | b <sup>†</sup> | LIII              |
| EE Mon   | DCEP   | 0.6821              | 10.866                     | 10.309                     | 10.094                     | -0.52                 | -0.55  | 14.41 ± 0.07   | 14 593 ± 477    | c              | LIII              |
| FG Mon   | DCEP   | 0.6529              | 10.513                     | 9.976                      | 9.743                      | -0.14                 | -0.17  | 13.96 ± 0.05   | 13 226 ± 450    | b <sup>†</sup> | LIII              |
| FI Mon   | DCEP   | 0.5169              | 10.425                     | 9.939                      | 9.733                      | -0.11                 | -0.14  | 13.55 ± 0.05   | 12 257 ± 447    | b <sup>†</sup> | LIII              |
| V446 Mon | CEP    | 0.2832              | 11.301                     | 10.791                     | 10.585                     | -0.30                 | -0.33  | 13.59 ± 0.07   | 12 716 ± 466    | c              | LIII              |
| V447 Mon | CEP    | 0.3951              | 10.111                     | 10.331                     | 10.854                     | -0.37                 | -0.40  | 15.21 ± 0.05   | 18 399 ± 502    | b <sup>†</sup> | LIII              |
| V484 Mon | CEP    | 0.4963              | 10.968                     | 10.533                     | 10.302                     | -0.06                 | -0.09  | 14.07 ± 0.07   | 13 862 ± 476    | c              | LIII              |
| V504 Mon | CEP    | 0.4431              | 9.713                      | 9.258                      | 9.071                      | 0.01                  | -0.02  | 13.33 ± 0.12   | 12 006 ± 503    | c              | LIII              |
| V526 Mon | DCEPS  | 0.4273              | 7.314                      | 7.075                      | 6.962                      | -0.17                 | -0.20  | 11.44 ± 0.08   | 9591 ± 453      | c*             | LIII              |
| V911 Mon | DCEP   | 0.6971              | 9.481                      | 8.932                      | 8.694                      | -0.01                 | -0.04  | 13.05 ± 0.07   | 11 822 ± 464    | c              | LIII              |
| VZ Mon   | DCEP   | 0.7062              | 10.088                     | 9.421                      | 9.132                      | -0.07                 | -0.10  | 13.40 ± 0.05   | 12 539 ± 461    | b <sup>†</sup> | LIII              |
| YY Mon   | DCEP   | 0.5384              | 11.314                     | 10.802                     | 10.638                     | -0.46                 | -0.49  | 14.53 ± 0.06   | 15 011 ± 480    | c              | LIII              |
| R Mus    | DCEP   | 0.8757              | 4.904                      | 4.577                      | 4.465                      | -0.08                 | -0.11  | 9.66 ± 0.05    | 7523 ± 450      | b <sup>†</sup> | LIII              |
| RT Mus   | DCEP   | 0.4894              | 7.181                      | 6.809                      | 6.660                      | 0.12                  | 0.09   | 10.50 ± 0.05   | 7464 ± 447      | b              | LIII              |
| TZ Mus   | DCEP   | 0.6942              | 8.944                      | 8.405                      | 8.180                      | 0.10                  | 0.07   | 12.54 ± 0.07   | 7106 ± 413      | c              | LIII              |
| BF Oph   | DCEP   | 0.6094              | 5.652                      | 5.495                      | 5.311                      | 0.14                  | 0.11   | 9.70 ± 0.05    | 7081 ± 452      | b              | LIII              |
| Y Oph    | DCEPS  | 1.2336              | 3.374                      | 2.882                      | 2.673                      | 0.06                  | 0.12   | 9.70 ± 0.05    | 7141 ± 452      | b              | LII               |
| CR Ori   | DCEP   | 0.6911              | 9.705                      | 9.294                      | 9.114                      | -0.19                 | -0.22  | 13.59 ± 0.06   | 13 023 ± 474    | c              | LIII              |
| DF Ori   | DCEP   | 0.5025              | 10.618                     | 10.090                     | 9.834                      | -0.28                 | -0.31  | 13.54 ± 0.07   | 12 868 ± 473    | c              | LIII              |
| AS Per   | DCEP   | 0.6966              | 6.928                      | 6.477                      | 6.258                      | 0.14                  | 0.11   | 10.70 ± 0.05   | 9199 ± 452      | a              | LIII              |
| AW Per   | DCEP   | 0.8105              | 5.213                      | 4.832                      | 4.657                      | 0.04                  | 0.01   | 9.56 ± 0.05    | 8731 ± 452      | a              | LIII              |
| BM Per   | DCEP   | 1.3608              | 6.667                      | 6.005                      | 5.706                      | 0.23                  | 0.20   | 12.17 ± 0.05   | 10 480 ± 453    | a              | LIII              |
| CI Per   | CEP    | 0.5286              | 10.666                     | 10.427                     | 10.293                     | -0.32                 | -0.35  | 14.38 ± 0.07   | 14 135 ± 465    | c              | LIII              |
| DW Per   | DCEP   | 0.5623              | 9.181                      | 8.733                      | 8.537                      | -0.05                 | -0.08  | 12.54 ± 0.06   | 10 509 ± 449    | c              | LIII              |
| GP Per   | CEP    | 0.3100              | 11.590                     | 11.124                     | 11.001                     | -0.80                 | -0.83  | 14.18 ± 0.07   | 14 508 ± 488    | c              | LIII              |
| HQ Per   | CEP    | 0.9364              | 9.179                      | 8.626                      | 8.465                      | -0.35                 | -0.38  | 13.67 ± 0.06   | 13 198 ± 475    | c              | LIII              |
| HZ Per   | DCEP   | 1.0523              | 9.149                      | 8.339                      | 8.002                      | -0.25                 | -0.28  | 13.30 ± 0.05   | 12 274 ± 459    | a              | LIII              |
| MM Per   | DCEP   | 0.6147              | 8.655                      | 8.260                      | 8.086                      | -0.07                 | -0.10  | 12.32 ± 0.05   | 10 554 ± 452    | a              | LIII              |
| OT Per   | DCEP   | 1.4165              | 8.735                      | 7.914                      | 7.565                      | -0.07                 | -0.10  | 14.07 ± 0.05   | 14 178 ± 470    | a              | LIII              |
| SV Per   | DCEP   | 1.0465              | 6.789                      | 6.354                      | 6.177                      | 0.06                  | 0.03   | 11.83 ± 0.05   | 10 177 ± 454    | a              | LIII              |
| SX Per   | DCEP   | 0.6325              | 8.757                      | 8.347                      | 8.167                      | -0.03                 | -0.06  | 12.44 ± 0.05   | 10 851 ± 455    | a              | LIII              |
| UX Per   | DCEP   | 0.6595              | 9.577                      | 9.171                      | 9.009                      | -0.05                 | -0.08  | 13.39 ± 0.07   | 11 736 ± 450    | c              | LIII              |
| UY Per   | DCEP   | 0.7296              | 8.079                      | 7.536                      | 7.334                      | 0.18                  | 0.15   | 11.82 ± 0.06   | 9737 ± 449      | c              | LIII              |
| V440 Per | DCEPS  | 0.8791              | 5.072                      | 4.598                      | 4.180                      | -0.04                 | 0.02   | 9.84 ± 0.18    | 8628 ± 454      | c*             | LII               |
| V891 Per | DCEP   | 0.5079              | 9.092                      | 8.445                      | 8.164                      | 0.09                  | 0.06   | 11.78 ± 0.07   | 9832 ± 452      | c              | LIII              |
| VX Per   | DCEP   | 1.0370              | 6.879                      | 6.439                      | 6.240                      | 0.06                  | 0.03   | 11.84 ± 0.05   | 9678 ± 447      | a              | LIII              |
| VY Per   | DCEP   | 0.7429              | 7.829                      | 7.247                      | 7.013                      | 0.04                  | 0.01   | 11.50 ± 0.06   | 9457 ± 449      | c              | LIII              |
| NT Pup   | DCEP   | 1.1921              | 9.149                      | 8.445                      | 8.261                      | -0.02                 | -0.05  | 14.20 ± 0.07   | 11 805 ± 409    | c              | LIII              |
| V335 Pup | DCEPS  | 0.6866              | 7.124                      | 6.819                      | 6.675                      | 0.09                  | 0.06   | 11.99 ± 0.08   | 9417 ± 444      | c*             | LIII              |
| RV Sco   | DCEP   | 0.7826              | 5.081                      | 4.694                      | 4.543                      | 0.11                  | 0.08   | 9.36 ± 0.05    | 7210 ± 452      | b              | LIII              |
| V482 Sco | DCEP   | 0.6559              | 5.976                      | 5.591                      | 5.438                      | 0.20                  | 0.17   | 9.83 ± 0.05    | 7021 ± 452      | b              | LIII              |
| V636 Sco | DCEP   | 0.8323              | 4.908                      | 4.537                      | 4.398                      | 0.10                  | 0.07   | 9.40 ± 0.05    | 7219 ± 452      | b <sup>†</sup> | LIII              |
| V950 Sco | DCEPS  | 0.5289              | 5.729                      | 5.425                      | 5.295                      | 0.21                  | 0.18   | 10.07 ± 0.05   | 6933 ± 452      | b <sup>†</sup> | LIII              |
| BX Sct   | DCEP   | 0.8069              | 7.834                      | 7.147                      | 6.774                      | 0.28                  | 0.25   | 11.32 ± 0.07   | 6395 ± 450      | c              | LIII              |
| CK Sct   | DCEP   | 0.8701              | 7.381                      | 6.819                      | 6.591                      | 0.21                  | 0.18   | 11.52 ± 0.05   | 6196 ± 449      | a              | LIII              |
| CM Sct   | DCEP   | 0.5930              | 8.300                      | 7.818                      | 7.558                      | 0.15                  | 0.12   | 11.60 ± 0.07   | 6153 ± 450      | c              | LIII              |
| CN Sct   | DCEP   | 0.9997              | 7.842                      | 7.069                      | 6.697                      | 0.33                  | 0.30   | 11.82 ± 0.05   | 5996 ± 446      | a              | LIII              |
| EW Sct   | CEP(B) | 0.7652              | 4.314                      | 3.726                      | 3.466                      | 0.04                  | 0.10   | 8.01 ± 0.05    | 7580 ± 452      | b <sup>†</sup> | LII               |
| SS Sct   | DCEP   | 0.5648              | 6.284                      | 5.929                      | 5.780                      | 0.14                  | 0.11   | 9.89 ± 0.05    | 7092 ± 451      | a              | LIII              |
| TY Sct   | DCEP   | 1.0435              | 7.232                      | 6.633                      | 6.365                      | 0.37                  | 0.34   | 11.83 ± 0.05   | 5990 ± 446      | a              | LIII              |
| V458 Sct | CEP(B) | 0.6848              | 7.173                      | 6.697                      | 6.562                      | 0.09                  | 0.08   | 10.99 ± 0.20   | 6488 ± 468      | c*             | SZI               |
| Y Sct    | DCEP   | 1.0146              | 6.460                      | 5.894                      | 5.627                      | 0.23                  | 0.20   | 11.02 ± 0.05   | 6510 ± 451      | a              | LIII              |
| BQ Ser   | CEP(B) | 0.6305              | 6.472                      | 5.972                      | 5.758                      | -0.04                 | 0.02   | 9.94 ± 0.05    | 7169 ± 451      | b              | LII               |
| DV Ser   | DCEP   | 1.3629              | 8.595                      | 7.843                      | 7.471                      | 0.47                  | 0.44   | 13.84 ± 0.07   | 4053 ± 321      | c              | LIII              |
| DG Sge   | DCEP   | 0.6471              | 9.135                      | 8.526                      | 8.275                      | 0.13                  | 0.10   | 12.41 ± 0.06   | 6711 ± 420      | c              | LIII              |
| GX Sge   | DCEP   | 1.1106              | 8.274                      | 7.575                      | 7.276                      | 0.29                  | 0.26   | 12.87 ± 0.05   | 6521 ± 399      | a              | LIII              |
| GY Sge   | DCEP   | 1.7081              | 5.545                      | 4.841                      | 4.512                      | 0.29                  | 0.26   | 12.10 ± 0.05   | 6779 ± 429      | a              | LIII              |
| S Sge    | DCEP   | 0.9234              | 4.183                      | 3.859                      | 3.752                      | 0.08                  | 0.14   | 9.11 ± 0.05    | 7582 ± 451      | b              | LII               |
| AP Sgr   | DCEP   | 0.7040              | 5.347                      | 5.012                      | 4.883                      | 0.10                  | 0.16   | 9.49 ± 0.05    | 7160 ± 452      | b              | LII               |
| BB Sgr   | DCEP   | 0.8220              | 5.044                      | 4.653                      | 4.500                      | 0.08                  | 0.14   | 9.44 ± 0.05    | 7203 ± 452      | b              | LII               |
| U Sgr    | DCEP   | 0.8290              | 4.506                      | 4.100                      | 3.912                      | 0.08                  | 0.14   | 8.85 ± 0.05    | 7371 ± 452      | a              | LII               |
| V350 Sgr | DCEP   | 0.7122              | 5.641                      | 5.279                      | 5.133                      | 0.18                  | 0.24   | 9.73 ± 0.05    | 7092 ± 452      | b              | LII               |
| W Sgr    | DCEP   | 0.8805              | 3.243                      | 2.923                      | 2.814                      | 0.02                  | 0.08   | 8.03 ± 0.05    | 7536 ± 452      | b              | LII               |
| Y Sgr    | DCEP   | 0.7614              | 4.067                      | 3.717                      | 3.577                      | 0.05                  | 0.11   | 8.36 ± 0.05    | 7483 ± 452      | b              | LII               |
| YZ Sgr   | DCEP   | 0.9802              | 5.364                      | 5.000                      | 4.840                      | 0.06                  | 0.12   | 10.33 ± 0.05   | 6848 ± 452      | a              | LII               |
| AE Tau   | CEP    | 0.5907              | 9.442                      | 8.949                      | 8.750                      | -0.18                 | -0.21  | 12.81 ± 0.07   | 11 584 ± 465    | c              | LIII              |
| EF Tau   | DCEP   | 0.5376              | 10.876                     | 10.402                     | 10.249                     | -0.74                 | -0.68  | 14.17 ± 0.07   | 14 703 ± 495    | c              | LII               |
| LR TrA   | DCEPS  | 0.3852              | 6.307                      | 6.020                      | 5.880                      | 0.31                  | 0.28   | 10.16 ± 0.07   | 7176 ± 450      | c*             | LIII              |
| R TrA    | DCEP   | 0.5301              | 5.257                      | 4.946                      | 4.831                      | 0.19                  | 0.16   | 8.87 ± 0.05    | 7519 ± 451      | b              | LIII              |
| S TrA    | DCEP   | 0.8010              | 5.021                      | 4.696                      | 4.581                      | 0.21                  | 0.18   | 9.53 ± 0.05    | 7328 ± 451      | b              | LIII              |
| U TrA    | CEP(B) | 0.4097              | 6.542                      | 6.351                      | 6.286                      | -0.15                 | -0.16  | 9.89 ± 0.19    | 7207 ± 455      | c*             | SZI               |
| AE Vel   | DCEP   | 0.8533              | 7.589                      | 7.096                      | 6.867                      | 0.14                  | 0.11   | 11.80 ± 0.07   | 8026 ± 433      | c              | LIII              |
| AP Vel   | CEP(B) | 0.4952              | 7.730                      | 7.351                      | 7.188                      | -0.06                 | -0.07  | 11.03 ± 0.19   | 8291 ± 446      | c*             | SZI               |
| CS Vel   | DCEP   | 0.7712              | 8.771                      | 8.246                      | 8.011                      | 0.12                  | 0.09   | 12.63 ± 0.05   | 8231 ± 414      | b              | LIII              |
| CX Vel   | DCEP   | 0.7963              | 8.309                      | 7.769                      | 7.517                      | 0.16                  | 0.13   | 12.21 ± 0.07   | 8296 ± 427      | c              | LIII              |
| DK Vel   | DCEP   | 0.3947              | 8.820                      | 8.496                      | 8.386                      | 0.16                  | 0.13   | 12.67 ± 0.12   | 8421 ± 418      | c              | LIII              |
| EX Vel   | DCEP   | 1.1217              | 8.365                      | 7.733                      | 7.553                      | 0.07                  | 0.04   | 13.30 ± 0.07   | 8871 ± 393      | c              | LIII              |
| FG Vel   | DCEP   | 0.8098              | 8.509                      | 7.961                      | 7.719                      | 0.02                  | -0.01  | 12.45 ± 0.07   | 8239 ± 420      | c              | LIII              |
| FN Vel   | CEP    | 0.7263              | 7.686                      | 7.264                      | 7.067                      | 0.15                  | 0.12   | 11.64 ± 0.07   | 7891 ± 435      | c              | LIII              |

Table 4. continued.

| Name        | Type   | $\log(P)$<br>[days] | $\langle J \rangle$<br>mag | $\langle H \rangle$<br>mag | $\langle K \rangle$<br>mag | [Fe/H] <sub>lit</sub> | [Fe/H] | $\mu^d$<br>mag | $R_G^c$<br>(pc) | Notes          | Ref. <sup>f</sup> |
|-------------|--------|---------------------|----------------------------|----------------------------|----------------------------|-----------------------|--------|----------------|-----------------|----------------|-------------------|
| SV Vel      | DCEP   | 1.1491              | 6.370                      | 5.944                      | 5.769                      | 0.12                  | 0.09   | 11.77 ± 0.05   | 7632 ± 433      | b <sup>†</sup> | LIII              |
| XX Vel      | DCEP   | 0.8441              | 8.246                      | 7.767                      | 7.574                      | 0.11                  | 0.08   | 12.51 ± 0.07   | 7760 ± 415      | c              | LIII              |
| AS Vul      | DCEP   | 1.0872              | 8.383                      | 7.728                      | 7.454                      | 0.22                  | 0.19   | 13.02 ± 0.05   | 7150 ± 390      | a              | LIII              |
| DG Vul      | CEP    | 1.1339              | 7.331                      | 6.642                      | 6.373                      | 0.19                  | 0.16   | 12.08 ± 0.07   | 7233 ± 427      | c              | LIII              |
| S Vul       | DCEP   | 1.8355              | 5.415                      | 4.819                      | 4.551                      | 0.12                  | 0.09   | 12.68 ± 0.05   | 7103 ± 407      | a              | LIII              |
| SV Vul      | DCEP   | 1.6533              | 4.547                      | 4.063                      | 3.868                      | 0.05                  | 0.11   | 11.51 ± 0.05   | 7284 ± 438      | a              | LII               |
| T Vul       | DCEP   | 0.6469              | 4.558                      | 4.273                      | 4.185                      | 0.01                  | 0.07   | 8.66 ± 0.05    | 7793 ± 451      | b              | LII               |
| U Vul       | DCEP   | 0.9026              | 4.506                      | 4.086                      | 3.891                      | 0.19                  | 0.16   | 9.06 ± 0.05    | 7597 ± 451      | a              | LIII              |
| X Vul       | DCEP   | 0.8007              | 5.912                      | 5.424                      | 5.194                      | 0.07                  | 0.13   | 9.95 ± 0.05    | 7560 ± 449      | a              | LII               |
| U Car       | DCEP   | 1.5885              | 4.133                      | 3.683                      | 3.510                      | 0.17                  | 0.25   | 10.98 ± 0.05   | 7574 ± 443      | b              | ROM               |
| WZ Car      | DCEP   | 1.3620              | 6.946                      | 6.470                      | 6.279                      | -0.02                 | 0.06   | 12.95 ± 0.05   | 7601 ± 396      | b              | ROM               |
| V Cen       | DCEP   | 0.7399              | 5.019                      | 4.642                      | 4.498                      | 0.04                  | 0.12   | 9.18 ± 0.05    | 7459 ± 451      | b              | ROM               |
| XX Cen      | DCEP   | 1.0396              | 5.937                      | 5.544                      | 5.396                      | 0.04                  | 0.12   | 11.07 ± 0.05   | 7015 ± 445      | b              | ROM               |
| $\beta$ Dor | DCEP   | 0.9931              | 2.387                      | 2.043                      | 1.943                      | -0.14                 | -0.06  | 7.53 ± 0.05    | 7936 ± 451      | b              | ROM               |
| $\zeta$ Gem | DCEP   | 1.0065              | 2.561                      | 2.215                      | 2.114                      | -0.19                 | -0.11  | 7.74 ± 0.05    | 8273 ± 452      | b              | ROM               |
| GH Lup      | CEP    | 0.9678              | 5.432                      | 4.973                      | 4.801                      | 0.05                  | 0.13   | 10.17 ± 0.05   | 7082 ± 450      | b              | ROM               |
| T Mon       | DCEP   | 1.4318              | 4.068                      | 3.622                      | 3.459                      | -0.04                 | 0.04   | 10.41 ± 0.05   | 9056 ± 452      | a              | ROM               |
| S Mus       | DCEP   | 0.9850              | 4.500                      | 4.139                      | 4.005                      | 0.13                  | 0.21   | 9.53 ± 0.05    | 7576 ± 450      | b              | ROM               |
| UU Mus      | DCEP   | 1.0658              | 7.469                      | 7.004                      | 6.818                      | 0.11                  | 0.19   | 12.51 ± 0.05   | 7097 ± 414      | b              | ROM               |
| S Nor       | DCEP   | 0.9892              | 4.674                      | 4.288                      | 4.149                      | 0.02                  | 0.10   | 9.67 ± 0.05    | 7232 ± 451      | b              | ROM               |
| U Nor       | DCEP   | 1.1019              | 5.858                      | 5.251                      | 4.979                      | 0.07                  | 0.15   | 10.63 ± 0.05   | 6876 ± 450      | b              | ROM               |
| EU Tau      | DCEPS  | 0.3227              | 6.691                      | 6.360                      | 6.254                      | 0.04                  | 0.12   | 10.30 ± 0.09   | 9073 ± 454      | c*             | ROM               |
| SZ Tau      | DCEPS  | 0.4981              | 4.779                      | 4.422                      | 4.298                      | 0.07                  | 0.15   | 8.93 ± 0.05    | 8518 ± 452      | b              | ROM               |
| AO Aur      | DCEP   | 0.8301              | 8.631                      | 8.200                      | 8.027                      | -0.41                 | -0.27  | 12.96 ± 0.05   | 11 835 ± 461    | a              | LEM               |
| AX Aur      | DCEP   | 0.4838              | 9.929                      | 9.491                      | 9.283                      | -0.22                 | -0.08  | 13.02 ± 0.05   | 11 955 ± 461    | a              | LEM               |
| BK Aur      | DCEP   | 0.9032              | 7.291                      | 6.885                      | 6.711                      | -0.07                 | 0.07   | 11.90 ± 0.05   | 10 207 ± 453    | a              | LEM               |
| SY Aur      | DCEP   | 1.0062              | 6.913                      | 6.525                      | 6.348                      | -0.07                 | 0.07   | 11.90 ± 0.05   | 10 271 ± 454    | a              | LEM               |
| Y Aur       | DCEP   | 0.5865              | 7.651                      | 7.287                      | 7.113                      | -0.26                 | -0.12  | 11.27 ± 0.05   | 9692 ± 453      | a              | LEM               |
| YZ Aur      | DCEP   | 1.2599              | 7.487                      | 6.905                      | 6.669                      | -0.33                 | -0.19  | 12.89 ± 0.05   | 11 668 ± 459    | a              | LEM               |
| AQ Car      | DCEP   | 0.9898              | 7.138                      | 6.757                      | 6.618                      | -0.30                 | -0.16  | 12.14 ± 0.05   | 7658 ± 425      | b              | LEM               |
| I Car       | DCEP   | 1.5507              | 1.706                      | 1.225                      | 1.073                      | 0.10                  | 0.24   | 8.40 ± 0.05    | 7845 ± 451      | b              | LEM               |
| UX Car      | DCEP   | 0.5661              | 6.992                      | 6.728                      | 6.620                      | -0.10                 | 0.04   | 10.82 ± 0.05   | 7698 ± 444      | b              | LEM               |
| V Car       | DCEP   | 0.8259              | 5.753                      | 5.402                      | 5.274                      | -0.06                 | 0.08   | 10.27 ± 0.05   | 7915 ± 447      | b              | LEM               |
| V397 Car    | DCEPS  | 0.3145              | 6.857                      | 6.533                      | 6.404                      | -0.08                 | 0.06   | 10.42 ± 0.07   | 7678 ± 447      | c*             | LEM               |
| VY Car      | DCEP   | 1.2785              | 5.404                      | 4.958                      | 4.792                      | -0.06                 | 0.08   | 11.22 ± 0.05   | 7627 ± 441      | b              | LEM               |
| RY Cma      | DCEP   | 0.6701              | 6.363                      | 6.042                      | 5.874                      | 0.00                  | 0.14   | 10.35 ± 0.05   | 8796 ± 450      | a              | LEM               |
| RZ Cma      | DCEP   | 0.6289              | 7.533                      | 7.178                      | 6.967                      | -0.20                 | -0.06  | 11.25 ± 0.05   | 9162 ± 448      | a              | LEM               |
| BV Mon      | DCEP   | 0.4792              | 9.005                      | 8.584                      | 8.420                      | -0.10                 | 0.04   | 12.18 ± 0.05   | 10 398 ± 452    | a              | LEM               |
| EK Mon      | DCEP   | 0.5975              | 8.516                      | 8.051                      | 7.792                      | -0.05                 | 0.09   | 11.86 ± 0.07   | 9960 ± 453      | c              | LEM               |
| UY Mon      | DCEPS  | 0.3799              | 8.175                      | 7.958                      | 7.897                      | -0.33                 | -0.19  | 12.26 ± 0.10   | 10 553 ± 464    | c*             | LEM               |
| WW Mon      | DCEP   | 0.6686              | 9.963                      | 9.507                      | 9.333                      | -0.32                 | -0.18  | 13.70 ± 0.05   | 13 176 ± 463    | a <sup>†</sup> | LEM               |
| GQ Ori      | DCEP   | 0.9353              | 7.068                      | 6.650                      | 6.503                      | 0.11                  | 0.25   | 11.81 ± 0.05   | 10 129 ± 453    | b              | LEM               |
| AD Pup      | DCEP   | 1.1333              | 7.723                      | 7.341                      | 7.144                      | -0.20                 | -0.06  | 13.12 ± 0.07   | 10 588 ± 434    | c              | LEM               |
| AP Pup      | DCEP   | 0.7062              | 5.788                      | 5.443                      | 5.322                      | -0.16                 | -0.02  | 9.93 ± 0.05    | 8234 ± 449      | b <sup>†</sup> | LEM               |
| AT Pup      | DCEP   | 0.8238              | 6.400                      | 6.054                      | 5.930                      | -0.22                 | -0.08  | 10.93 ± 0.05   | 8484 ± 445      | b              | LEM               |
| MY Pup      | DCEPS  | 0.7555              | 4.333                      | 4.050                      | 3.950                      | -0.25                 | -0.11  | 9.54 ± 0.05    | 8096 ± 450      | b <sup>†</sup> | LEM               |
| RS Pup      | DCEP   | 1.6169              | 4.365                      | 3.828                      | 3.619                      | 0.07                  | 0.21   | 11.09 ± 0.05   | 8585 ± 444      | b              | LEM               |
| VX Pup      | CEP(B) | 0.4787              | 7.085                      | 6.760                      | 6.667                      | -0.15                 | -0.01  | 10.54 ± 0.17   | 8703 ± 453      | c*             | LEM               |
| WX Pup      | DCEP   | 0.9512              | 7.134                      | 6.721                      | 6.572                      | -0.15                 | -0.01  | 11.94 ± 0.05   | 9351 ± 441      | b              | LEM               |
| AV Tau      | DCEP   | 0.5582              | 9.196                      | 8.648                      | 8.405                      | -0.17                 | -0.03  | 12.29 ± 0.05   | 10 809 ± 457    | a              | LEM               |
| ST Tau      | DCEP   | 0.6058              | 6.269                      | 5.904                      | 5.746                      | -0.14                 | 0.00   | 9.98 ± 0.05    | 8897 ± 452      | a              | LEM               |
| AH Vel      | DCEPS  | 0.6260              | 4.568                      | 4.327                      | 4.235                      | -0.05                 | 0.09   | 9.41 ± 0.05    | 8074 ± 450      | b <sup>†</sup> | LEM               |
| AX Vel      | CEP(B) | 0.4138              | 6.773                      | 6.478                      | 6.366                      | -0.15                 | -0.01  | 10.03 ± 0.05   | 8120 ± 448      | b              | LEM               |
| BG Vel      | DCEP   | 0.8403              | 5.410                      | 4.972                      | 4.797                      | -0.10                 | 0.04   | 10.52 ± 0.05   | 8000 ± 446      | b <sup>†</sup> | LEM               |
| DR Vel      | DCEP   | 1.0492              | 6.583                      | 6.035                      | 5.811                      | -0.01                 | 0.13   | 11.36 ± 0.05   | 8054 ± 439      | b              | LEM               |
| RY Vel      | DCEP   | 1.4493              | 5.638                      | 5.136                      | 4.920                      | -0.05                 | 0.09   | 11.85 ± 0.05   | 7774 ± 432      | b              | LEM               |
| RZ Vel      | DCEP   | 1.3096              | 4.919                      | 4.474                      | 4.298                      | 0.05                  | 0.19   | 10.83 ± 0.05   | 8249 ± 445      | b              | LEM               |
| ST Vel      | DCEP   | 0.7678              | 7.244                      | 6.734                      | 6.538                      | -0.14                 | 0.00   | 11.19 ± 0.07   | 8158 ± 442      | c              | LEM               |
| SW Vel      | DCEP   | 1.3700              | 5.873                      | 5.407                      | 5.222                      | -0.15                 | -0.01  | 11.93 ± 0.05   | 8457 ± 433      | b              | LEM               |
| SX Vel      | DCEP   | 0.9800              | 6.500                      | 6.133                      | 5.991                      | -0.18                 | -0.04  | 11.49 ± 0.05   | 8334 ± 439      | b              | LEM               |
| T Vel       | DCEP   | 0.6665              | 6.170                      | 5.782                      | 5.632                      | -0.02                 | 0.12   | 10.06 ± 0.05   | 8084 ± 448      | b              | LEM               |
| V Vel       | DCEP   | 0.6406              | 6.021                      | 5.687                      | 5.567                      | -0.30                 | -0.16  | 9.96 ± 0.05    | 7888 ± 448      | b              | LEM               |

**Table 5.** Individual ages, distances, and metallicities for the current sample of open clusters.

| ID         | Age<br>(Gyrs) | $R_G$<br>(kpc) | $[Fe/H]_{lit}$ | $[Fe/H]_{rsc}$ | Ref. met.               | Ref. age-dist.   |
|------------|---------------|----------------|----------------|----------------|-------------------------|------------------|
| Be 17      | 10.06         | 10.3           | -0.15          | -0.13          | Friel et al. (2005)     | SF <sup>a</sup>  |
| Be 18      | 5.69          | 11.5           | -0.44          | -0.44          | Yong et al. (2012)      | SF               |
| Be 20      | 4.05          | 15.4           | -0.30          | -0.31          | Sestito et al. (2008)   | SF               |
| Be 21      | 2.18          | 13.7           | -0.31          | -0.31          | Yong et al. (2012)      | SF               |
| Be 22      | 4.26          | 11.4           | -0.45          | -0.45          | Yong et al. (2012)      | SF               |
| Be 25      | 4.00          | 17.6           | -0.20          | -0.22          | Carraro et al. (2007b)  | C <sup>b</sup>   |
| Be 29      | 4.34          | 18.1           | -0.31          | -0.32          | Sestito et al. (2008)   | SF               |
| Be 31      | 5.32          | 11.5           | -0.53          | -0.49          | Friel et al. (2005)     | SF               |
| Be 32      | 5.91          | 10.7           | -0.38          | -0.38          | Yong et al. (2012)      | SF               |
| Be 39      | 7.00          | 11.1           | 0.03           | 0.05           | Friel et al. (2010)     | SF               |
| Be 66      | 3.98          | 12.0           | -0.48          | -0.46          | Villanova et al. (2005) | SF               |
| Be 73      | 1.50          | 16.7           | -0.22          | -0.24          | Carraro et al. (2007b)  | C                |
| Be 75      | 3.00          | 15.6           | -0.22          | -0.24          | Carraro et al. (2007b)  | C                |
| Blanco1    | 0.1           | 7.9            | 0.4            | -0.02          | Ford et al. (2005)      | W                |
| Cr 110     | 1.70          | 9.7            | 0.03           | 0.03           | Pancino et al. (2010)   | B <sup>c</sup>   |
| Cr 261     | 6.00          | 6.9            | 0.13           | 0.12           | Sestito et al. (2008)   | B                |
| Hyades     | 0.70          | 8.0            | 0.11           | 0.11           | Carrera et al. (2011)   | SF               |
| IC 166     | 2.00          | 10.2           | -0.32          | -0.32          | Friel & Janes (1993)    | FJ               |
| IC 4651    | 1.68          | 7.1            | 0.11           | 0.15           | Carretta et al. (2004)  | SF               |
| King 8     | 0.80          | 11.3           | -0.40          | -0.40          | Friel & Janes (1993)    | FJ               |
| M 67       | 4.30          | 8.5            | -0.01          | 0.01           | Jacobson et al. (2011b) | SF               |
| Mel 66     | 5.33          | 8.9            | -0.33          | -0.34          | Sestito et al. (2008)   | SF               |
| Mel 71     | 0.2           | 10.3           | -0.32          | -0.10          | Brown et al. (1996)     | W                |
| NGC 1193   | 4.23          | 11.4           | -0.22          | -0.20          | Friel et al. (2010)     | SF               |
| NGC 1245   | 1.06          | 10.5           | -0.04          | -0.02          | Jacobson et al. (2011b) | SF               |
| NGC 1817   | 1.12          | 9.7            | -0.16          | -0.14          | Jacobson et al. (2011b) | SF               |
| NGC 188    | 6.30          | 8.8            | -0.03          | -0.01          | Jacobson et al. (2011b) | SF               |
| NGC 1883   | 0.65          | 11.7           | -0.01          | 0.01           | Jacobson et al. (2009)  | C                |
| NGC 1901   | 0.8           | 7.9            | -0.08          | -0.08          | Carraro et al. (2007b)  | W                |
| NGC 2099   | 0.43          | 9.2            | 0.01           | 0.01           | Pancino et al. (2010)   | B                |
| NGC 2112   | 2.50          | 8.6            | -0.52          | -0.52          | Friel & Janes (1993)    | FJ               |
| NGC 2141   | 2.45          | 12.0           | 0.00           | 0.02           | Jacobson et al. (2009)  | SF               |
| NGC 2158   | 2.00          | 11.5           | -0.28          | -0.26          | Jacobson et al. (2011b) | C                |
| NGC 2194   | 0.87          | 10.5           | -0.08          | -0.06          | Jacobson et al. (2011b) | SF               |
| NGC 2204   | 2.00          | 11.2           | -0.23          | -0.21          | Jacobson et al. (2011a) | SF               |
| NGC 2243   | 4.80          | 10.1           | -0.42          | -0.40          | Jacobson et al. (2011a) | B                |
| NGC 2324   | 0.67          | 10.7           | -0.17          | -0.18          | Bragaglia et al. (2008) | SF               |
| NGC 2355   | 0.79          | 10.0           | -0.08          | -0.06          | Jacobson et al. (2011b) | SF               |
| NGC 2360   | 1.90          | 8.8            | -0.28          | -0.28          | Friel & Janes (1993)    | FJ               |
| NGC 2420   | 2.20          | 10.0           | -0.20          | -0.18          | Jacobson et al. (2011b) | SF               |
| NGC 2425   | 3.55          | 9.5            | -0.15          | -0.13          | Jacobson et al. (2011b) | C                |
| NGC 2477   | 1.00          | 8.3            | 0.07           | 0.06           | Bragaglia et al. (2008) | SF               |
| NGC 2506   | 1.70          | 10.3           | -0.20          | -0.16          | Carretta et al. (2004)  | B                |
| NGC 2539   | 0.4           | 8.8            | 0.13           | 0.13           | Santos et al. (2009)    | W                |
| NGC 2660   | 0.73          | 8.5            | 0.04           | 0.03           | Bragaglia et al. (2008) | SF               |
| NGC 2682   | 5.00          | 8.5            | -0.09          | -0.09          | Friel & Janes (1993)    | FJ               |
| NGC 3680   | 4.00          | 7.8            | -0.16          | -0.16          | Friel & Janes (1993)    | FJ               |
| NGC 3960   | 0.90          | 7.3            | -0.12          | -0.08          | Bragaglia et al. (2006) | B                |
| NGC 5822   | 1.20          | 7.4            | -0.21          | -0.21          | Friel & Janes (1993)    | FJ               |
| NGC 6134   | 0.93          | 7.1            | 0.15           | 0.19           | Carretta et al. (2004)  | W <sup>d</sup>   |
| NGC 6192   | 0.13          | 6.5            | 0.12           | 0.10           | Magrini et al. (2010)   | W                |
| NGC 6253   | 3.00          | 6.5            | 0.36           | 0.35           | Sestito et al. (2008)   | B                |
| NGC 6404   | 0.50          | 6.1            | 0.11           | 0.09           | Magrini et al. (2010)   | C                |
| NGC 6475   | 0.20          | 7.6            | 0.03           | 0.03           | Villanova et al. (2009) | C                |
| NGC 6583   | 1.00          | 5.9            | 0.37           | 0.35           | Magrini et al. (2010)   | C                |
| NGC 6791   | 8.00          | 7.6            | 0.42           | 0.42           | Geisler et al. (2012)   | C                |
| NGC 6819   | 2.00          | 7.6            | 0.09           | 0.11           | Bragaglia et al. (2001) | B                |
| NGC 6939   | 2.2           | 8.1            | 0.00           | 0.00           | Jacobson et al. (2007)  | W                |
| NGC 7142   | 4.04          | 9.2            | 0.13           | 0.15           | Jacobson et al. (2008)  | SF               |
| NGC 752    | 1.24          | 8.2            | 0.08           | 0.08           | Carrera et al. (2011)   | SF               |
| NGC 7789   | 1.80          | 8.9            | 0.02           | 0.04           | Jacobson et al. (2011b) | SF               |
| Praesepe   | 0.70          | 8.1            | 0.16           | 0.16           | Carrera et al. (2011)   | SF               |
| PWM4       | 7.00          | 18.4           | -0.34          | -0.34          | Yong et al. (2012)      | YON <sup>e</sup> |
| Ruprecht 4 | 0.80          | 12.0           | -0.09          | -0.11          | Carraro et al. (2007b)  | C                |
| Ruprecht 7 | 0.80          | 13.3           | -0.26          | -0.28          | Carraro et al. (2007b)  | C                |
| Saurer 1   | 5.00          | 20.1           | -0.38          | -0.38          | Carraro et al. (2004)   | C                |
| To 2       | 2.50          | 14.9           | -0.60          | -0.60          | Friel & Janes (1993)    | FJ               |

**Notes.** From left to right the columns give the cluster ID, the Galactocentric distance, the iron abundance available in the literature, the metallicity rescaled to current solar abundance, the references for the metallicity and the references for ages and distances. The acronyms given in Col. 7 refers to SF: (Salaris et al. 2004; Friel 1995), C (Carraro group): (Carraro et al. 2002, 2005a,b,c; Moitinho et al. 2006; Villanova et al. 2007, 2009), B (BOCCE): (Gratton & Contarini 1994; Bragaglia et al. 2001; Kalirai & Tosi 2004; Bragaglia et al. 2006; Carretta et al. 2004, 2005, 2007), W: (WEBDA), and YON: (Yong et al. 2012).

**Table 6.** Structural parameters and metallicities of the candidate Cepheid groups.

| ID   | $x$<br>(kpc) | $y$<br>(kpc) | $z$<br>(kpc) | $R_G$<br>(kpc) | $\delta R_G^-$<br>(kpc) | $\delta R_G^+$<br>(kpc) | $D$<br>(kpc) | $N_s$ | $P$<br>(days) | $\sigma(P)$<br>(days) | $\bar{\rho}_{CG}$<br>(kpc <sup>-3</sup> ) | $\Delta[\text{Fe}/\text{H}]$ | $\sigma(\Delta[\text{Fe}/\text{H}])$ |
|------|--------------|--------------|--------------|----------------|-------------------------|-------------------------|--------------|-------|---------------|-----------------------|---|------------------------------|--------------------------------------|
| I    | 0.766        | -1.612       | -0.033       | 6.374          | 0.384                   | 0.475                   | 1.213        | 20    | 8.69          | 5.17                  | 16.8                                      | -0.039                       | 0.010                                |
| II   | -0.939       | -1.562       | -0.035       | 6.447          | 0.286                   | 0.430                   | 0.827        | 7     | 8.69          | 3.78                  | 4.8                                       | -0.003                       | 0.004                                |
| III  | -1.636       | -0.655       | -0.003       | 7.466          | 0.775                   | 0.560                   | 1.661        | 37    | 7.48          | 7.35                  | 37.7                                      | -0.063                       | 0.010                                |
| IV   | 0.016        | -0.503       | -0.034       | 7.437          | 0.503                   | 0.501                   | 1.879        | 52    | 6.91          | 5.20                  | 45.7                                      | -0.009                       | 0.008                                |
| V    | 2.182        | -0.137       | 0.044        | 8.103          | 0.464                   | 0.371                   | 0.847        | 7     | 8.74          | 5.84                  | 8.8                                       | 0.009                        | 0.002                                |
| VI   | 1.549        | 0.918        | -0.099       | 8.993          | 0.133                   | 0.186                   | 0.497        | 6     | 5.30          | 1.34                  | 4.2                                       | 0.033                        | 0.003                                |
| VII  | 2.608        | 1.167        | 0.050        | 9.473          | 0.396                   | 0.190                   | 0.654        | 11    | 6.72          | 3.51                  | 4.7                                       | 0.062                        | 0.007                                |
| VIII | 1.732        | 1.515        | 0.014        | 9.613          | 0.219                   | 0.261                   | 0.641        | 11    | 5.08          | 2.37                  | 4.2                                       | 0.040                        | 0.009                                |
| IX   | 2.511        | 1.777        | -0.008       | 10.036         | 0.144                   | 0.226                   | 0.621        | 7     | 5.38          | 0.79                  | 4.4                                       | 0.046                        | 0.006                                |
| X    | 3.269        | 1.754        | -0.047       | 10.231         | 0.187                   | 0.230                   | 0.449        | 6     | 5.63          | 1.60                  | 6.8                                       | 0.033                        | 0.007                                |

**Notes.** Structural parameters of the ten candidate Cepheid groups identified in Sect. 4. From left to right Col. 1 gives the identification number, while Cols 2–4 give the Galactic coordinates ( $x, y, z$ ) of the barycenter. Columns 5–7 give the Galactocentric radius of the barycenter together with the Galactocentric distance of both the inner and the outer edge of the Cepheid group. Column 8 gives the diameter of the CG, while Col. 9 lists the number of Cepheid per CG. Columns 10 and 11 give the mean period and its intrinsic dispersion, while Col. 12 gives the density. Columns 13 and 14 give the mean residual iron abundance and its intrinsic dispersion.



**Table 7.** Intrinsic parameters for field and cluster (NGC 1850, NGC 1866) Magellanic Cepheids with accurate iron abundances.

| ID       | Period<br>(days) | [Fe/H] | Ref.                     | $A_V$<br>mag | Ref.  |
|----------|------------------|--------|--------------------------|--------------|---|
| SMC      |                  |        |                          |              |   |
| HV 817   | 18.9234          | -0.83  | Romaniello et al. (2008) | 0.92         | Caldwell et al. (1986, 2001)  |
| HV 823   | 31.9154          | -0.81  | Romaniello et al. (2008) | 0.94         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 824   | 65.7658          | -0.74  | Romaniello et al. (2008) | 0.99         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 829   | 85.3100          | -0.75  | Romaniello et al. (2008) | 0.76         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 834   | 73.4514          | -0.64  | Romaniello et al. (2008) | 0.47         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 837   | 42.7563          | -0.82  | Romaniello et al. (2008) | 0.92         | Caldwell et al. (1986, 2001)  |
| HV 847   | 27.1019          | -0.76  | Romaniello et al. (2008) | 0.96         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 865   | 33.3426          | -0.85  | Romaniello et al. (2008) | 1.14         | Caldwell et al. (1986, 2001)  |
| HV 1365  | 12.4165          | -0.83  | Romaniello et al. (2008) | 0.77         | Caldwell et al. (1986, 2001)  |
| HV 1954  | 16.7109          | -0.76  | Romaniello et al. (2008) | 0.79         | Caldwell et al. (1986, 2001)  |
| HV 2064  | 33.6512          | -0.64  | Romaniello et al. (2008) | 0.94         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 2195  | 41.7830          | -0.68  | Romaniello et al. (2008) | 0.87         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 2209  | 22.6464          | -0.66  | Romaniello et al. (2008) | 0.61         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 11211 | 21.3796          | -0.82  | Romaniello et al. (2008) | 0.92         | Caldwell et al. (1986, 2001)  |
| HV 821   | 127.3140         | -0.79  | Luck et al. (1998)       | 1.14         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 824   | 65.8635          | -0.75  | Luck et al. (1998)       | 0.99         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 829   | 85.1990          | -0.65  | Luck et al. (1998)       | 0.76         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 834   | 73.6390          | -0.66  | Luck et al. (1998)       | 0.47         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 11157 | 69.0872          | -0.76  | Luck et al. (1998)       | 0.43         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| LMC      |                  |        |                          |              |   |
| G 458    | 74               | -0.4   | Luck & Lambert (1992)    | 0.48         | van Genderen/van Genderen & Nitihardjo (1989); Caldwell et al. (2001) |
| HV 1003  | 24.4             | -0.75  | Luck & Lambert (1992)    | 1.20         | Karczmarek et al. (2012)  |
| HV 1013  | 24.0991          | -0.60  | Romaniello et al. (2008) | 0.95         | Karczmarek et al. (2012)  |
| HV 1023  | 26.6073          | -0.28  | Romaniello et al. (2008) | 0.87         | Martin & Warren (1979)  |
| HV 12452 | 8.7297           | -0.36  | Romaniello et al. (2008) | 0.82         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 12700 | 8.1470           | -0.36  | Romaniello et al. (2008) | 0.56         | Martin & Warren (1979)  |
| HV 2257  | 39.3699          | -0.36  | Luck et al. (1998)       | 1.35         | Karczmarek et al. (2012)  |
| HV 2260  | 12.9420          | -0.37  | Romaniello et al. (2008) | 0.85         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 2294  | 36.5595          | -0.42  | Romaniello et al. (2008) | 1.27         | Karczmarek et al. (2012)  |
| HV 2337  | 6.8707           | -0.36  | Romaniello et al. (2008) | 0.87         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 2338  | 42.1944          | -0.37  | Luck et al. (1998)       | 1.22         | Karczmarek et al. (2012)  |
| HV 2352  | 13.6144          | -0.48  | Romaniello et al. (2008) | 0.88         | Karczmarek et al. (2012)  |
| HV 2369  | 48.3059          | -0.63  | Romaniello et al. (2008) | 1.14         | Karczmarek et al. (2012)  |
| HV 2405  | 6.9183           | -0.28  | Romaniello et al. (2008) | 0.47         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 2447  | 118.3115         | -0.26  | Luck et al. (1998)       | 0.67         | Karczmarek et al. (2012)  |
| HV 2580  | 16.9044          | -0.25  | Romaniello et al. (2008) | 0.98         | Karczmarek et al. (2012)  |
| HV 2733  | 8.7297           | -0.28  | Romaniello et al. (2008) | 0.43         | Martin & Warren (1979)  |
| HV 2793  | 19.1867          | -0.11  | Romaniello et al. (2008) | 0.84         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 2827  | 78.8860          | -0.36  | Romaniello et al. (2008) | 0.63         | Karczmarek et al. (2012)  |
| HV 2836  | 17.5388          | -0.18  | Romaniello et al. (2008) | 1.06         | Martin & Warren (1979)  |
| HV 2864  | 10.9901          | -0.20  | Romaniello et al. (2008) | 0.81         | Martin & Warren (1979); Caldwell et al. (1986)                        |
| HV 2883  | 108.9680         | -0.20  | Luck et al. (1998)       | 1.24         | Martin & Warren (1979); van Genderen (1983); Freedman et al. (1985)   |
| HV 5497  | 99.3116          | -0.25  | Romaniello et al. (2008) | 0.66         | Karczmarek et al. (2012)  |
| HV 6093  | 4.7863           | -0.6   | Romaniello et al. (2008) | 0.81         | Soszynski et al. (2008); Soszyński et al. (2010)                      |
| HV 877   | 45.0817          | -0.46  | Romaniello et al. (2008) | 0.92         | Karczmarek et al. (2012)  |
| HV 879   | 36.8129          | -0.14  | Romaniello et al. (2008) | 1.28         | Karczmarek et al. (2012)  |
| HV 883   | 133.5850         | -0.19  | Luck et al. (1998)       | 1.41         | Karczmarek et al. (2012)  |
| HV 900   | 47.5085          | -0.43  | Luck et al. (1998)       | 1.09         | Karczmarek et al. (2012)  |
| HV 909   | 37.5654          | -0.27  | Luck et al. (1998)       | 1.09         | Karczmarek et al. (2012)  |
| HV 953   | 47.9             | -0.47  | Luck & Lambert (1992)    | 1.08         | Karczmarek et al. (2012)  |
| HV 971   | 9.2897           | -0.29  | Romaniello et al. (2008) | 1.42         | Martin & Warren (1979)  |
| HV 997   | 13.1522          | -0.22  | Romaniello et al. (2008) | 0.91         | Soszynski et al. (2008); Soszyński et al. (2010)                      |

**Notes.** From left to right the columns give the source ID, the period, the iron abundance available in the literature and its reference, the visual amplitude, and its reference.

Table 7. continued.

| ID       | Period<br>(days) | [Fe/H] | Ref.                      | $A_V$<br>mag | Ref.                   |
|----------|------------------|--------|---------------------------|--------------|------------------------|
| NGC 1850 |                  |        |                           |              |                        |
| 9        | 30.4             | -0.12  | Sebo & Wood (1995)        | 1.2          | Sebo & Wood (1995)     |
| 17       | 18.66            | -0.12  | Sebo & Wood (1995)        | 0.8          | Sebo & Wood (1995)     |
| 110      | 11.858           | -0.12  | Sebo & Wood (1995)        | 1.0          | Sebo & Wood (1995)     |
| 58       | 8.558            | -0.12  | Sebo & Wood (1995)        | 1.0          | Sebo & Wood (1995)     |
| 269      | 7.01             | -0.12  | Sebo & Wood (1995)        | 0.9          | Sebo & Wood (1995)     |
| 341      | 3.593            | -0.12  | Sebo & Wood (1995)        | 0.8          | Sebo & Wood (1995)     |
| 679      | 2.7105           | -0.12  | Sebo & Wood (1995)        | 0.8          | Sebo & Wood (1995)     |
| NGC 1866 |                  |        |                           |              |                        |
| HV 12197 | 3.14381          | -0.43  | Mucciarelli et al. (2011) | 0.77         | Welch et al. (1991)    |
| HV 12198 | 3.52279          | -0.43  | Mucciarelli et al. (2011) | 0.65         | Welch et al. (1991)    |
| HV 12199 | 2.63918          | -0.43  | Mucciarelli et al. (2011) | 0.69         | Welch et al. (1991)    |
| HV 12200 | 2.7248           | -0.43  | Mucciarelli et al. (2011) | 0.82         | Welch et al. (1991)    |
| HV 12202 | 3.10112          | -0.43  | Mucciarelli et al. (2011) | 0.55         | Welch et al. (1991)    |
| HV 12203 | 2.95411          | -0.43  | Mucciarelli et al. (2011) | 0.65         | Welch et al. (1991)    |
| HV 12204 | 3.43876          | -0.43  | Mucciarelli et al. (2011) | 0.93         | Welch et al. (1991)    |
| V4       | 3.3157           | -0.43  | Mucciarelli et al. (2011) | 0.25         | Welch et al. (1991)    |
| V6       | 1.944252         | -0.43  | Mucciarelli et al. (2011) | 0.38         | Welch et al. (1991)    |
| V7       | 3.453            | -0.43  | Mucciarelli et al. (2011) | 0.46         | Welch et al. (1991)    |
| V8       | 2.0088           | -0.43  | Mucciarelli et al. (2011) | 0.31         | Welch et al. (1991)    |
| We 2     | 3.054847         | -0.43  | Mucciarelli et al. (2011) | 0.65         | Welch & Stetson (1993) |
| We 3     | 3.045            | -0.43  | Mucciarelli et al. (2011) | 0.60         | Welch & Stetson (1993) |
| We 4     | 2.8604           | -0.43  | Mucciarelli et al. (2011) | 0.45         | Welch & Stetson (1993) |
| We 6     | 3.289            | -0.43  | Mucciarelli et al. (2011) | 0.50         | Welch & Stetson (1993) |
| We 8     | 3.043            | -0.43  | Mucciarelli et al. (2011) | 0.51         | Welch et al. (1991)    |
| WS 11    | 3.0544           | -0.43  | Mucciarelli et al. (2011) | 0.40         | Welch & Stetson (1993) |
| WS 5     | 2.8950           | -0.43  | Mucciarelli et al. (2011) | 0.40         | Welch & Stetson (1993) |
| WS 9     | 3.0710           | -0.43  | Mucciarelli et al. (2011) | 0.44         | Welch et al. (1991)    |