THE CHEMICAL COMPOSITION OF FIELD HALO STARS

Bengt Gustafsson
Stockholm Observatory
Saltsjöbaden, Sweden*)

ABSTRACT: Recent studies of the variation of relative abundances of elements with over-all metallicity in halo stars are reviewed. The reality of these "trends" and the scatter around them are commented on. The uncertainties in the analyses are illustrated by empirically traced inconsistencies ascribed to departures from LTE.

I. REVIEWS

The very impressive improvements, to which ESO has contributed significantly, in the design of high-resolution spectrometers and suitable detectors for these instruments in the last 15 years have dramatically increased our knowledge about the chemical composition of halo stars. In particular, it has now become possible to, e.g., with the ESO CAT/CES+CCD system, observe extensive samples of Pop. II dwarfs. Since these stars are presumably little affected by mixing of interior nuclear-burning products to their surfaces, they can be regarded as samples of interstellar matter from the early evolution of the Galaxy.

The results of current surveys of the chemical composition of halo dwarfs, and giants, were recently summarized by Spite and Spite (1985). Analyses of the CNO element abundances in such stars were reviewed by Sneden (1985), and Lambert (1985) discussed the results obtained for the light elements from Sodium to Calcium. The methodological problems in analyses of metal-poor late-type stars were commented on by Gustafsson (1983). Here, I shall restrict the discussion to a very schematic presentation of the over-all results from the chemical analyses of late-type halo stars (including comments on some very recent results) and discuss the weight of these results. I shall not discuss abundances of the lightest elements (see, e.g., Spite et al. 1987 and references cited therein for a discussion of Lithium and the new results for Boron presented by Molars in this volume), nor shall I comment on the isotopic abundances (see, e.g., the paper by Barbuy in the present proceedings). Also, unlike several of the review papers listed above, the chemical composition trends for stars belonging to Intermediate Pop. II (with [Fe/H] > -1.0) are not discussed here.

II. TRENDS

A schematic summary of the systematic variations of abundance ratios relative to iron is presented in Fig. 1. This figure is a compilation of the compilations

*) Present address: Astronomical Observatory, Box 515, S-751 20 Uppsala, Sweden
Figure 1. Schematic relative-abundance results for Pop. II stars. The hatched areas indicate results from recent analyses of, mainly, dwarf stars - see the text for further references. Dashed lines indicate various suggested trends which still need confirmation.
from the sources mentioned above, as well as from more recent studies, to be
listed below. Some elements can be assumed to be produced in the stellar interior
and mixed to the surface during the subgiant-giant phases (notably C, N and the s
elements); for such elements the sample is restricted to dwarf stars.

The major trends seen directly in Fig. 1 seem to be well established, in the
sense that reasonably independent up-to-date studies tend to confirm them, at
least qualitatively. However, some more questionable trends, which have been
suggested but still need independent confirmation, can also be seen. These less
well established trends are marked in Fig. 1 as dashed lines.

I shall now comment on probable and possible trends for the different elements:

The Carbon abundances of metal-poor dwarfs tend to follow the Iron abundances
relatively closely, at least for [Fe/H] > -1.8 (cf. Sneden 1985, Laird 1985,
Tomkin, Sneden and Lambert 1986). There is a probable or possible tendency for a
negative [C/Fe]; e.g., Tomkin et al. (1986) found [C/Fe] = -0.23 ± 0.15 (s.d.) for
stars with [Fe/H] > -1.8, and Laird (1985) obtained a similar tendency. Both these
studies were based on CH bands; we note in passing that the high-excitation C I
lines tend to lead to significantly higher C/H ratios. The possible trend noted
by Tomkin et al. (1986) for a raise in [C/Fe] with [Fe/H] decreasing below -1.8
may well be an artifact of their use of scaled solar temperature structures.
However, the study at lower resolution by Carbon et al. (1987) of 83 subdwarfs
also suggests an increase in [C/Fe] for the most metal-poor stars; this tendency
needs further investigation.

In contrast to earlier analyses, contemporary studies indicate that Nitrogen
also follows Iron relative closely in the metal-poor dwarfs. However, the
uncertainties in the individual Nitrogen abundance determinations are considerable
- e.g., recent results (since 1982) of [N/Fe] for the extensively studied dwarf
HD 140283 range from 1.0 to -0.5 (Barbuy et al. 1985). This great uncertainty
is partially the result of the difficult criteria that are used for estimating
the Nitrogen abundances; electronic transitions of NH and CN located in the ultra-
violet or blue parts of the spectrum. There seems to be some tendency for [N/Fe]
or [N/C] to be smaller than zero (Carbon et al. 1987), but in view of the un-
certainties in the analysis this tendency cannot be regarded as very well
established.

The general tendency for Oxygen to come out overabundant in chemical analyses
of Pop. II stars is well established. A number of recent investigations (cf. Gratton
and Ortolani 1986 for references) suggest [O/Fe] ≈ 0.5 ± 0.1 for both metal-poor
dwarfs and giants; this includes studies based on the forbidden O I λ6300 as well
on the highly excited IR lines. Less clear, however, is whether this tendency is
gradual, such that [O/Fe] increases significantly when [Fe/H] diminishes below
-1.0 or whether it stays relatively constant within the Pop. II metallicity interval.

*) Interesting exceptions are the Nitrogen rich dwarfs, discussed by, e.g., Laird (1985)
Some of this uncertainty is in fact due to the uncertainties concerning [Fe/H] for the very metal-poor dwarfs.

The general trend for the so-called $\alpha$ elements (Mg, Si, Ca, Ti) to be overabundant relative to Iron in metal-poor stars was discovered early (Wallerstein 1962) and is nowadays rather well established (Francois 1986, Laird 1986, Magain 1987a, Luck and Bond 1983, Lambert 1985 and references quoted therein). A typical value for this enrichment is $[\alpha/Fe] = 0.3 - 0.4$. The situation is not totally clear, though; the model dependence in these determinations is considerable. Also, note that Barbuy, Spite and Spite (1985) found roughly solar [Mg/Fe] values for two of their three halo stars and did not confirm the overabundance of Titanium.

The issue whether there is a systematic steady increase in $[\alpha/Fe]$ beyond, e.g., [Fe/H] = -2, as has been proposed by several authors and for several $\alpha$ elements, is not resolved yet. The statistics is still scanty and the data are uncertain for the most metal-poor stars, such that diverging conclusions are possible. We note that Luck and Bond (1983a) suggested a tendency for [Ti/Fe] to drop towards the solar value for the most metal-poor stars.

For the odd-Z elements Sodium and Aluminium recent studies (Francois 1986a and b, Gratton and Sneden 1987, Magain 1987a) suggest solar or sub-solar abundances relative to Iron. For [Na/Mg] or [Al/Mg] values between -0.2 and -1.2 are obtained, in accordance with the well-known odd-even effect of carbon burning (Arnett 1971, Woosley and Weaver 1982). For Al/Mg Magain (1987a) traces a decrease with decreasing [Mg/H]; however, this is not in agreement with Francois (1986a).

Also note that Bessell and Norris (1984) find [Al/Mg] = -0.5 for their ultra-metal-deficient red giant CD -38°245 ([Fe/H] = -4.5), suggesting that Al in this star has been produced as a primary element and in contradiction with recent theoretical predictions.

Although the previously much debated problems with the discrepancy between different abundance determinations for Al may now be essentially resolved (Magain 1987a) there are obviously still considerable uncertainties, e.g. related to the model sensitivity of the abundance criteria used. For Sodium the present data do not seem to admit any firm conclusions as regards a systematic variation of [Na/Mg] with [Fe/H] for the Pop. II stars (Magain 1987a, Francois 1986b).

The data are more meagre for the odd-Z element Scandium but those available suggest that the Sc abundances also show the predicted odd-even effect with respect to Ca and Ti (cf. Spite and Spite 1985, Barbuy et al. 1985, Ferrin 1986).

Also Manganese tends to show an odd-even effect for metal-poor stars with respect to Iron (see Gratton's paper in this volume and references quoted there).

It is, however, not yet clear whether there is a trend for [Mn/Fe] to decrease with decreasing [Fe/H] within Pop. II, or whether there is an approximately constant Mn depletion for Pop. II stars with different Iron abundance.
The rest of the elements within the Iron Group, as well as Zinc and Copper, seem to follow Iron. An interesting exception may be Nickel, which has been claimed to be over-abundant relative to Iron by Luck and Bond (1983b) for the most metal-poor giants. However, several other independent studies (cf. Barbuy et al. 1985 and references cited therein, and Sneden and Filippenkovsky 1985) do not confirm this tendency.

Among the heavier elements Strontium, Yttrium, and Zirconium as well as Barium are over-deficient for stars with \([\text{Fe/H}] \approx -1.5\) (cf. Spite and Spite 1985 and references cited therein, and Luck and Bond 1983a). The deficiency is about two times greater for the heavier element Ba than for the lighter group. Although for the more metal-rich stars these elements are mainly formed in the \(s\)-process, in Extreme Pop. II stars much of them may in fact be due to the \(r\)-process (Truran 1981, Luck and Bond 1983a). This suggestion is corroborated by the fact that the abundance of these elements does not seem to decrease, relative to Iron, when the Iron abundance decreases to extreme values. Bessell and Norris (1984) thus found \([\text{Sr/Fe}]\) and \([\text{Ba/Fe}]\) values for CD \(-36^\circ 245\) which are not very different from those of the more metal-rich stars with \([\text{Fe/H}] \approx -3\).

For the elements Europium and Neodymium, which are probably mainly produced by the \(r\)-process (cf. Luck and Bond 1983) the abundances roughly seem to follow that of Iron. The question of whether there is a real cosmic scatter in \([r/\text{Fe}]\) at a given \([\text{Fe/H}]\) is of considerable importance and will be commented on subsequently.

III. QUESTIONS

Given the trends outlined above one may ask a number of questions, for instance the following ones:

1. Is the scatter around the mean relations, at a given \([\text{Fe/H}]\), real or just caused by errors in the analyses?
2. Are the rather abruptly changing directions, e.g. at \([\text{Fe/H}] \approx -1\) or \(-1.5\), real and thus reflecting changes in importance of different nucleosynthesis sites as the Galaxy evolved?
3. What is real in the trends and what is just due to systematic errors in the analyses?
4. Are there peculiar stars, deviating from the trends? If so, what are the origins of these stars?
5. What do these trends tell us about the history of our Galaxy?

In current literature much discussion is devoted to the last questions. Here, we shall conversely concentrate our interest towards the first three items in the list. For discussions of certain aspects of items (4) and (5) the reader is referred to the reviews presented in this volume by D. L. Lambert and F. Matteucci.
IV. SCATTER AND DISCONTINUITIES?

It is certainly of considerable importance for the understanding of the evolution of the Halo to find out of to which degree the scatter around the mean trends relative to [Fe/H] is real, and to which degree it merely reflects the uncertainties in the analyses. A related problem is whether the changes of slope in these trends are as abrupt as the schematic lines often drawn in diagrams demonstrating the trends may suggest. For instance, if there is no significant scatter in the α/Fe ratios for a given [Fe/H], it would indicate that the mixing of the halo gas was rather efficient, or that Mg and Fe at a given time were produced in relatively constant proportions by different objects contributing to the nucleosynthesis. If the real changes of slope in the [α/Fe] vs. [Fe/H] diagrams around [Fe/H] = −1.0 are abrupt that may indicate a sudden change in the relative importance of different sites of nucleosynthesis.

Lambert (1985) suggested that the great scatter around the main trends was mainly observational. That this is the case was recently convincingly demonstrated by Magain (1987a) for [Mg/Fe] – he found that if existing observational data were critically evaluated and homogeneously analysed the scatter at a given [Mg/H] diminished very significantly. Through a similar procedure Magain also found evidence for a well defined and steep slope in the [Al/Fe] – [Fe/H] diagram.

It is not known whether the great scatter present in [O/Fe] at a given [Fe/H] is significant, nor whether the considerable scatter in s and r elemental abundances for Pop. II stars at a given [Fe/H] is real. Clear peculiarities, such as the Pop. II Barium star HD 115444, which also seems to be Europium rich (Griffin et al. 1982), do not exclude the possibility that the normal stars show well-defined abundance patterns where almost all elements are only functions of [Fe/H]. Existing observing facilities make it possible to systematically study whether this is the case for most of the halo s-stars or not.

As long as the scatter in the relative abundances for Pop. II stars have not been studied and, if found to be observational, diminished considerably, it is very hard to judge whether the abrupt changes of slope in the suggested trends are real or not. In view of the possible systematic errors, the inhomogeneous sets of observations and the change of observational criteria with increasing metal abundance it seems quite possible that the abundance ratios could be gradually varying – many of the trends are in fact possible to approximate with one single straight line for all the [Fe/H] interval (including Pop. I). High signal/noise surveys, extending over the "critical points" at [Fe/H] = −1.0, −1.5, −1.8, and −2.5 would be needed to clarify this situation.
V. REALITIES?

There is a considerable number of sources of possible systematic errors in abundance determinations for metal-poor late-type stars. Here, I shall not discuss those connected with the derivation of reliable equivalent widths from noisy late-type spectra with insufficient resolution, although those problems certainly may be of considerable importance (cf. also the continuum-placement problems in echelle spectra discussed by Geisler, 1986). Nor shall I discuss the problems of obtaining reliable gf-values (from the Solar spectrum where the lines are often too strong, or from laboratory measurements where the lines may be too weak), nor those of estimating the effects of hyperfine structure and isotope shifts (for which basic data are often too meagre).

The art of selecting a model atmosphere with the right fundamental parameters for, e.g., a solar-type metal-poor star is rapidly developing. The infrared-flux method of Blackwell and Shallis (1977) seems to produce reliable and relatively model-independent effective temperatures (Magain 1987b, Saxner and Hammarbäck 1985) - alternatively, the Balmer lines should provide suitable temperature indicators (cf. Cayrel et al. 1985). For the F-type stars and early G-type stars the Balmer discontinuity may be used for estimating the surface gravity although the calibration of, e.g., Strömgren's \( c_1 \) index in terms of log g is still uncertain for metal-poor stars and the "Hyades anomaly" problem casts some doubt concerning the use of this criterion for applications where an accuracy better than 0.15 dex in log g is needed (cf. Strömgren et al. 1982, Nissen 1987). The possibilities of the strong-line method of Blackwell and Willis (1977, cf. also Edvardsson 1987) have not yet been explored for metal-poor stars, but such work is in progress. Finally, one should warn against the use of the ionization equilibria for estimating the gravity of the metal-poor stars since the "over-ionization" (relative to the Saha equilibrium) by hot ultraviolet radiation may be severe (cf. Saxner 1984 and references given below).

The most problematic uncertainties in the analysis of late-type metal-poor stars are those caused by our lack of basic understanding concerning their atmospheres. The model atmospheres are usually based on the assumptions of plane-parallel stratification, mixing-length convection and LTE. On the other hand, we know that these atmospheres are transparent, due to the low abundances of elements providing electrons for the H\(^-\) ions, which contribute most of the continuous opacity. Thus, we see deeper than into corresponding Pop. I stars, into layers that are strongly affected by convection. Also, the high transparency enables hot photoionizing radiation to penetrate up to the line-forming regions and cause significant deviations from the Saha equilibrium. These effects are systematically dependent on the overall metal abundance, i.e. on [Fe/H]. Do they cause our trends?
Here I shall not give a review of the modelling problems for metal-poor atmospheres; the reader is referred to, e.g., Gustafsson (1983) for a more comprehensive discussion. Instead, I shall take one single example – the discovery by Ruland et al. (1980) that lines with different excitation energy of neutral metals give systematically different abundances of Fe, Ti and Cr for the Pop. I giant Pollux (K0 III).

Ruland et al. showed that the abundances derived from high-excitation lines tend to agree with those derived from the corresponding ions, but they deviate significantly, by 0.3 to 0.5 dex, from those derived from low-excitation lines of the neutral atoms. From the line list of Ruland et al. we estimate that $\delta[\xi]/\delta \chi \sim 0.15 \text{ dex eV}^{-1}$ ([\xi] denoting the logarithmic abundance) for iron, which is much more that one could account for by a reasonable increase of the adopted effective temperature.

Ruland et al. suggested that this phenomenon should be interpreted as the result of an over-ionization of the metals in the upper layers of the stellar photosphere. The low excitation lines are formed closer to the surface than the high excitation lines of corresponding strengths, and this difference in depth of formation could lead to the phenomenon. The interpretation was subsequently supported by detailed statistical-equilibrium calculations by Steenbock (1985), although those calculations do not reproduce the full magnitude of the effect. The magnitude of the calculated effect was, however, found to be very dependent on the highly uncertain collision cross sections for collisions between the metal atoms and hydrogen atoms.

In his Procyon (F5 IV-V) analysis, which like the Pollux study was based on first-class observational material, Steffen (1985) found a corresponding effect. When a model atmosphere with $T_{\text{eff}} = 6500$ K was adopted on the basis of photometry, a difference of nearly 0.15 dex in mean iron abundances, derived from low ($\chi < 3$ eV) and high ($\chi > 4$ eV) excitation lines was obtained. From this we estimate $\delta[\xi]/\delta \chi \sim 0.05 \text{ dex eV}^{-1}$. An effect of this magnitude seems to be at least partially reproduced by statistical-equilibrium calculations.

Magain (1987c) has obtained first-class observations of a considerable number of iron lines of the metal-poor solar-type dwarf HD 76932 ([Fe/H] = -1.0) and again found a significant variation of $c$ relative to $\chi$ for iron; for the other neutral atoms the number of lines is too small for firm conclusions but they are not inconsistent with the results for Fe. Temperature and gravity were estimated from Strömgren photometry. The variation is approximately $\delta[\xi]/\delta \chi \sim 0.06 \text{ dex eV}^{-1}$. In contrast to Peterson and Carney (1979), Peterson (1980, 1981) found no such trends for metal-poor stars, but the scatter in her $[\xi] - \chi$ diagrams seems large enough to admit a dependence like that of Magain's. Also, her low-excitation lines are strong enough to be severely affected by microturbulence.
why an [ε]-χ tendency could be masked by an adjustment of the microturbulence parameter.

In the current survey of the chemical composition of disk stars Edwardsson, Nissen and I found a similar tendency for a group of 8 stars with -1.0 ≤ [Fe/H] ≤ -0.8. For a sample of about 20 Fe I lines, all with stellar equivalent widths less than 50 mA and spanning a range in χ from 2 to 5 eV, we find δ[Fe]/δε=0.05 ±0.01 dex eV⁻¹.

The effects of departures from LTE in Pop. II stars on the abundance estimates for Li have been investigated with statistical equilibrium calculations by Steenbock and Holweger (1984). They find departures from the Saha-Boltzmann equilibrium which lead to abundance effects in qualitative agreement with those discussed above, although they quantitatively are smaller. For the presumably most realistic set of collision cross sections effects on [Li/H] (derived from the resonance doublet) of about 0.04 and 0.20 dex were obtained for a halo dwarf and giant model, respectively. In both cases the LTE assumption would lead to an underestimated abundance.

The different empirical results listed above have in common a very high signal-to-noise ratio, high spectral resolution and up-to-date model-atmosphere analyses. They may look rather consistent - yet, they are certainly not. They are partly based on "astrophysical" (solar) gf values, but on different solar models and with LTE assumed. In fact, the problem of deriving accurate empirical gf values for these lines may explain some of the [ε]-χ tendencies found.) And they indeed refer to stars of different types. My intention is not to argue that these effects are necessarily present, and due to departures from the Saha-Boltzmann equilibrium, in Pop. II stars. Instead, I claim that departures of this magnitude from standard model spectra are not inconceivable. If such effects are there, what would then be the consequences?

VI. SPECULATIONS

Let us, inspired by the finding by Ruland et al (1980) that also other elements than Iron follow the same [ε]-χ tendency, for the moment assume that other elements in a typical analysis of a metal-poor dwarf would follow the tendency found by Magain for neutral Iron in HD 769321. Needless to say, this assumption is ad hoc, but possibly at least as well founded as the assumption that LTE would prevail. Typical lines used for determining chemical abundances in solar-type Pop. II stars are listed in Table 1. We note that in the sequence Na, Mg, Al, Si and Fe the typical excitation energies for the lower levels of the red transitions are 2.1, 5.5, 3.6, 5.9 and 4.0 eV, respectively. Adopting Magain's relation between Δ[ε] and χ one would get effects on the true abundances of -0.11, +0.09, -0.03 and +0.11 for Na, Mg, Al and Si, respectively, relative to Iron. I.e., much of the observed odd-even effect would show up as the result of an oversimplified analysis, even if the real abundance ratios relative to Iron were solar.
Table 1. Typical spectral lines of neutral atoms that are used in current abundance analyses of Pop. II solar-type stars

<table>
<thead>
<tr>
<th>Element</th>
<th>(\lambda(\text{Å}))</th>
<th>(\chi(\text{eV}))</th>
<th>Element</th>
<th>(\lambda(\text{Å}))</th>
<th>(\chi(\text{eV}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>O I</td>
<td>6300</td>
<td>0.0</td>
<td>Si I</td>
<td>8728</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>7774</td>
<td>9.1</td>
<td></td>
<td>8742</td>
<td>5.9</td>
</tr>
<tr>
<td>Na I</td>
<td>5895-60</td>
<td>2.1</td>
<td>Ca I</td>
<td>6161-70</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>8183-94</td>
<td>2.1</td>
<td></td>
<td>6142-45</td>
<td>5.6</td>
</tr>
<tr>
<td>Mg I</td>
<td>4167</td>
<td>4.3</td>
<td>Ti I</td>
<td></td>
<td>0 - 3</td>
</tr>
<tr>
<td></td>
<td>4703</td>
<td>4.3</td>
<td></td>
<td>4283-4456</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>5771</td>
<td>4.3</td>
<td>Mn I</td>
<td>4030</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>8712-36</td>
<td>5.9</td>
<td></td>
<td>5394</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>6319</td>
<td>5.1</td>
<td>Fe I</td>
<td>5420</td>
<td>2.1</td>
</tr>
<tr>
<td>Al I</td>
<td>3961</td>
<td>0.0</td>
<td></td>
<td>8772-73</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>6696-98</td>
<td>3.1</td>
<td></td>
<td>6696-98</td>
<td>3.1</td>
</tr>
</tbody>
</table>

There are certainly arguments against this conspiracy theory. One is that Ca is overabundant relative to iron in Pop. II stars. Another is that the K abundance, as determined from resonance lines of K I, seems to follow the α elements (Gratton and Sneden 1987). The argument that Oxygen abundances determined from the forbidden \(\lambda6300\) line and from the high excitation IR triplet are consistent is not a heavy argument against the conspiracy since Oxygen is mainly neutral in these atmospheres, so that the over-ionization mechanism proposed by Ruland et al. would not work.

There is, on the other hand, also additional evidence for this kind of effect. One is the much-debated tendency for lines in the (ultra-)violet - blue spectral regions, e.g. of Al and Mg, to give lower abundances than those in the red. The blue lines have systematically lower excitation energies. Although much of this blue-red discrepancy seems to vanish when a critical selection of lines and observations is made (Magain 1987a) there are still reports about deviating lines. E.g., Barbuy et al. (1985) find that the Mg I intercombination line \(\lambda4571\) (\(\chi=0.0\) eV) gives significantly lower abundances in Pop. II stars than the rest of their Mg I lines (with \(\chi\) ranging from 2.7 to 4.3 eV). Another argument is that several additional elements that are found to be depleted are analysed with low excitation lines - a good example is Mn, discussed by Gratton in this volume. We also note in passing that the negative [Zr/Ti] values found by Brown, Tomkin and Lambert (1983) for neutral species in G and K giants, with the corresponding ions giving ratios greater by more than a factor of two, might also be a result of a similar effect. The difference in \(\chi\) between the Ti I and the Zr I lines is, however, only about 0.8 eV, which would require a greater \(\partial[\text{e}]/\partial\chi\) value than any of those estimated above.

Summing up this discussion we find that there are still systematic
inconsistencies between different spectral lines, leading to different abundances by at least 0.2 dex for metal-rich late-type stars. We have some reasons to believe that this situation may be worse in Pop. II stars. We cannot exclude the possibility that much of the abundance trends found for Pop. II stars are artifacts of the primitive analysis.

VII. CONCLUSIONS

The application of new panoramic detectors with linear response and of effective spectrometers has revolutionized the chemical analysis of halo stars in the last decade. This has made it possible not only to detect systematic abundance trends at, or even below, the 0.2 dex level, but also to trace systematic errors in the analysis from inconsistencies of the same order of magnitude. We have no reason to exploit the first possibility - the application of adequate and accurate criteria for abundances - and not bother about the second one - the development of adequate and accurate criticism of abundances on empirical grounds. If the latter possibility is forgotten, at the end the theorists may tell the observers what they should have seen; a situation which in fact is not so usual in astronomy and therefore possibly a bit embarrassing for the observers. Recent progress as regards methods for simulating convection and radiative transfer in stellar atmospheres may well give the theorists this lead. At least as a necessary complement to this - why not keep both eyes open when you observe?
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DISCUSSION

F. MATSUCCI: By computing chemical evolution models it turns out that the change in the slope in \([O/Fe], [\alpha/Fe]\) as a function of \([Fe/H]\) relations is quite well reproduced by assuming the current nucleosynthesis results suggesting that \(O\) and \(\alpha\)-elements are mainly produced by massive stars whereas \(\sim 70\%\) of iron should be produced by type I SNe, coming from the low and intermediate mass star range. The change of the slope is therefore due to the appearance of iron in a substantial proportion.

B. GUSTAFSSON: I guess you are right. I think, however, that it is quite important that the relative abundance trends be established, or disproved, relatively independently of what the necessarily somewhat schematic models of the "chemical" evolution of the halo may suggest.

H. RICHER: Two questions: (1) In the selected Mg sample the distribution with [Fe/H] is flat but there is a zero-point offset from zero. Do you believe the offset itself is real? (2) Do you have a similarly selected plot for the oxygen abundance?

B. GUSTAFSSON: (1) Yes, I think that the Mg overabundance relative to iron is real. (2) No, I don't. It may be worthwhile to carry out a homogeneous analysis of existing oxygen line data, just as Magain did for Mg and Al.

R. CAYREL: I share your worry about systematic effects on abundances in metal poor stars due to the unblocking of UV radiation and NLTE effects. It seems to me necessary to push atomic physicists towards the determination of collisional cross-sections with neutral \(H\) atoms, which outnumber electrons by a factor \(10^5\) in metal-poor atmospheres.

B. GUSTAFSSON: I fully agree. I think this point was also nicely illustrated by Steenbock's calculations.