METAL ABUNDANCES FOR K GIANTS IN A FIELD IN SCUTUM

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SUMMARY

UBViyz photometric observations of ~100 K giants in a region of Scutum (l ≈ 25°, b ≈ -4°) out to distances of 10 kpc show that the average value of [Fe/H] for the intrinsically brighter (Mv < 1) K-giants along the line of sight is just about the same as that found for the average K giant in the solar vicinity. It is also possible that a group of low luminosity metal-rich stars was detected.

1. INTRODUCTION

This paper is concerned with the determination of metal abundances for ~100 K-giant field stars, 1–10 kpc distant, in a field in Scutum by means of the UBViyz photometric system described by Jennens & Helfer (1975a, Paper I).

The principal field studied was the S4 field investigated by Schubarth (1970) by UGR photometry of 48-in. Palomar Schmidt plates. The 15′ × 25′ field lies in a dense part (∼10″ average image separation) of the Scutum cloud of the Milky Way at l = 25°4, b = -4°4 (α1950 = 18h 50m, δ = -8°7) close to the position of the globular cluster NGC 6712. A finding chart and catalogue very kindly supplied by Schubarth gave photometry for ~2000 stars down to mG ~ 18. The colours were transformed to V, U–B, B–V using the transformations of Steinlin (1968); stars for which U < 18 which had round images with clear background to radius 7″ and for which 0.7 < (B–V)0 < 1.5 (using Schubarth’s values of the colour excesses) were selected for observation. Only ~10 of these had mv < 14. Consequently, a rectangular area 40′ × 80′ including most of the S4 field, was photographed in V (IIAD + GG11) and R (103aE + No. 2403) using the 60-cm Mees Cassegrain in 1972 May (plate centres: α1950 = 18h 49m, δ1950 = -8° 36′, l = 25°4, b = -4°0; and α1950 = 18h 49.6m, δ = -8° 17′, l = 25°7, b = -3°9). A photoelectric sequence in BVi was established in 1972 June with the same telescope and used to calibrate iris photometry of the plates. About 50 stars with approximate (B–V) values falling in the range (0.8, 1.7), with clear sky regions around them, were selected and added to the program.

Observations were made using the UBViyz system during 1973 June, July and August using Cerro Tololo’s 90-cm telescope on parts of five nights and Cerro Tololo’s 150-cm telescope on part of a sixth night. The observations reported upon

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in Jennens & Helfer (1975b, Paper II) and Jennens (1975, Paper III) were taken during the same observing sessions and with the same equipment. Because of the lack of time, some stars were not observed through the $U$ filter; for these stars, estimates of $E(B-V)$ had to be made by using the Re2 index alone (cf. Paper I) and no measurements of the $X$ index (cf. Paper I) were available to check the photometry. Stars for which $U$ filter observations were available and for which $|X| > 0.05$ were excluded from this study. Generally individual stars were observed only once; for this reason, even though stars as faint as $m_V = 16.0$ were observed, this paper concerns itself only with stars with $m_V \leq 14.8$, since corrections for the sky background are necessarily somewhat uncertain for the fainter stars.

2. RESULTS

This program involved observing faint field stars in a dense star field, where considerable obscuration is known to occur, with a moderate size telescope in a limited time. The internal photometric errors appear to be slightly larger than

![Diagram](https://example.com/diagram.png)

**Fig. 1.** The distribution of $[\text{Fe/H}]$ with distance, using individual stellar determinations of $E(B-V)$. Triangles designate stars for which $M_V \geq 1.8$; circles designate stars for which $M_V < 1.8$. A filled symbol indicates a star for which $0.17 < E(B-V) < 0.29$; an open symbol indicates a star for which $E(B-V)$ fell outside the range $0.23 \pm 0.09$; a shaded symbol represents stars for which $E(B-V) = 0.29 - 0.32$ or $0.14 - 0.17$. A large symbol indicates that the photometric index, $X$, (cf. Jennens & Helfer 1975a), fell into the acceptable range, $|X| \leq 0.05$; a small symbol indicates that no measurement of $X$ for the star was available. A ( ) encloses one star with $M_V(yz) = -2.8$, for which necessarily our abundance determination is uncertain. No star for which $m_V > 14.8$ or for which $(V-I)_0 > 0.65$ is included. An error cross for 1 per cent photometry is given in the lower left-hand portion of the diagram. The solid horizontal line at $[\text{Fe/H}] = -0.24$ is the average obtained for over 300 bright K giants in the solar vicinity (on this scale $[\text{Fe/H}] = -0.11$ for the Sun); horizontal dashed lines, displaced $\pm 0.4$ from the solid line, indicate the errors expected from 1 per cent photometry. The quantity, $x$, plotted along the abscissa, is the galacto-centric distance, assuming $R_0 = 10$ kpc.
Table I

<table>
<thead>
<tr>
<th>$m-M$</th>
<th>$m_V = 10$</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>Field stars</th>
</tr>
</thead>
<tbody>
<tr>
<td>8–9</td>
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<td>9–10</td>
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<td>6</td>
<td>0</td>
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</tr>
<tr>
<td>10–11</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11–12</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12–13</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td></td>
<td>3$^*$ ($M = +2.5$)</td>
</tr>
<tr>
<td>13–14</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td>5$^*$ ($M = +1.5$)</td>
</tr>
<tr>
<td>14–15</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>6$^*$ ($M = 0.5$)</td>
</tr>
</tbody>
</table>

* Possibly too low a number due to observational bias.

1 per cent. Consequently, determinations of $E(B-V)$, [Fe/H] and $M_V$ for individual stars are subject to considerable uncertainty (cf. Paper I) and statistical inferences of only a very general nature may be drawn. Because of these uncertainties, photometric absolute magnitudes have not been corrected for possible abundance effects (Pagel & Tomkin 1969; Helfer 1969).

Fig. 1 and Table I show the reduced data, using individual determinations of the colour excess; the cooler stars for which $(V-I)_0 > 0.65$ are not included. Table I is arranged in the form of a $m$–log $\pi$ table with lines of constant absolute magnitude running diagonally from upper left to lower right; for convenience of comparison, the corresponding numbers for the solar neighbourhood K-giants (deduced from Table I, Helfer 1969) are listed at the right-hand side of the table, with an arbitrary normalization. (Table I cannot be used for determining star densities because of the arbitrary way in which stars were selected for observation, but within any one column, $m_V = \text{const.}$, the relative proportion of low luminosity to high luminosity is of interest.)

Absorption estimates for individual stars show some correlation with distance in that some of the more nearby stars were more reddened than the average. We have examined the Palomar Schmidt prints for fine absorption structure in the vicinity of these stars and there is a possibility that this excess reddening is real. If, however, we assume that the individual colour excess determinations are not reliable and use a mean colour excess, $E(B-V) = 0.23$, for the entire region, we then obtain the results shown in Fig. 2 and Table II; here the cooler stars have been included. There is no way of judging which of the two diagrams more accurately represents the true state of affairs (though Table II does show a surprising lack of low-luminosity K-giants, $\langle M_V \rangle = +2.5$ at $m_V = 12$).

Both diagrams agree in showing that the average value of [Fe/H] at large distances along the line of sight is very close to the average value observed for the field stars in the solar vicinity. Examination of Table I for $m-M > 11$ and of Table II for $m-M > 12$ shows that most of the observed stars are the younger more luminous K-giants ($M_V \sim 1$), so that this conclusion is really applicable only to the young portion of the disc population. (Note that up to $m-M \sim 14$, the line of sight is within 400 pc of the galactic plane; considering the results of Paper III, it is reasonable to assume the stars studied reflect galactic disc rather than galactic halo abundances.)

Both diagrams also agree, but only in a qualitative sense, in showing that there may be an excess of metal-rich stars at the smaller distance moduli. The average
value of [Fe/H] for these metal-rich stars is difficult to determine because of the large scatter and the disparity between the two diagrams, but it seems safe to conclude that this average value is at least \( \sim 0.1 \) and may be just possibly as large as \( \sim 0.5 \). This possible excess of metal-rich stars may be associated with a small metal-rich region \( \sim 1 \) kpc distant along the line of sight. However, examination of the two tables suggests another possible hypothesis. At the smaller distance moduli at which this possible excess of metal-rich stars is observed, most of the stars observed are the less luminous \( (M_V > 1) \) older K-giants. One may generalize and

### Table II

**Observed magnitude distribution \( E(B-V) = 0.23 \) (cf. Fig. 2)**

<table>
<thead>
<tr>
<th>( m-M )</th>
<th>( m_V = 10 )</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>Field stars</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-9</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>9-10</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10-11</td>
<td>0</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>11-12</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>11</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>12-13</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td></td>
<td>3* ( (M = +2.5) )</td>
</tr>
<tr>
<td>13-14</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td></td>
<td>5 ( (M = 1.5) )</td>
</tr>
<tr>
<td>14-15</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>6 ( (M = 0.5) )</td>
</tr>
</tbody>
</table>

* Possibly too low a number due to observational bias.
hypothesize that they may be part of an older disc population which is actually metal rich. (Note that the $UBV_{iyz}$ system apparently does not have a tendency to systematically overestimate the metal abundance of all low luminosity K-giants, since the metal deficient stars studied in Paper III were of low luminosity.)

The suggestion that we recognize the existence of a metal-rich component of the older disc population seems reasonable in the light of many observations of comparatively old metal-rich stars. In the solar vicinity, characterized by $\langle [Fe/H] \rangle = -0.24$, the spectroscopic abundance work of Hearnshaw (1972) and of Oinas (1974), as well as previous photometric abundance work showing that a class of low luminosity metal-rich giants exist (e.g. Helfer 1969), suggest that this postulated component of the disc could be reasonably assigned the value $\langle [Fe/H] \rangle \approx 0.1$ in the solar vicinity and an age, based on the luminosities of the stars and Hearnshaw's work of $\sim 1$ to $\sim 7 \times 10^8$ yr. We have already noted, in Paper II (Jennens & Helfer 1975b) that maximum metal abundances in galactic clusters seemed to have occurred $\sim 10^9$ yr ago and younger clusters seem to be somewhat metal deficient. Also, the extrapolation of the extremely steep gradient of [Fe/H] with height above the galactic plane found in Paper III to $z = 0$ would require the local solar neighbourhood to have an old metal-rich component.

A third conclusion follows from examination of the two tables. Aside from the deficiency of the least luminous giants, $M_V = +2.5$ at $m_V = 12$ in Table II, the ratio of the lower luminosity giants ($M_V > 1$) to the higher luminosity giants ($M_V < 1$) remains approximately constant in each column with a value similar to that found in the solar neighbourhood. (Two minor anomalies, the deficiency of very luminous giants at $m = 12$ and the surplus of the higher luminosity giants at $m = 14$, could easily be the result of inadequate sampling.) This result implies that the form of luminosity function for the K-giants does not undergo appreciable variation along the line of sight. The result is somewhat surprising because the projection of the line of sight on to the galactic plane passes through regions in which the mass density is three to four times that observed in the solar neighbourhood (Schmidt 1965) while the mean gas density remains, crudely speaking, just about that observed in the solar neighbourhood (Kerr & Westerhout 1965).

REFERENCES
