Copper and Barium Abundances in the Ursa Major Moving Group

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ABSTRACT

We present Cu and Ba abundances for 7 G-K dwarf stars, members of the solar-metallicity, 0.3 Gyr old Ursa Major Moving Group. All analyzed member stars show [Ba/Fe] excesses of +0.3-plus, associated with [Cu/Fe] deficiencies of up to −0.23 dex. The present results suggest that there is an anti-correlation between the abundances of Cu and the heavy elements produced by the main component of the neutron capture s-process. Other possible anomalies are Na and C deficiencies with respect to normal solar-metallicity stars. The new data do not confirm the recent claim that the group member HR6094 is a Ba dwarf star.

Key words: open clusters and associations: individual: Ursa Major – stars: Galaxy: abundances – stars: abundances.

1 INTRODUCTION

Associations and clusters are very good samples of stars which provide information on the chemical composition of homogeneous stars whose physical parameters can be determined with reduced uncertainties as compared to field stars. There is not a nearby, well-populated open cluster with an age 0.2 – 0.3 Gyr old that can be analyzed in detail such as the Pleiades and Hyades, although the Ursa Major Group (UMaG hereafter) is a loose and sparse group of stars that kinematically reveal their common origin. The UMaG is a 0.3 Gyr old kinematical group of solar metallicity located in the solar neighborhood. Soderblom & Mayor (1993) identified probable member stars of the group as being those stars where both the kinematical parameters and the chromospheric activity indicators point decidedly towards membership. As pointed out by Soderblom & Mayor, there are good reasons for the study of UMaG in detail. The UMaG has a sparse but tangible nucleus in the velocity space; statistically, it appears to be real; the kinematics of the UMaG stars are well determined due to the group’s proximity; there are reliable spectroscopic indicators to estimate the ages of young solar-type stars; its space velocity is distinct from other young field stars so that there should be few interlopers to contaminate the sample. Therefore the UMaG is important in the study of stellar kinematic groups as well as feasible in providing a sample of young stars not found in other nearby clusters.

Porto de Mello & da Silva (1997) claimed the solar-type, solar metallicity star HR6094, member of the UMaG, to be the first solar-metallicity, young Ba dwarf star to be identified. They found marked overabundances for the s-process elements which could be explained by the process of mass transfer in a binary system, in which the secondary component accreted matter from the primary one (now the white dwarf companion) when it was an asymptotic giant branch star self-enriched in s-process elements. A 30 Myr old, common proper motion white dwarf star located 0.026 pc away was tentatively identified as the former primary; if confirmed, this could be the first Ba system in which the remnant of the late AGB star responsible for the heavy elements enrichment may have been directly spotted. If so, this would be the first identification of the Ba phenomenon in a near-zero-age star of solar metallicity. We have observed seven G-K dwarf stars (including HR6094), selected by Soderblom & Mayor (1993) as probable members of the UMaG, in order to establish the abundance pattern of the UMaG stars and therefore the anomalous status of HR6094 within the UMaG, thereby confirming its condition of a Ba dwarf star. Besides this, we aim to study the possible existence of a connection between the abundances of Cu and Ba.

The studies of Pereira & Porto de Mello (1997) and Pereira, Smith & Cunha (1998) verified that there is a deficiency of Cu abundances relative to Fe connected to an overabundance of [Ba/Fe] in symbiotic stars. Another similar result is found by Vanture (1992) for the CH star HD26, which shows [Cu/Fe]=−1.5 and [Y/Fe]=+1.0 dex. The scientific importance in studying the abundance of Cu is because it has been noticed that Cu is manufactured by several mechanisms still poorly known in the literature. The study of [Cu/Fe] in stars of different metallicities gives an important indication of the nucleosynthetic processes derived from...
2 OBSERVATIONS AND ANALYSIS

High S/N, moderately high-resolution spectra of the UMaG stars and a sample of normal solar-type disc stars were obtained at the condé spectrograph of 1.6-m telescope of the Observatório do Pico dos Dias, Brazil. We discuss separately the observations for the two samples.

The selected UMaG stars were observed in two 140 Å wide spectral regions centered in $\lambda$5810 and $\lambda$6145, in September 1997. We targeted at the $\lambda$5853, $\lambda$6141 Ba II and the $\lambda$5782 Cu I spectral features. Na I, Fe I and Fe II lines are also present in the $\lambda$6145 region; a few useful Fe I lines were measured in the $\lambda$5810 region. The spectral resolution was 0.3 Å and all spectra were integrated to S/N $\geq$ 200. Three of the seven selected UMaG stars were observed in both regions: the remaining were observed only in $\lambda$5810. Clear sky spectra were obtained in both regions as a solar template.

A sample of 13 solar-type disc stars spanning -0.8 < [Fe/H] < 0.0 were observed between 1991 and 1997 in 140 Å wide spectral regions centered at $\lambda$5244 and $\lambda$5810, at a resolution of 0.3 Å. Three more 100 Å wide spectral regions centered at $\lambda$5053, $\lambda$5614 and $\lambda$6707 were observed at a resolution of 0.2 Å. S/N ratios in excess of 200 were obtained for nearly all stars. There are many unblended Fe I and Fe II lines in these spectral ranges: we also targeted at the $\lambda$5218 Cu I line. Sky and Moon spectra were observed at very high S/N for each region.

Effective temperatures for the UMaG stars were determined from the (B-V), (b-y) and $\beta$ color indices through the calibrations of Saxner & Hammarbäck (1985). Most of the UMaG stars had no Fe II lines for a spectroscopic determination of the surface gravity. This parameter was then determined by plotting the stars in the theoretical solar-metallicity HR diagram of Charbonnel et al. (1993) by means of the derived T$_{\text{eff}}$, Hipparcos paralaxes (ESA, 1997) and the bolometric corrections of Habets & Heintze (1981). Surface gravities were calculated by deriving the stellar masses from their positions with respect to the theoretical tracks. Microturbulent velocities $\xi$ were obtained by forcing the Fe I line abundances to be independent of line strength: this was done only for HR2047, HR6094 and HR6748, observed in both the $\lambda$5810 and $\lambda$6145 regions. For all other stars $\xi$ was derived from the relation given by Edvardsson et al. (1993) (hereafter, E93). Atmospheric parameters for the solar-type disc star sample were determined exclusively from the spectral data. Effective temperatures, surface gravities, Fe abundances and microturbulent velocities were determined from the simultaneous solution of the excitation & ionization equilibria of Fe. Exceptions to this are HR2883, HR3018, HR7875, HR8181, and HR8697 for which the atmospheric parameters were taken from the E93 analysis. In all cases, the Fe abundances derived from the Fe I lines available in our spectra were fully consistent with the metallicities given by E93.

The equivalent widths ($W_{\lambda}$s) of the spectra were converted to elemental abundances using the modified MARCS atmospheric models (E93) and a computer code developed by M. Spite (Paris-Meudon Observatory). Tables 1 and 2 show the measured $W_{\lambda}$s for all available lines in the UMaG stars and normal disc stars, respectively. Both the stellar and solar $W_{\lambda}$s were converted to the $W_{\lambda}$ system of Meylan, Furenlid & Wiggs (1993), who generated solar $W_{\lambda}$s by fitting Voigt profiles to the observed line profiles of the Kurucz et al. (1984) Solar Atlas, by means of the relation $W_{\lambda}(\text{OPD}) = 1.05 W_{\lambda}$ (Atlas). This relation has been established by a linear regression between the common lines, and is consistent with the low scattered light levels expected for this conventional coude spectrograph. The dispersion of the regression is 3 mA and we take this as an estimate of the error of the $W_{\lambda}$ measurements. Solar gf values were derived from the solar $W_{\lambda}$s and a solar model atmosphere also computed in the modified MARCS code. For the $\lambda$5218 and $\lambda$5782 Cu I lines, the hyperfine structure was explicitly taken into account according to the data of Steffen (1985) (Table 3).

All analyses were rigorously differential with respect to the Sun, the standard star, for which we adopted T$_{\text{eff}}$ = 5777 K, log $g$ = 4.44 and $\xi$ = 1.2 km.s$^{-1}$. In such a differential analysis the internal errors are the ones to worry about: these are estimated at 1σ, respectively, for the UMaG stars and solar-type disc stars, as $\sigma$ (T$_{\text{eff}}$) = 70 K, $\sigma$ (log $g$) = 0.10 dex, $\sigma$ ([Fe/H]) = 0.12 dex, $\sigma$ (ξ) = 0.3 km.s$^{-1}$, and $\sigma$ (T$_{\text{eff}}$) = 70 K, $\sigma$ (log $g$) = 0.30 dex, $\sigma$ ([Fe/H]) = 0.07 dex, $\sigma$ (ξ) = 0.153 km.s$^{-1}$. For the disc star sample with the exception of the stars for which the atmospheric parameters were taken from E93, we opted for the spectroscopic surface gravities to keep with atmospheric parameters derived exclusively from the line data: an analysis in the theoretical HR diagram similarly as done for the UMaG stars pointed to full consistency between the spectroscopic surface gravities and the gravities derived from the Hipparcos paralaxes. Atmospheric parameters and elemental abundances are given, respectively, for the UMaG stars and solar-type disc stars, in Tables 4 and 5. In Table 4 one may notice the good consistency, within the uncertainties, of the [Fe/H] and [Fe/H] abundances. The abundance data sets of the UMaG and the disc stars are thus fully consistent with each other, allowing direct comparisons.

In Table 6 we list the effects upon the abundance ratios [Cu/Fe] and [Ba/Fe] of changing the atmospheric parameters and the $W_{\lambda}$ within the estimated errors. Errors in T$_{\text{eff}}$
and in the W₆₅₈₃ are seen to dominate the total uncertainty of the [Cu/Fe] ratio, which is 0.09 dex, whereas errors in the microturbulent velocity mostly affect [Ba/Fe], for which the compounded r.m.s. uncertainty is 0.11 dex.

### 3 CONCLUSIONS AND DISCUSSION

One of the objectives of this analysis was to obtain Ba abundances of the Ursa Major Group and therefore verify the status of the member HR6094 as a Ba dwarf star. The anomalous Ba dwarf status of HR6094 was previously proposed by Porto de Mello & da Silva (1997) as being unique for a young, solar metallicity, though we note that Jeffries & Smalley (1996) report a solar metallicity, rapidly rotating K-dwarf star, member of a binary system, which also shows Ba excess. Figure 1 shows the observed spectra of the UMaG member, HR6748, and of a normal star, HR77. The normal star’s atmospheric parameters are very similar to those of HR6748 as seen in Tables 4 and 5. It is clearly seen that the λ5853 BaII line is stronger in the UMaG star spectrum. Since the [Ba/Fe] abundance ratio have shown to change +0.03 as Tₑₑₑ changes +100 K, one would expect the λ5853 BaII line to be stronger in HR77 spectrum which is slightly hotter than HR6748, if the two stars had a similar [Ba/Fe] ratio.

The observed [Ba/Fe] for the UMaG stars stand out in their comparison to solar neighborhood normal stars with the same metallicity. Figure 2 shows [Ba/Fe] vs. [Fe/H] for the UMaG stars, plotted with normal disc stars from E93 and the stars listed in Table 5. We may assume good homogeneity between our abundance data and E93’s, as judged by the similar methods of analysis and the very similar metallicities found for the common stars (section 2); particularly, for HR2047 the atmospheric parameters, Fe and Ba abundances show excellent agreement with our values. One can see that the UMaG stars (represented by filled circles in the figure) form a separated group resembling the locus of Ba dwarf stars represented by crosses in the figure.

There are a few other UMaG stars with abundance determinations in the literature. For those stars with derived Ba abundances, there is a good agreement in the existence of an overabundance of Ba relative to Fe. The study by Wallerstein (1962) found for HD115043 (a probable member of UMaG according to Soderblom & Mayor 1993) [Ba/Fe]=+0.40 based on photographic plates. Oinas (1974) performed a model atmosphere analysis of ξ Boo (a possible UMaG member) obtaining [Ba/Fe]=+0.2 based also on a photographic plate. These studies claim uncertainties of ~0.2 dex in their analyses. More recently, E93 analyzed HR2047, another UMaG member also analyzed here, and found [Ba/Fe]=+0.25 and [Y/Fe]=+0.31, while
stars (from Soderblom 1985) compatible with both the UMaG HR5011 has chromospheric activity level (log R′HK) age determination reliability. The UMaG and the Hyades all older than about 1.6 Gyr, a measure taken to increase cal isochrone fitting to observational HR diagrams and are stars from E93 had their ages determined from theoretical disc star, HR5011, from Porto de Mello (1998). The modulation from E93 and added points for: the present results an inverse [Ba/Fe] correlation with age.

Porto de Mello & da Silva (1997) found [Ba/Fe]=+0.37 and [Y/Fe]=+0.22 for HR6094, which they thought was a Ba dwarf. E93 argue that their Ba abundance determination might be considered normal for young stars in the light of a primordial origin for the UMaG abundances. In any of these cases, the fact that all analyzed stars in the group show overabundances of Ba is striking. The enrichment of the s-process elements from an AGB star through the Ba star phenomenon could be a reasonable explanation if not all the seven stars had shown similar overabundances. There is an insufficient number of stars younger than 1.5 Gyr in Figure 3 to permit any further conclusion. Certainly, such lack of stars postpones any conclusion about what is going on with the Ba abundances for the youngest stars in the solar vicin-

### Table 1. Measured equivalent widths for the Ursa Major stars.

| Ion  | \(\lambda(\text{Å})\) | \(\chi_{ex}\) | log\(gf\) | HR531B | HR1321 | HR1322 | HR2047 | HD41593 | HR6094 | HR6748 |
|------|----------------|-------------|----------|--------|--------|--------|--------|--------|--------|--------|
| FeI  | 5778.463       | 2.59        | -3.44    | 25     | 21     | 30     | —      | 43     | 24     | —      |
| FeI  | 5811.916       | 4.14        | -2.41    | —      | 9      | 15     | 10     | 17     | —      | 26     | 22     |
| FeI  | 5814.805       | 4.28        | -1.82    | 22     | 28     | 42     | —      | 42     | 61     | 42     |
| FeI  | 5852.222       | 4.55        | -1.18    | 40     | 36     | 45     | 42     | 61     | 42     | 34     |
| FeI  | 5855.086       | 4.61        | -1.53    | 23     | —      | 27     | 19     | 32     | 23     | 18     |
| FeI  | 5856.096       | 4.29        | -1.54    | 33     | 30     | 40     | 31     | 49     | 38     | 31     |
| FeI  | 5859.596       | 4.55        | -0.42    | 79     | 71     | 86     | 76     | 96     | 80     | 74     |
| FeI  | 6093.649       | 4.61        | -1.35    | —      | —      | —      | —      | 30     | —      | 33     | 28     |
| FeI  | 6096.671       | 3.98        | -1.80    | —      | —      | —      | —      | 34     | —      | 40     | —      |
| FeI  | 6151.623       | 2.18        | -3.27    | —      | —      | —      | —      | 40     | —      | 51     | 42     |
| FeI  | 6159.382       | 4.61        | -1.89    | —      | —      | —      | —      | —      | —      | 17     | —      |
| FeI  | 6173.340       | 2.22        | -2.79    | —      | —      | —      | —      | 66     | —      | 74     | 64     |
| FeI  | 6187.995       | 3.94        | -1.60    | —      | —      | —      | —      | 42     | —      | 50     | 42     |
| FeI  | 6191.571       | 2.43        | -1.56    | —      | —      | —      | —      | —      | —      | 138    | —      |
| FeII | 6084.105       | 3.20        | -3.81    | —      | —      | —      | —      | 26     | —      | 23     | 19     |
| FeII | 6149.240       | 3.89        | -2.72    | —      | —      | —      | —      | 42     | —      | 43     | 38     |
| CuI  | 5782.136       | 1.64        | —        | 65     | 55     | 73     | 57     | 95     | 67     | 54     |
| BaII | 5853.688       | 0.60        | -0.76    | 80     | 78     | 85     | 82     | 83     | 89     | 84     |
| BaII | 6141.727       | 0.70        | +0.30    | —      | —      | —      | 152    | —      | 161    | 151    |

The overabundance of s-process elements in the diagram is real within the uncertainties.

Other suggested anomalies are Na, C and Cu deficiencies with respect to normal solar-metallicity stars. The average [Na/Fe] abundance ratio found for three UMaG stars with available NaI lines is \((-0.15\text{ dex})\). Porto de Mello & da Silva (1997) and Tomkin, Woolf & Lambert (1995) respectively, have found a 0.2 dex C-deficiency for both HR6094 and HR2047. As argued by Porto de Mello & da Silva, a C-deficiency may accompany the operation of the hot-bottom burning in AGB stars. Regarding the homogeneity of the abundance pattern found for the analyzed member stars, it is likely that the Group as a whole is C-deficient.

The results found for the Cu abundances deserve a special attention as is shown in Figure 5 for the [Cu/Fe] abundance ratios. We have plotted [Cu/Fe] vs. [Fe/H] for the UMaG stars and disc stars, as found in the present work, and stars from Sneden et al. (1991) and Porto de Mello (1998), that lie in the same metallicity range. Porto de Mello’s (1998) analysis follows strictly the same methods employed...
Table 2. Measured equivalent widths for the normal disc stars.

| Ion  | λ(Å)   | ex   | loggf | Moon | HR | HR | HR | HR | HR | HR | HR | HR | HR | HR |
|------|--------|------|-------|------|----|----|----|----|----|----|----|----|----|----|
| FeI  | 5196.056 | 4.26 | -0.72 | 81   | 65 | 73 | 70 | 80 | 76 | 75 | 41  | —  | 55  | —  | —  |
| FeI  | 5197.929 | 4.30 | -1.51 | 37   | 24 | 31 | 26 | 26 | 34 | 28 | 12  | 10  | 18  | —  | —  |
| FeI  | 5221.188 | 3.63 | -2.14 | 33   | 24 | 32 | 21 | 25 | 36 | 33 | 7   | 10  | 16  | 6   | 23  |
| FeI  | 5225.525 | 0.11 | -4.37 | 88   | 68 | 82 | 81 | 82 | 85 | 100 | 39  | 44  | 53  | 30  | 67  |
| FeI  | 5242.491 | 3.63 | -1.04 | 93   | 79 | 88 | 78 | 85 | 93 | 85 | 54  | 56  | 72  | 53  | 80  |
| FeI  | 5243.773 | 4.26 | -0.95 | 68   | 53 | 62 | 51 | 58 | 70 | 54 | 27  | 29  | 45  | 27  | 55  |
| FeI  | 5247.049 | 0.09 | -4.57 | 81   | 60 | 77 | 78 | 81 | 80 | 99  | 33  | 40  | 56  | 28  | 65  | 61  |
| FeI  | 5250.216 | 0.12 | -4.54 | 81   | 59 | 74 | 75 | 80 | 76 | 93  | 32  | 47  | 28  | 65  | 39  |
| FeI  | 5778.463 | 2.59 | -3.44 | 25   | 15 | 17 | 18 | 20 | 13  | 24  | —  | 11  | 16  | 10  | —  | —  |
| FeI  | 5811.916 | 4.14 | -2.41 | 11   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  |
| FeI  | 5814.805 | 4.28 | -1.82 | 25   | 15 | 22 | 16 | 23 | 24  | —  | 11  | 17  | 11  | —  | —  |
| FeI  | 5852.222 | 4.55 | -1.18 | 43   | 29 | 35 | 32 | 32 | 40  | 34  | —  | 19  | 9   | 29  | 22  |
| FeI  | 5855.086 | 4.61 | -1.53 | 24   | 14 | 18 | 14 | 18 | 21  | 14  | —  | 11  | 18  | 11  | 8   |
| FeI  | 5856.096 | 4.29 | -0.95 | 68   | 53 | 62 | 51 | 58 | 70 | 54 | 27  | 29  | 45  | 27  | 55  |
| FeI  | 5956.706 | 0.86 | -4.34 | 63   | —  | —  | —  | —  | —  | —  | 48  | —  | —  | —  | —  |
| FeI  | 5969.578 | 4.28 | -2.56 | 6    | —  | —  | —  | —  | —  | 8   | 10  | —  | —  | —  | —  |
| FeI  | 5983.688 | 4.55 | -0.62 | 74   | —  | —  | —  | —  | —  | —  | 65  | —  | —  | —  | —  |
| FeI  | 6003.022 | 3.88 | -0.90 | 92   | —  | —  | —  | —  | —  | —  | 79  | —  | —  | 76  | —  |
| FeI  | 6008.566 | 3.88 | -0.84 | 95   | —  | —  | —  | —  | —  | —  | 85  | —  | —  | 79  | —  |
| FeI  | 6056.013 | 4.73 | -0.39 | 80   | 63 | 55 | 61 | 60 | —  | —  | —  | —  | —  | —  | —  |
| FeI  | 6078.499 | 4.79 | -0.20 | 89   | 71 | 75 | 56 | 67 | 62 | 38 | 37 | 58  | 36  | 64  | 55  |
| FeI  | 6079.016 | 4.65 | -0.88 | 54   | 40 | 28 | 38 | 38 | 36 | 17 | 16 | 31  | 16  | 35  | 28  |
| FeI  | 6082.708 | 2.22 | -3.48 | 40   | 27 | 33 | 29 | 32 | —  | 42  | 8   | 10  | 16  | 7   | 17  |
| FeI  | 6093.649 | 4.11 | -1.35 | 43   | 29 | 35 | 32 | 32 | 40  | 34  | —  | 19  | 9   | 29  | 22  |
| FeI  | 6096.671 | 3.98 | -1.80 | 39   | 27 | 34 | 24 | 28 | 30  | 11 | 9  | 16  | 10  | 15  | 11  |
| FeI  | 6098.250 | 4.56 | -1.76 | 18   | 14 | 13 | 11 | 13 | —  | —  | —  | —  | —  | —  | —  |
| FeI  | 6151.623 | 2.18 | -3.27 | 10   | 9  | 10 | 9  | 16 | 10 | —  | —  | —  | —  | 12  | —  |
| FeI  | 6185.704 | 5.65 | -0.75 | 18   | 15 | 15 | 9  | 15 | 9   | —  | —  | —  | —  | 14  | —  |
| FeI  | 6187.905 | 3.94 | -1.60 | 51   | 37 | —  | 33 | 45 | 41  | —  | —  | —  | —  | 37  | —  |
| FeI  | 6191.571 | 2.43 | -1.56 | 137  | 118 | 116 | 126 | 133 | —  | —  | —  | —  | 118  | —  |
| FeI  | 6696.671 | 3.98 | -1.48 | 19   | 24 | 14 | 15 | 13 | 18 | 16 | —  | —  | 11  | —  | —  |
| CuI  | 5218.209 | 3.82 | —     | 60   | 44 | 57 | 50 | 49 | 44 | 49 | 34  | 32  | 44  | 34  |
| BaII | 5853.688 | 0.60 | -0.76 | 68   | 67 | 79 | 64 | 50 | 79 | 66 | —  | 71  | 43  | 62  | 31  |
| BaII | 6141.727 | 0.70 | 0.30  | 125  | 119 | 108 | 127 | 109 | 95 | 86 | 120 | 88 | 113 | 130 | 86 |

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Table 3. Hyperfine structure for CuI lines.

| Ion  | $\lambda$(Å) | $\chi$ | log $gf$ |
|------|---------------|--------|--------|
| CuI  | 5218.059      | 3.82   | -1.33  |
| CuI  | 5218.061      | 3.82   | -0.85  |
| CuI  | 5218.063      | 3.82   | -0.98  |
| CuI  | 5218.065      | 3.82   | -0.26  |
| CuI  | 5218.069      | 3.82   | -0.48  |
| CuI  | 5218.071      | 3.82   | -0.48  |
| CuI  | 5218.074      | 3.82   | -0.14  |
| CuI  | 5782.032      | 1.64   | -3.53  |
| CuI  | 5782.042      | 1.64   | -3.84  |
| CuI  | 5782.054      | 1.64   | -3.14  |
| CuI  | 5782.064      | 1.64   | -3.19  |
| CuI  | 5782.073      | 1.64   | -2.79  |
| CuI  | 5782.084      | 1.64   | -2.69  |

Table 4. Atmospheric parameters and elemental abundances for UMa Group stars. HR2047, HR6094 and HR6748 were observed in both the $\lambda$5810 and $\lambda$6145 regions: for these stars, the [Ba/Fe] ratios refer to [FeII/H], for the other stars, no Fe II lines were available and the [Ba/Fe] ratios refer to [FeI/H]. For all other elements, the [element/Fe] ratios refer to [FeI/H]. The number of lines available for each species is given in parentheses.

| Star  | $T_{\text{eff}}$ (K) | log g | $\xi$ (km.s$^{-1}$) | [FeI/H] | [FeII/H] | [Cu/Fe] | [Ba/Fe] |
|-------|----------------------|-------|---------------------|--------|----------|--------|--------|
| HR531B| 5833                 | 4.53  | 1.1                 | -0.02(5) | —        | -0.12(1) | +0.39(1) |
| HR1321| 5557                 | 4.51  | 0.9                 | -0.27(6) | —        | -0.23(1) | +0.48(1) |
| HR1322| 5950                 | 4.49  | 1.2                 | +0.17(7) | —        | -0.12(1) | +0.32(1) |
| HR2047| 5929                 | 4.49  | 1.1                 | -0.02(10)| +0.10(2)| -0.14(1) | +0.29(2) |
| HD15021| 5277                | 4.49  | 0.7                 | +0.06(6) | —        | -0.22(1) | +0.39(1) |
| HR6094| 5895                 | 4.52  | 1.5                 | +0.03(13)| +0.07(2)| -0.11(1) | +0.30(2) |
| HR6748| 5895                 | 4.49  | 1.0                 | -0.06(9) | -0.03(2)| -0.17(1) | +0.44(2) |

Table 5. Atmospheric parameters and elemental abundances for the normal disc stars.

| Star  | $T_{\text{eff}}$ (K) | log g | $\xi$ (km.s$^{-1}$) | [Fe/H] | [Cu/Fe] | [Ba/Fe] |
|-------|----------------------|-------|---------------------|--------|--------|--------|
| HR77  | 5970                 | 4.48  | 0.88                | -0.07  | -0.09(1)| +0.18(1)|
| HR98  | 5860                 | 4.05  | 1.50                | -0.11  | +0.07(1)| +0.03(1)|
| HR173 | 5270                 | 3.75  | 1.15                | -0.70  | -0.06(1)| -0.02(1)|
| HR509 | 5320                 | 4.30  | 0.70                | -0.50(2)| -0.08(1)| -0.03(2)|
| HR695 | 5830                 | 3.87  | 1.17                | +0.03  | -0.01(1)| +0.06(1)|
| HR914 | 5020                 | 3.66  | 0.73                | -0.57(2)| -0.13(1)| +0.01(2)|
| HR2883| 5990                 | 4.18  | 1.65                | -0.75(2)| -0.02(1)| -0.07(2)|
| HR3018| 5820                 | 4.42  | 1.21                | -0.78(2)| -0.07(1)| -0.15(2)|
| HR7855| 5991                 | 4.09  | 1.78                | -0.44(2)| 0.00(1) | -0.03(2)|
| HR8181| 6139                 | 4.34  | 1.57                | -0.67(2)| 0.00(1) | -0.02(2)|
| HR8550| 5753                 | 4.27  | 1.10                | -0.25(2)| -0.04(1)| +0.01(2)|
| HR8697| 6288                 | 3.97  | 2.17                | -0.25(2)| -0.03(1)| +0.07(2)|
| HR9088| 5551                 | 4.45  | 0.85                | -0.73(2)| -0.13(1)| -0.18(2)|

Table 6. Dependence of Cu and Ba abundances on input parameters.

| $\Delta T_{\text{eff}}$ | $\Delta$ log g | $\Delta$ [Fe/H] | $\Delta$ [FeII/H] | $\Delta$ $\xi$ | $\Delta$ $W_{\lambda}$ |
|-------------------------|---------------|----------------|------------------|-------------|----------------|
| +100 K                  | -0.10 cm.s$^{-2}$ | +0.10 dex | +0.3 km.s$^{-1}$ | +3 mÅ |
| [Cu/Fe]                | +0.06        | +0.01 | +0.01 | -0.01 | +0.06 |
| [Ba/Fe]                | +0.03        | -0.02 | +0.04 | -0.09 | +0.04 |
in the present work, while Sneden et al’s (1991) data are somewhat heterogeneous particularly in what pertains to the atmospheric parameters. Keeping in mind these limitations, nevertheless the UMaG stars appear as an isolated group as compared to normal stars with the same [Fe/H]. The [Cu/Fe] ratio increases as [Fe/H] increases for the normal stars. Unfortunately, there are no Cu abundances determined for other stars with [Fe/H] > 0, although the turnover in the [Cu/Fe] versus [Fe/H] diagram is clear at [Fe/H] ≈ 0 (marked by the vertical dotted line). Since SNeIa starts to produce iron-peak elements at [Fe/H] ~ −1.2 (Matteucci et al. 1993), the [Cu/Fe] ratio should be constant with [Fe/H] after 0.0. It rather increases for higher [Fe/H] which might suggest that there is another nucleosynthetic process producing Cu.

The [Cu/Fe] deficiency seems to follow the [Ba/Fe] overabundance, i.e., [Cu/Fe] decreases as the [Ba/Fe] ratio increases, suggesting that there may be a connection between the Cu destruction and the production of Ba (and other heavy elements produced by the main component of the s-process). Another piece of evidence in favor of a nucleosynthetic connection between the s-process and Cu has been recently found by Pereira & Porto de Mello (1997) and Pereira et al. (1998), who found remarkable Cu depletions for two Ba stars which are also symbiotic systems: both appear appreciably enriched in the s-process elements, resembling classical low metallicity Ba giants, and present remarkable Cu deficiencies with respect to giant halo stars of the same metallicity. Figure 6 shows a plot of [Cu/Fe] versus [Ba/Fe] for the UMaG stars, disc stars and these two Ba stars. The fact that Cu is deficient in these Ba stars, where the s-process elements are enhanced, leads us to believe that Cu is depleted in the process of synthesizing neutron capture elements. Another evidence for this anti-correlation between Cu and Ba comes from stars more metal-rich than the Sun. For higher metallicities the [Cu/Fe] ratio is supersolar (Figure 5). If one considers that Castro et al. (1997) and E93 found that the [Ba/Fe] ratio is underabundant for disc stars with [Fe/H] > 0, a possible conclusion would be that as Ba becomes underabundant, the abundance of Cu goes up, indicating that Cu may be acting as seed for the neutron capture process, and its depletion will be lessened in the metal-rich stars, which are underabundant in Ba. Unfortunately these last two studies do not provide Cu abundances. Clearly, it is necessary to obtain further Cu abundances for
disc stars. Boesgaard, Budge & Burck (1988) have argued that the mixing of enriched material from which the cluster stars were made was not uniform about 0.3 – 0.7 Gyr ago for the young star clusters in the solar vicinity. One could hypothesize that the ejecta of a few AGB stars, early in the lifetime of the group, are responsible for the observed altered Cu and s-process abundances. This event need not to have happened necessarily during the condensation of the group, but possibly early enough that it still retained high spatial cohesion. It remains highly speculative that appreciable enrichment through matter accretion could remain efficient over distance scales of tenths of parsecs, but it is not inconceivable that AGB stars with 4–5 $M_\odot$ may have evolved fast enough to provoke accretion of nucleosynthetically altered matter upon their lower mass fellow group members before the group lost its initial compactness. Such a scenario will be tested when accurate and detailed abundance data of other young stars of the solar vicinity become available, to be compared with the abundance pattern found here for the UMaG. One may then decide if the UMaG is either indeed anomalous or merely reflects the chemical evolution of the galactic disc for very young star systems. Possibly, the remnants of those AGB stars are now observed as the two white dwarf stars that follow the member stars HR6094 and Sirius.

We can thus summarize the chemical pattern of the UMaG stars as follows: they are C-deficient by 0.2 dex, Na-deficient by 0.15 dex, Cu-deficient by 0.2 dex and enriched in the main s-process elements by 0.3 – 0.5 dex. We have already launched an observational effort to obtain echelle spectra for all the probable UMaG members in order to investigate the elements that have shown to be anomalous in the Group. Obviously, further data on the abundance pattern of young clusters and kinematical groups are of great interest.

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