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THE ACCURACY OF STELLAR METAL ABUNDANCES FROM INTERCOMPARISON OF CATALOGUES

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Abstract. The accuracy of some spectral, photometric and astrometric catalogues of stars near the main sequence has been estimated from an intercomparison of the data for stars in common. The technique of estimating the accuracy of catalogues developed earlier at the Tartu Astrophysical Observatory is adapted to a form suitable for practical applications.

Key words: methods: data analysis – catalogues – stars: abundances

1. Introduction

Quantitative estimates of the accuracy of catalogues of physical parameters of objects are relevant to almost all branches of astronomy and astrophysics (as well as to the other physical sciences). Investigators often try to estimate uncertainties in the catalogued data through a careful analysis of all sources of errors. However, some of the sources may escape detection and the unknown so-called cosmic dispersion is always inherent in the data. If three or more independent catalogues with the objects in common are available, their external random r.m.s. errors may be estimated from the data residuals (without resorting to any additional information) after the removal of systematic differences. The reader may find the latest example of such an approach in the paper of Norris and Ryan (1989) where the UBV photometric errors have been estimated through the intercomparison of 26 stars common to three groups. These authors quote a method outlined by Chun and Freeman (1978) as an earlier use of the same approach.

Kuzmin, Malyuto and Eelsalu (1986) showed how to estimate the errors when three catalogues are available and some of the data are present in only two of the three catalogues. This more general approach is used in the present paper.

This example deals with an analysis of three recent large catalogues of the [Fe/H] determinations for halo proper-motion stars. The estimation of the accuracies of the [Fe/H] values may be critical in judging between different scenarios for the formation of our Galaxy (Norris and Ryan 1989, Schuster and Nissen 1989a,b).

2. Observational data

Included in the analysis are data from three recent and statistically independent catalogues of the [Fe/H]values of high-velocity and metal-poor stars.

1. SF – catalogue of Sandage and Fouts (1987) with the [Fe/H] values derived from the photoelectric UBV photometry for high-proper-motion stars,

2. LCL – catalogue of Laird, Carney and Latham (1988) with the [Fe/H] values derived from a comparison of the high-resolution low S/N spectra to a grid of synthetic spectra for high-proper-motion stars,

3. SN – catalogue of Schuster and Nissen (1989a,b) with the [Fe/H] values from the $uvby\beta$ photometry for high-velocity and metal-poor stars.

All the three catalogues have been used by their authors to study correlations between kinematics of stars and metallicity. The knowledge of the [Fe/H] errors is especially important in this aspect. For example, Norris and Ryan (1989) suspect that large errors of the [Fe/H] values in the SF catalogue may smooth out the dependence of the kinematics on [Fe/H].

3. Comparison of catalogues

We confine our analysis to halo stars ([Fe/H] < -1.0). Only stars simultaneously occurring in two or three catalogues have been considered.

The comparison of the data displayed in Figs. 1–5 explains the problems arising. First of all, we divided the SF catalogue into two parts: Table II (program stars) and Table III (stars from the literature). Visual inspection of Figs. 1–4 shows that the data of Tables II

and III taken together have larger scatter than the data of Table II separately while comparing with the LCL and SN data (quantitative estimates of the scatter are given below). The data of Table III, compiled from the different published sources, are probably heterogeneous and of lower accuracy. Therefore, we analyze the data of Tables II+III and the data of Table II separately.

The effect of interstellar reddening has not been taken into account in the SF catalogue, and this is not always correct (Norris and Ryan 1989). In our comparisons (Figs. 1–4), special designations (triangles) have been introduced for the stars with $E_{B-V} \geq 0.05$ (according to LCL) or $E_{b-y} \geq 0.035$ (according to SN) outside the interval $0.38 < B-V < 0.68$. In the $U-B, B-V$ diagram, these stars clearly deviate from the other ones in the sense that the reddened stars with $B-V < 0.38$ turn upwards whereas those with $B-V > 0.68$ turn downwards. It is certainly the influence of a geometrical effect in the diagram: the reddening lines are approximately parallel to the standard relation in the interval $0.38 < B-V < 0.68$ and, as a consequence, the reddening has only a small influence on [Fe/H] determinations from the ultraviolet excess $\delta_{0.6}$. Outside this interval, the reddening affects the [Fe/H] determinations significantly. Therefore, those SF catalogue stars outside the interval $0.38 < B-V < 0.68$ which are reddened (triangles in Figs. 1–4) or without the data on reddening (squares in Figs. 1–4) have not been included in a further analysis.

Schuster and Nissen (1989a) have deduced from intercomparison of the LCL and the SN catalogues that the first one is heterogeneous because the assumption made by LCL of a smooth distribution of interstellar dust is not valid. Only the [Fe/H] determinations from LCL with small differences between the reddening values of SN and LCL ($|\Delta(B-V)| < 0.03$) are homogeneous. Comparing the LCL and SN data in Fig. 5 we introduced special designations for stars with small differences between the reddening values of SN and LCL ($|\Delta(B-V)| < 0.03$, triangles) and for stars without data on reddening in the SN catalogue (squares). As it has been expected, the mentioned stars tend to show systematic deviations. Therefore, we analyze the LCL catalogue as a whole and the stars from the LCL catalogue with $|\Delta(B-V)| < 0.03$ separately.

To avoid biases in the data, only the stars located between the two parallel dashed lines going through the points (–1.0,–1.0) and (–2.7,–2.7) perpendicularly to a one-to-one relation in Figs. 1–5

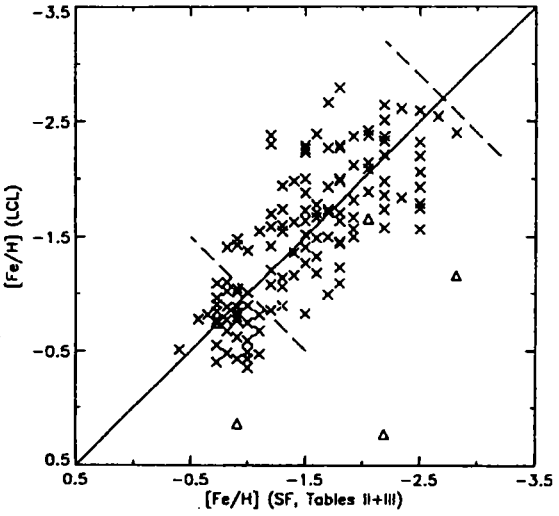

Fig. 1. Comparison of [Fe/H] for stars available simultaneously in the SF (Tables II+III of Sandage and Fouts 1987) and LCL catalogues. Triangles denote the reddened stars with $E_{B-V} \geq 0.05$ outside the interval $0.38 < B-V < 0.68$. The line at 45° is shown.

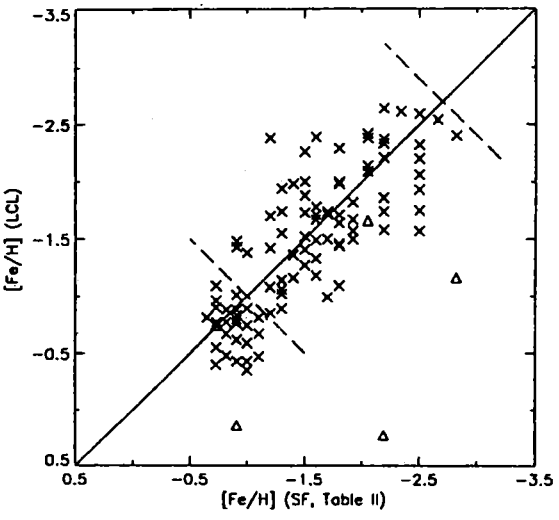

Fig. 2. The same as in Fig. 1 but for the SF (Table II of Sandage and Fouts 1987) and LCL catalogues. Designations are the same as in Fig. 1.

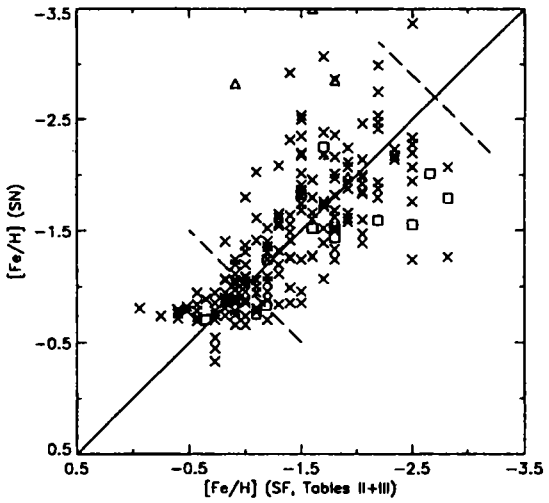

Fig. 3. The same as in Fig. 1 but for the SF (Tables II+III of Sandage and Fouts 1987) and SN catalogues. Triangles denote the reddened stars with $E_{b-y} \geq 0.035$ outside the interval $0.38 < B-V < 0.68$, squares are the stars without data on reddening in the SN catalogue. Other designations are the same as in Fig. 1.

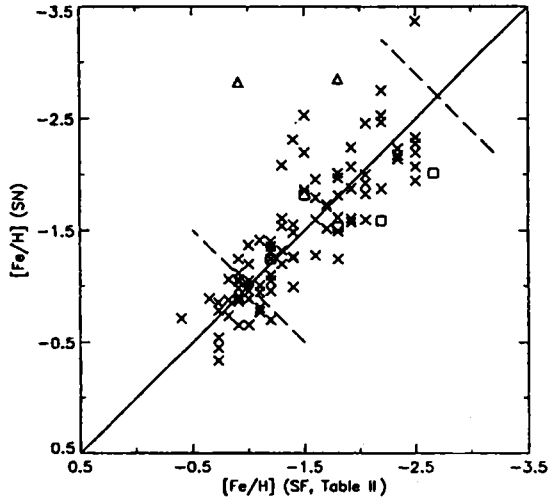

Fig. 4. The same as in Fig. 1 but for the SF (Table II of Sandage and Fouts 1987) and SN catalogues. The designations are the same as in Fig. 3.

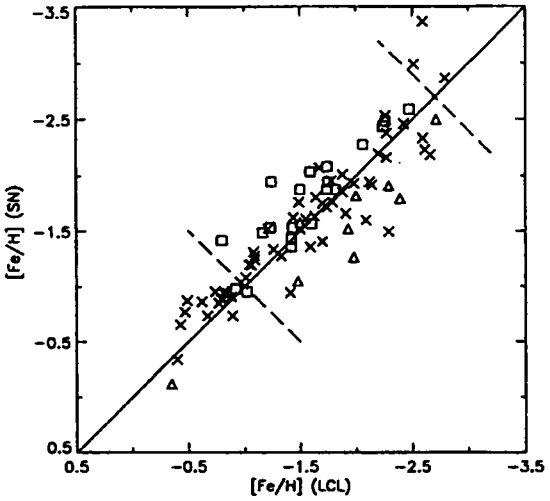

Fig. 5. The same as in Fig. 1 but for the LCL and SN catalogues. Triangles denote the stars with large differences between the reddening values of SN and LCL ($|\Delta(B-V)| > 0.03$), squares are the stars without data on reddening in the SN catalogue.

have been included into the analysis. The scales of the data of the catalogues are assumed to be identical. This assumption follows from the inspection of the figures.

Let 1 correspond to the data of Tables II+III of the SF catalogue, 1A – to the data of Table II of the SF catalogue alone, 2 – to the LCL catalogue, 2A – to the sample of stars with $|\Delta(B-V)| < 0.03$ from the LCL catalogue, 3 – to the SN catalogue. Our calculations show that there are only small systematic differences between the data:

$$\begin{aligned}
\Delta_{1,2} &= 0.06 \pm 0.44 \quad (104 \text{ stars}),\\
\Delta_{1A,2} &= -0.02 \pm 0.40 \quad (53 \text{ stars}),\\
\Delta_{2,3} &= 0.00 \pm 0.29 \quad (68 \text{ stars}),\\
\Delta_{2A,3} &= -0.03 \pm 0.25 \quad (40 \text{ stars}).
\end{aligned}$$

The technique of deducing the external r.m.s. errors of the catalogues from the variances of their data residuals is a minor modification of the technique of Kuzmin, Malyuto and Eelsalu (1986).

4. Discussion of the results

Table 1 explains the results of analysis of the above-mentioned catalogues. The variances of the external random r.m.s. errors are limited to 4 to 12 %. Therefore, the internal coincidence of the data is high.

Table 1. External random r.m.s. errors of [Fe/H] deduced from a comparison of the catalogues

Catalogues	σ_{SF}	σ_{LCL}	σ_{SN}
1,2,3	0.42±0.015	0.19±0.015	0.20±0.015
1A,2,3	0.30±0.01	0.26±0.01	0.15±0.01
1A,2A,3	0.28±0.02	0.18±0.015	0.18±0.015

Only the results in the last line of the table are reliable because the samples used are homogeneous. The data in the two upper lines of the table should be considered only as indications to heterogeneity of the original catalogues.

We see from the last line of the table that our estimates of the accuracy of the LCL (homogeneous sample) and SN data are in good agreement with the estimates of the accuracy of [Fe/H] determinations from the internal uncertainties of these data (0.15 and 0.20, as obtained by Laird et al. 1988 and Schuster and Nissen 1989a, respectively).

5. Conclusions

Analysis of the catalogues of Sandage and Fouts (1987), Laird et al. (1988) and Schuster and Nissen (1989a,b) has been performed with the use of a method based on data intercomparisons. The analysis allowed us to estimate the external r.m.s. errors of the catalogues and, to some extent, to study inhomogeneities of the catalogues.

We conclude that catalogues of the *UBV* photometry might be reliable sources of [Fe/H] determinations, provided that the data are homogeneous and reddening effects are taken into account. Our estimates of the accuracy of the refined SF catalogue are higher than any of the estimates of previous authors (0.45 of Norris and Ryan 1989, 0.35 of Schuster and Nissen 1989a). If a significant amount of reddened data is expected, the use of stars within only the interval $0.38 < B - V < 0.68$ would be recommended, where reddening

effects are unimportant. If there are more than two homogeneous *UBV* catalogues intended for analysis, the accuracy of each of them may be estimated using the method described in this paper and the data may be averaged with appropriate weights before performing the analysis.

We confirm the conclusion of Schuster and Nissen (1989a) that unsmooth distribution of interstellar dust along the line of sight influences the [Fe/H] estimates by the method of Laird et al. (1988). Our estimates of the external r.m.s. errors of the Schuster and Nissen (1989a,b) catalogue and of the corrected sample of stars from the catalogue of Laird et al. (1988) are in agreement with the internal uncertainties estimated by the authors themselves.

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