Metallicity Gradients in the Solar Neighbourhood

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Abstract

We estimated iron and metallicity gradients in the radial and vertical directions with the F and G type dwarfs in the Solar neighbourhood taken from the RAdial Velocity Experiment (RAVE) Data Release 4 (DR4). These stars were selected according to their atmospheric model parameters and their space velocities and Galactic orbits were calculated utilizing the proper motions, distance and radial velocity components. The radial and vertical directions iron and metallicity gradients were calculated for sub-samples defined by the contraints on e_p and Z_{max}. We estimated a significant gradients for stars have, which circular orbits and small Z_{max} distances. Thin disc sample was defined by the constraints $e_p \leq 0.10$ and $Z_{max} \leq 825$ pc. The radial iron and metallicity gradients were calculated for the thin disc sample as $d[Fe/H]/dR_m = -0.081 \pm 0.029$ and $d[M/H]/dR_m = -0.060 \pm 0.012$ dex kpc^{-1}, respectively. The vertical iron gradients estimated for the F and G type dwarfs on circular orbits are $d[Fe/H]/dZ_{max} = -0.176 \pm 0.039$ dex kpc^{-1} and $d[Fe/H]/dZ_{max} = -0.119 \pm 0.036$ dex kpc^{-1} for the distance intervals $Z_{max} \leq 825$ and $Z_{max} \leq 1500$ pc, respectively. Radial iron gradient ($d[Fe/H]/dR_m = -0.081 \pm 0.029$ dex kpc^{-1}) value for the thin disc is one highest gradient value in the literature.

DATA SELECTION

The sample consists of F and G type dwarfs selected from the recent RAVE DR4 database Kordopatis et al. (2013) which are identified as explained. The temperature scale is limited to $5310 \leq T_{eff}$(K)≤ 7310 (Cox, 2000). The surface gravities of the star sample are identified by the zero age main sequence (ZAMS) and the terminal age main sequence (TAMS) lines via mass tracks in the $\log T_{eff}$-$\log g$ plane as taken from Ekström et al. (2012), who adopted the solar abundance as $Z_\odot = 0.014$ (Fig 1). We assumed that stars satisfying the stated conditions are F and G type dwarfs.

We used the procedure in Bilir et al. (2008) to estimate their M_J absolute magnitudes, which provide distances in combination with the true apparent J_0 magnitudes.

The $(J-H)_0$ vs M_J colour-absolute magnitude diagram of the star sample thus obtained is given in Fig 2.

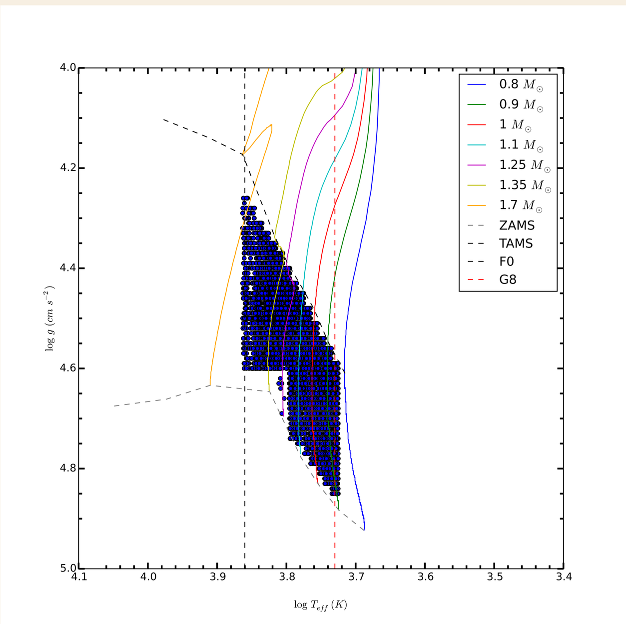

Figure 1: The $\log T_{eff}$-$\log g$ diagram.

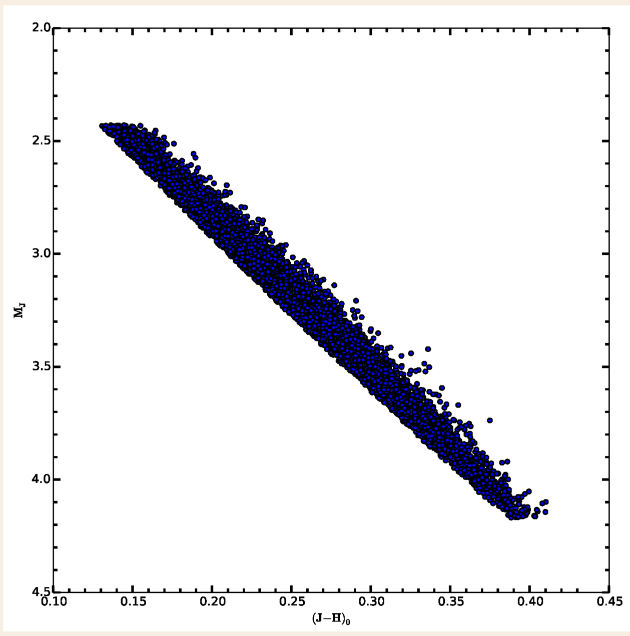

Figure 2: Colour-absolute magnitude diagram.

RESULTS

We restricted our sample with $S/N \geq 40$ (7935 stars) to obtain the best quality data and applied the constraint related to the planar eccentricity, $e_p \leq 0.10$, to limit the sample stars with circular orbits. This sample lie at the solar circle, $7 \leq R_m \leq 9$ kpc. The number of stars for which [M/H] metallicity were determined is 3204, while 2719 indicated iron abundance [Fe/H]. We estimated metallicity gradients for the two sub-samples for a set of Z_{max} intervals, $0 < Z_{max} \leq 825$, $0 < Z_{max} \leq 500$, $500 < Z_{max} \leq 800$, $800 < Z_{max} \leq 1000$, and $1000 < Z_{max} \leq 1500$ pc, which are presented in Table 1.

Table 1: Radial iron and metallicity gradients for the F and G type dwarfs on circular orbits, $e_p \leq 0.10$, for different Z_{max} intervals. N indicates the number of stars. Signal to noise ratio is $S/N \geq 40$.

Z_{max} range	$\langle[Fe/H]\rangle$	$d[Fe/H]/dR_m$	N	$\langle[M/H]\rangle$	$d[M/H]/dR_m$	N
(pc)	(dex)	(dex kpc^{-1})		(dex)	(dex kpc^{-1})	
0-825	−0.035	−0.081±0.029	2679	−0.023	−0.060±0.012	3153
0-500	−0.017	−0.083±0.030	2491	−0.014	−0.063±0.011	2935
500-800	−0.081	−0.048±0.037	183	−0.100	−0.028±0.057	212
800-1000	−0.130	+0.112±0.059	22	−0.027	+0.138±0.056	29
1000-1500	−0.064	+0.114±0.140	18	−0.072	−0.034±0.137	23
≥1500	–	–	5	–	–	5
Total	–	–	2719	–	–	3204

Thin disc sample was defined by the constraints $e_p \leq 0.1$ and $Z_{max} \leq 825$ pc. The radial iron gradient was calculated for the thin disc sample and showed Fig 5.

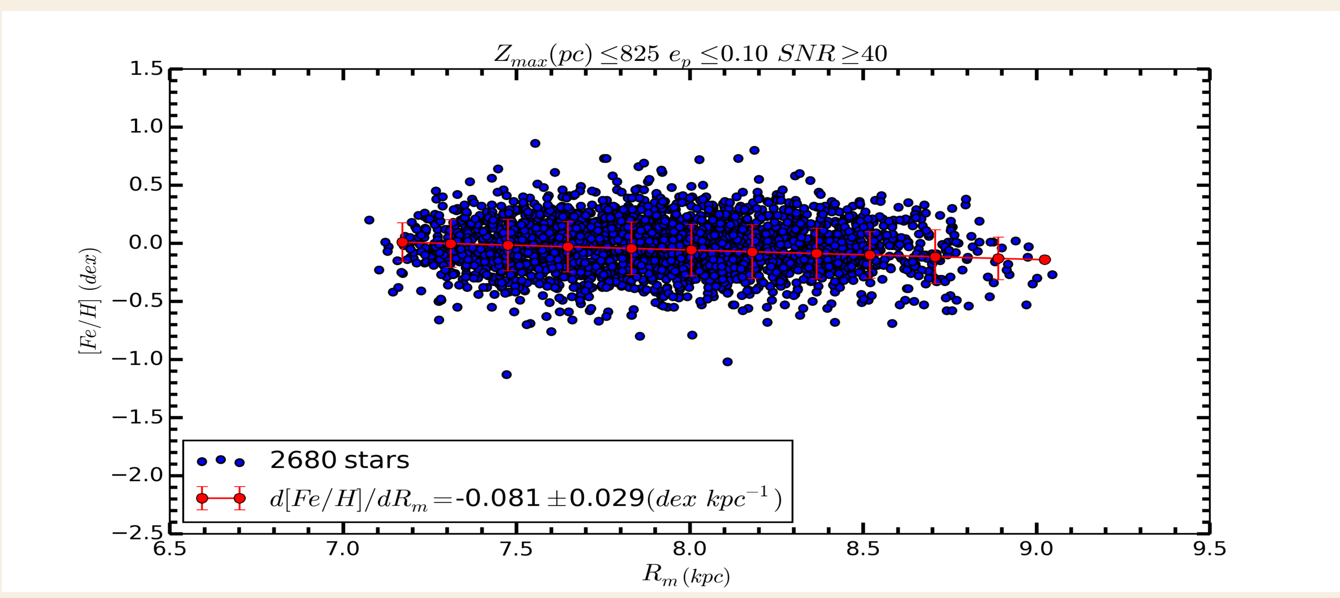

Figure 5: Radial iron gradient for thin disc sample.

SPACE VELOCITIES & GALACTIC ORBITS

We combined the distances, radial velocities and proper motions of sample stars and applied the standard algorithms and transformation matrices of Johnson & Soderblom (1987) to obtain their Galactic space velocity components, U, V and W. We applied LSR correction to our sample stars' space velocities and then $U_\odot$, $V_\odot$ and $W_\odot$ values obtain from Coşkunoğlu et al. (2011). Here we will give only the results we obtained. Correction for differential Galactic rotation is necessary for accurate determination of U, V and W velocity components. We applied the procedure of Mihalas & Binney (1981) to the distribution of the sample stars and estimated the first-order Galactic differential corrections for the U and V velocity components of the sample stars. The velocity component W is not affected by Galactic differential rotation Mihalas & Binney (1981). Sample Toomre diagram is shown in Fig 3.

To determine a possible orbit for a given sample star, we performed test-particle integration in a Milky Way potential consisting of three components: halo, disc and bulge potentials. We used *MWpotential2014* code of *Galpy* (Bovy, 2015) to calculate the Galactic orbit parameters of the sample stars. The orbital parameters used in this study are Z_{max}: maximum distance to the Galactic plane, R_a and R_p: apogalactic and perigalactic radial distances, R_m: the arithmetic mean of R_a and R_p, and e_p: the planar eccentricity. e_p histogram of sample is shown in Fig 4.

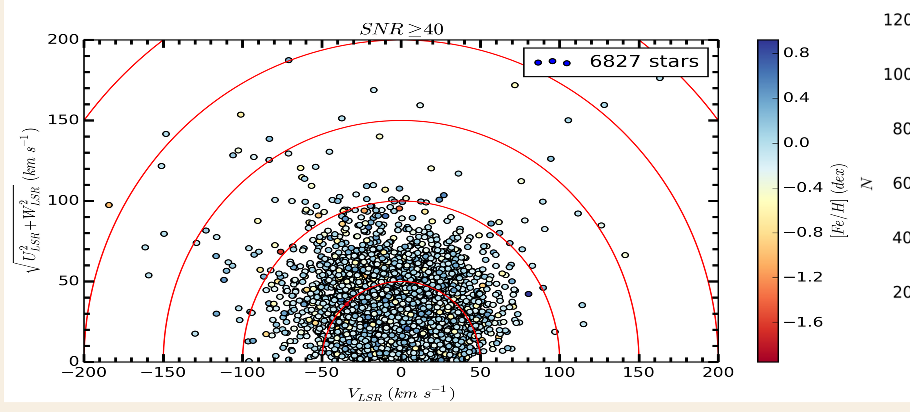

Figure 3: Toomre diagram of sample stars.

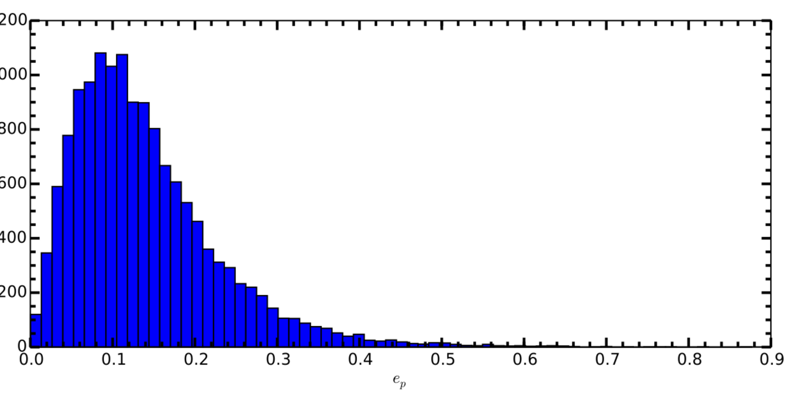

Figure 4: e_p histogram of sample stars.

CONCLUSION

Two constraints, $Z_{max} \leq 825$ pc and $e_p \leq 0.10$, provide a sample of thin-disc stars at the solar circle with radial iron and metallicity gradients in the vertical distance intervals, $0 < Z_{max} \leq 500$ and $500 < Z_{max} \leq 800$ pc. Negative or positive small gradients at further vertical distances probably originate from the mixture of two Galactic disc populations; i.e. thin and thick discs. The metallicity gradients could not be detected for stars on elongated orbits, $e_p > 0.1$. Vertical iron and metallicity gradients estimated for the thin-disc sample are compatible with the ones in previous research. And we conculude that Galactical orbit parameters very important for the gradient studies and population analysis.

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