PART II

SOME COMMENTS ON A CATALOGUE OF ATMOSPHERIC PARAMETERS AND [Fe/H] DETERMINATIONS

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SOME COMMENTS ON A CATALOGUE OF ATMOSPHERIC PARAMETERS AND [Fe/H] DETERMINATIONS*

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Abstract. A few examples are given showing the utility of the catalogue of iron/hydrogen determinations for astrophysical researches.

These are:

(a) Histograms of dwarfs and giants analyzed in detail with spectral type between O and M.
(b) Logarithmic abundances diagrams of given stars.
(c) The impact on spectral classification of high-dispersion-detailed-analysis results.
(d) The use of well-determined chemical and physical parameters of nearby stars for the construction of HR diagrams in the (M_{bol} $-\log T_{\text{eff}}$) plane.

The spectra of F, G and K stars having the iron lines at their best visibility, special emphasis has been given to the results concerning these stars.

1. Introduction

The need for a catalogue of metal abundances of spectroscopically analyzed stars is felt more and more. Our actual knowledge of the chemical history of the Galaxy is based upon such metal/hydrogen determinations.

The discrepancies between different metal/hydrogen determinations in stellar atmospheres, whether based on various photometric systems or on spectroscopic analyses have put the individual astronomer in a very uncomfortable position of doubt faced with these different abundance results.

A list of metal/hydrogen values based on fairly homogeneous observing material (dispersion better than 20 Å mm^{-1}) and using a homogeneous model atmosphere technique could become a working tool for astronomers interested in abundance problems and abundance dilemmas. We present this catalogue not only for the use of such astronomers but also for others who simply need a summary of chemical composition of stellar atmospheres. In assembling this catalogue, we hope to help astronomers concerned by the impact of abundances in spectral classification, photometric systems, the study of: internal structure, evolutionary tracks and isochrones, galactic structure, heavy metal enrichment in the Universe, and last but not least, to advance our understanding of the early history of the Galaxy.

In carrying out this task, we have been faced with the following problems:

(1) How many stars have been subjected to detailed analyses?
(2) Are analyses of 'normal' stars available everywhere in the HR diagram?
(3) What are the percentages of stars analyzed in the different parts of the HR diagram?
(4) How many times has a given star been analyzed in these last twenty years?

* See appendix, pp. 223–259.

B. Hauck and P. C. Keenan (eds.), Abundance Effects in Classification, 29–46.

(5) How much does the metal hydrogen ratio for a given star differ between different authors?
(6) What can we say about the metal/hydrogen ratio of the Hyades dwarfs in comparison to the same ratio in the Sun?
(7) What can we say about abundance peculiarities in metal-deficient stars, barium stars etc...?
(8) To what extent can a detailed analysis change the meaning of the spectral type of a given star?

These are some of the questions the authors wanted to answer in preparing the catalogue.

2. Description of the Catalogue

We have taken as metal/hydrogen parameter in the stars contained in the catalogue the logarithmic difference between the relative abundance of iron in a given star and the relative abundance of iron in a standard star. This difference is written in the form: $[\mathrm{Fe/H}]^{\mathrm{star}}_{\mathrm{stand}}$. The $[\mathrm{Fe/H}]^{\mathrm{star}}_{\mathrm{stand}}$ in the next to last column comes exclusively from detailed analyses based on high dispersion spectra.

The question arises when starting the catalogue, what other kinds of parameters could be useful to know at once with the iron/hydrogen abundance in a star. There were of course the atmospheric parameters with which the analysis giving the reported [Fe/H] ratio had been done: effective temperature, gravity and microturbulence, or if the analysis was a coarse analysis the excitation and ionization temperatures and the electron pressure. As other useful parameters the authors have chosen: the apparent and absolute magnitude; the spectral type in the MK system; and some photometric data. Kinematic data have been omitted.

The catalogue is composed of two tables. In Table I the authors have found it useful to report the absolute abundance determinations of iron in the solar photosphere as found by various authors. These values have been taken from Blackwell (1974) and are given on the scale $\log N_{\mathrm{H}} = 12.00$. In Table II the iron/hydrogen abundances are given of about 500 stars. The description of this table is given in the introduction to the catalogue and is omitted here.

3. Methods of Abundance Analysis

In the background of each abundance determination from detailed analysis there are two kinds of astronomical 'Workers': the first are interested in the structure of the atmosphere of stars, via the theory of line formation. They calculate model atmospheres and try carefully to improve the physics of the models. The second are more interested in the kinds of stars for which they want to know the atmospheric parameters and the abundances, and they apply the model-atmosphere technique to get detailed abundances – and are not so interested in the physics of the atmosphere of the star itself. Roughly the first group belongs to Com. 36 and the second to Com. 29.

The 'first ones' are sometimes anxious about the physics involved in the models. The 'second ones' are sometimes nervous about the doubts of the 'first ones'.

To avoid the uncertainties of oscillator strengths Greenstein introduced in the late fifties the technique of the differential curve of growth analysis. The principle is to obtain the abundances of the elements in a star A relative to the abundances in a star B, taken as standard. If both stars have nearly the same spectral type, the same spectral lines can be used in both objects and the knowledge of the oscillator strengths is no longer needed. Another advantage of this method is that it cancels systematic errors in equivalent widths measurements if the same spectroscopic equipment is used to get the spectra of both stars. A third advantage of the differential method is that departures from local thermodynamical equilibrium (LTE) are eliminated if they are expected to be about the same in both stars.

The [Fe/H] results contained in the catalogue come mostly from differential detailed analyses. These results are scattered over the last twenty years. In the beginning, say until 1965, the analyses relied upon the one-layer approximation but gradually as model computations became routine, thanks to some of the great producers of model-atmospheres (like Mihalas, Harvard-Smithsonian and the school of Kiel), and to the big computers, the analyses relied upon appropriate model atmosphere computations.

The recent early spectral type [Fe/H] results rely chiefly upon the Mihalas (1966) grid of model atmospheres and of those of Kurucz *et al.* (1973). The recent late-type [Fe/H] results rely upon the models of Carbon and Gingerich (1969), Peytremann (1974), Böhm-Vitense (1975), Mäckle *et al.* (1975) and Gustafsson (1975).

A critical discussion of the abundance results of the effective temperatures and gravities will be given in the next section. Special emphasis will be given to the results concerning F, G and K stars.

4. Critical Discussion of the Temperature Gravity and Abundance Results

As we are first presenting the catalogue to this Symposium, which is devoted to abundance effects on spectral classification, the first critical examination will be made of stars which are evidently misclassified. But let us proceed according to the order of questions asked in the Introduction:

4.1. Number of Stars Submitted to Detailed Analysis

The authors have been surprised by the great number of [Fe/H] determinations, almost 500 stars with known metal/hydrogen content could become a very comfortable sample for venturing some statistical conclusions on the metal/hydrogen content in the Galaxy.

4.2. Are analyses of normal stars available everywhere in the HR diagram?

Yes, if we judge as normal the result $[Fe/H]^{star}_{stand} = 0$, the standard having a normal solar chemical composition.

4.3. What are the percentages of stars analyzed in the different parts of the HR diagram?

The number of stars of a given spectral and luminosity class having [Fe/H] determinations changes very much from one end to the other of the HR diagram.

The following histograms give a concrete view of these numbers: the histogram on Figure 1 deals with dwarfs and subgiants, that of Figure 2 with III and II luminosity class giants.

Figures 1 and 2 show that there are very few [Fe/H] for O and B stars, and almost none for M and later type stars. This is obvious because the Fe lines are not at their best visibility in the spectre of these kinds of stars.

In the interval of A, F, G and K stars, there are some very high peaks on the two histograms.

On Figure 1 the A_m and A_p stars peak can be interpreted as the need to have a great

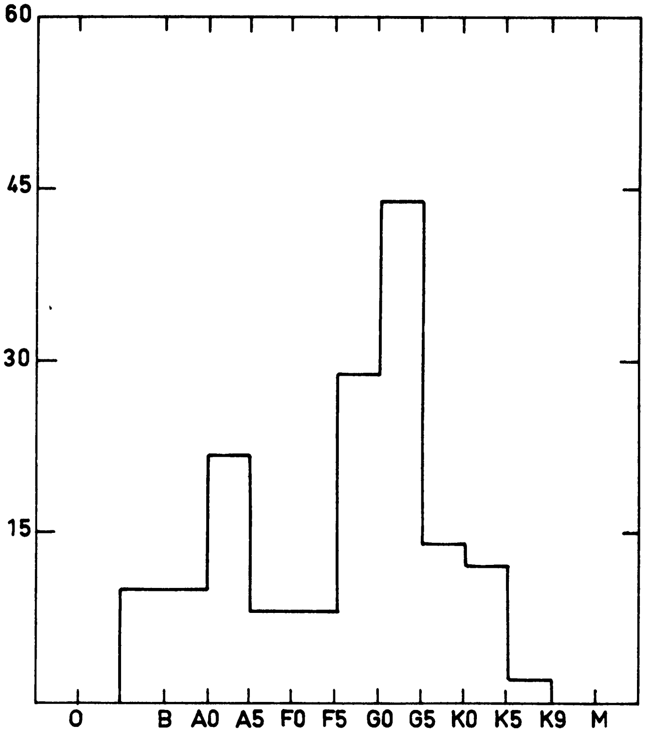

Fig. 1. Histogram of dwarfs and subgiants contained in the Catalogue.

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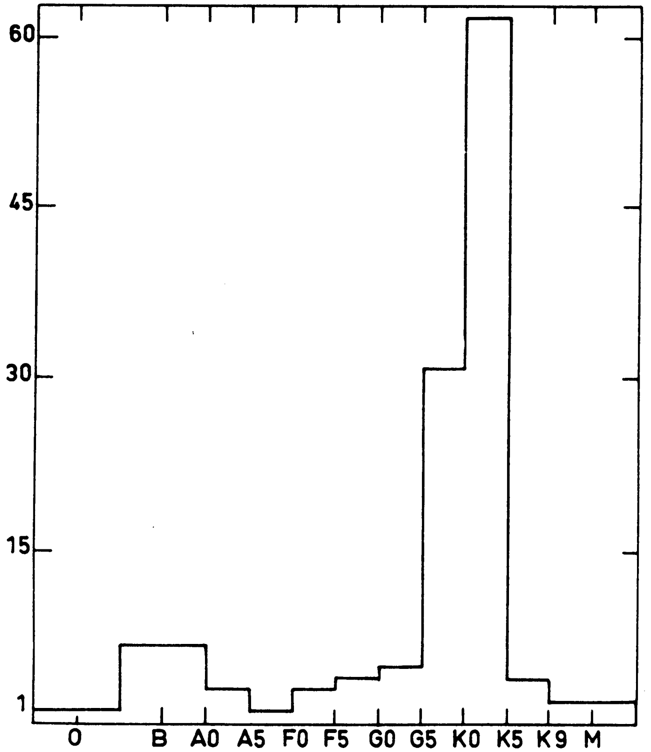

Fig. 2. Histogram of giants of luminosity classes III and II contained in the Catalogue.

sample of such stars to facilitate the study of their peculiarities and to find out the cause of their peculiarities.

The peak of F and G dwarfs and subgiants is due to the need to improve our actual knowledge of a galactic structure.

On Figure 2 the peak of G and K giants proves the interest of astronomers in studying population effects and also evolution problems as the existence of the asymptotic giant branch.

Questions from 4 to 7 relate to the importance of good metal/hydrogen determinations and the use that can be made of them in several astrophysical problems. They will be answered by means of abundance diagrams. These diagrams are now very familiar to 'abundance people'; they show the values of the logarithmic metal/hydrogen or metal/iron differences between the star and the standard star in respect to all the elements, analyzed in the atmosphere of a star. As an example, we present such diagrams for: the star: 85 Peg (Figure 3), HR 3018 (Figure 4), the three Hyades dwarfs, N 63, 64, 73 (Figure 5), the four Hyades giants: γ Tau, δ Tau ϵ Tau, θ^1 Tau (Figure 6).

Furthermore we present in Figure 7 an $\left[\frac{N_{el}}{N_H}\right]^*_\odot$ versus the elements analyzed in the star, of the most metal-deficient giants (more than by a factor of 5) contained in the

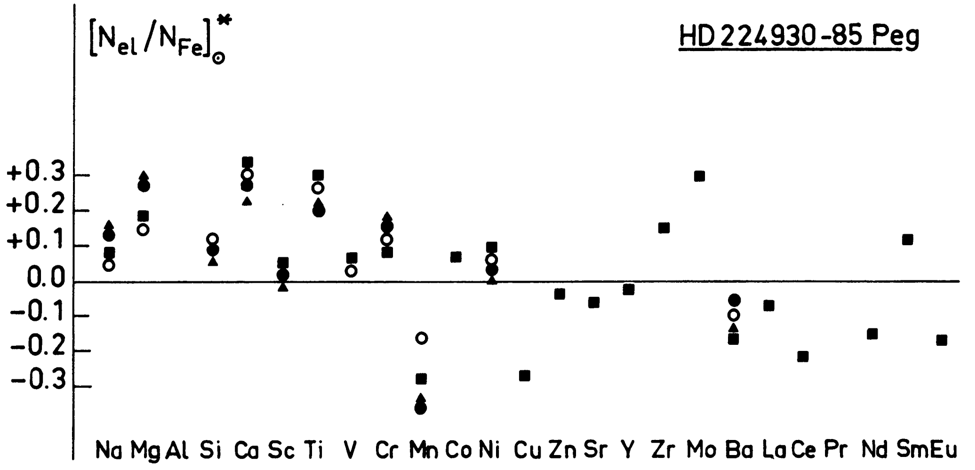

Fig. 3. Logarithmic abundances $\left[\frac{N_{el}}{N_{Fe}}\right]^*_\odot$ of the elements measured in 85 Peg by Wallerstein 1959 (filled circles), Wallerstein 1961 (triangles), Helfer 1963 (squares), Spite 1968 (open circles). This diagram illustrates the relative agreement between different detailed abundances analyses.

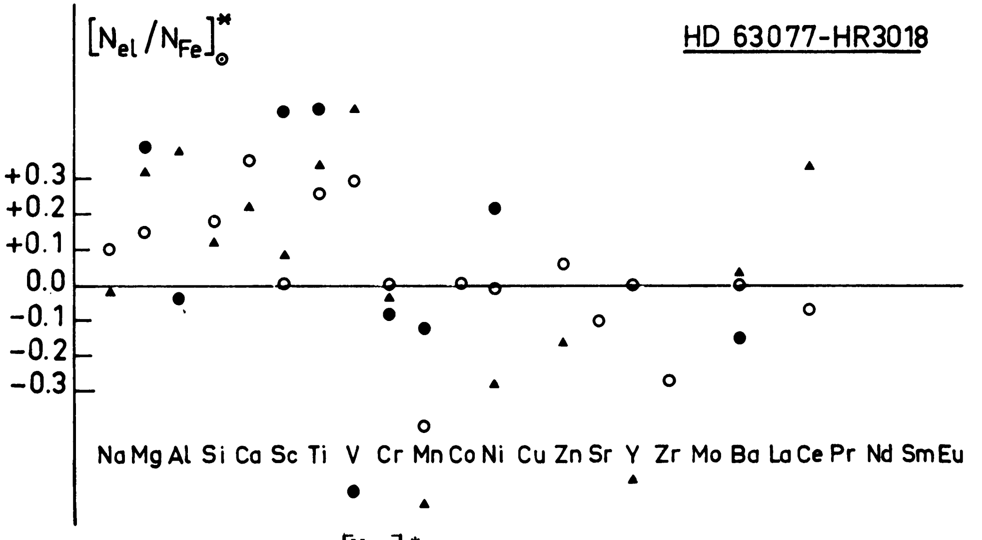

Fig. 4. Logarithmic abundances $\left[\frac{N_{el}}{N_{Fe}}\right]^*_\odot$ of the elements measured in HR 3018 by Kondo 1957 (filled circles), Hearnshaw 1972 (triangles), Da Silva 1975 (open circles).

catalogue, and we compare this diagram to that of the very metal-deficient subdwarfs, and to that of the barium stars of the list of Warner (1965), Figures 8 and 9. We leave to the people interested in nucleosynthesis or diffusion problems to interpret these diagrams, without, however, emphasizing that the dwarfs and the giants of the Hyades seem to have a normal solar iron/hydrogen abundance.

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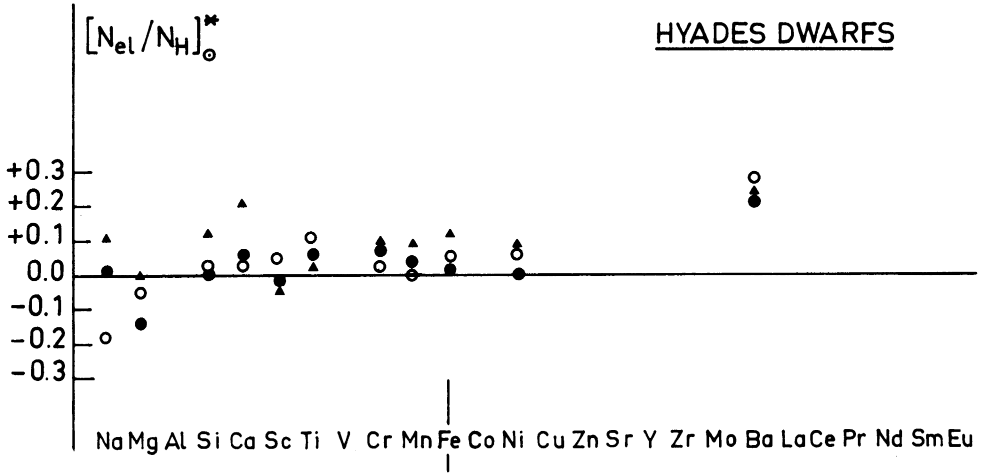

Fig. 5. Logarithmic abundances $\left[\frac{N_{el}}{N_H}\right]^*_\odot$ of the elements measured in three dwarfs of the Hyades: N 63 (filled circles), N 64 (triangles), N 73 (open circles). The abundance differences in the three dwarfs do not exceed the given error bar: ± 0.2 dex.

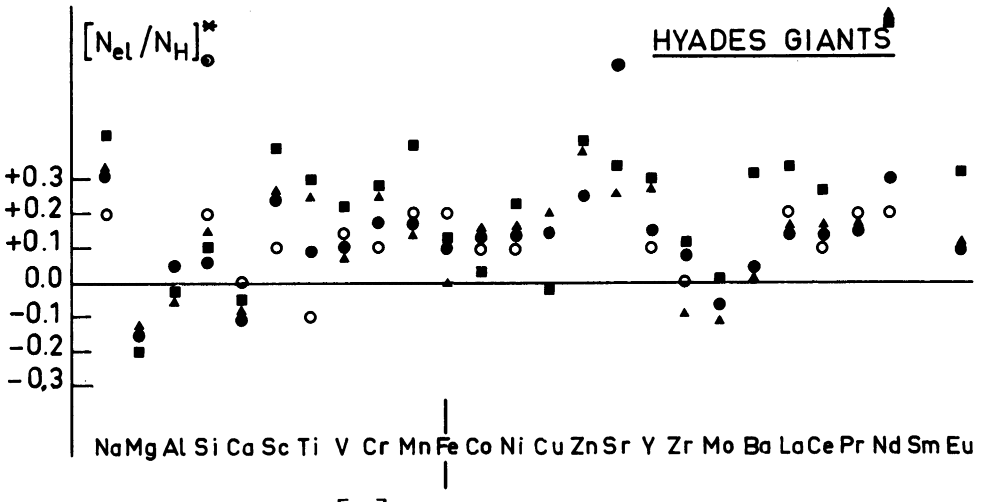

Fig. 6. Logarithmic abundances $\left[\frac{N_{el}}{N_H}\right]^*_\odot$ of the elements measured in the four giants of the Hyades: γ Tau (filled circles), δ Tau (triangles), ϵ Tau (squares), θ^1 Tau (open circles).

Question 8 is the most pertinent and the most critical: 'TO WHAT EXTENT CAN A DETAILED ANALYSIS CHANGE THE MEANING OF THE SPECTRAL TYPE OF A GIVEN STAR?'

The spectral classification is basically a two-dimensional classification and it is not surprising that its interpretation becomes a problem when a third parameter (metal/hydrogen) is varied. Therefore one should avoid translating the spectral type of highly

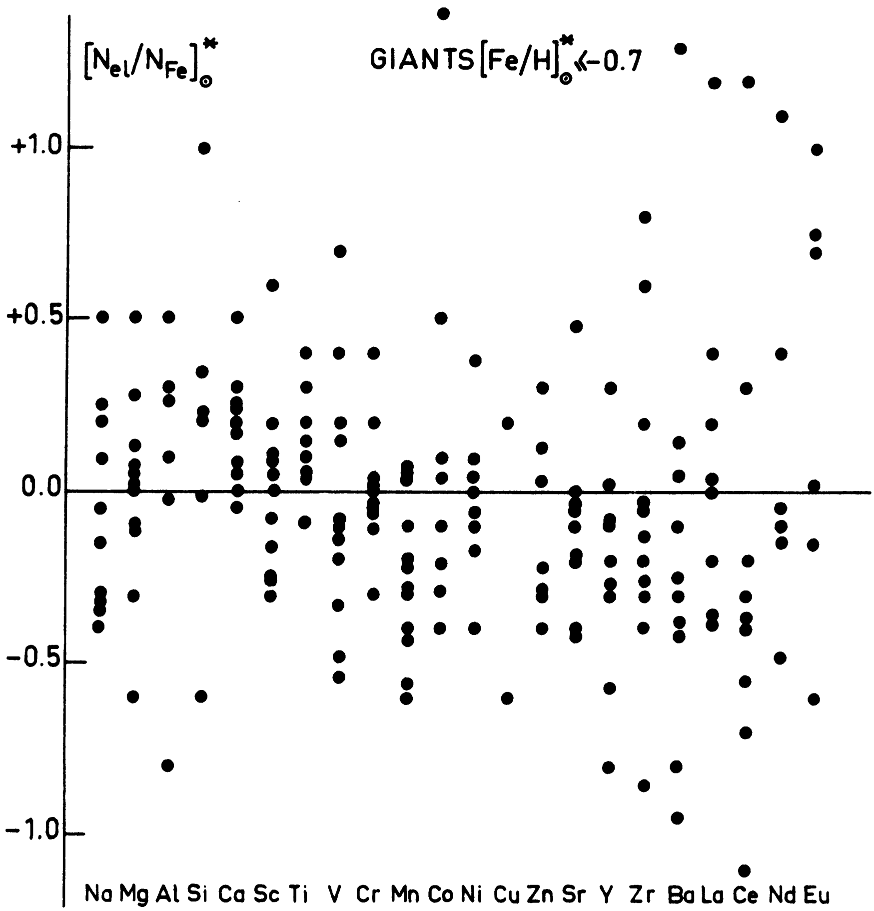

Fig. 7. Logarithmic abundances $\left[\frac{N_{el}}{N_{Fe}}\right]^*_\odot$ of the elements measured in the most metal-deficient giants contained in the Catalogue.

metal-deficient stars into effective temperature and luminosity as currently done for population I stars.

As an example, let us take HD 122563, HD 165195, HD 221170 the most metal-deficient stars known until now. In our catalogue HD 122563 is classified as GOIV and has an iron/hydrogen abundance of [Fe/H] = −2.70. It was submitted to several analyses which gave as result that its effective temperature and luminosity correspond actually to a spectral type K2II of a population I star.

In my view, this is one of the major problems in spectral classification, because I would never have chosen HD 122563 for an observing programme of halo-population bright giants knowing only its spectral type.

The Table I contains other such extreme examples of discordance between MK classification and detailed analysis classification.

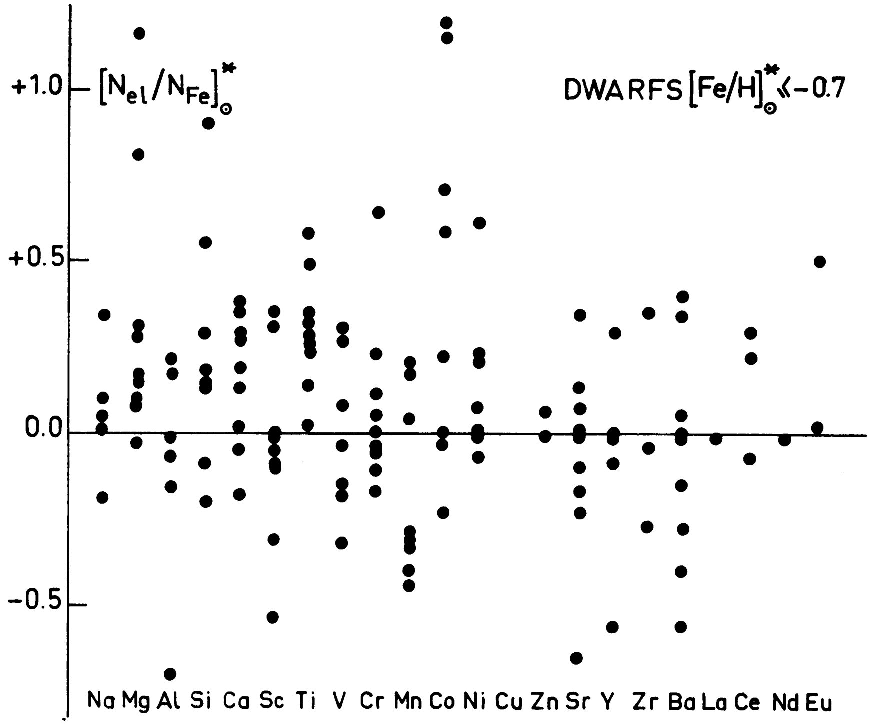

Fig. 8. Logarithmic abundances $\left[\frac{N_{el}}{N_{Fe}}\right]^*_\odot$ of the elements measured in the most metal-deficient dwarfs contained in the Catalogue.

The columns of Table I are self-explanatory except for column 5, which contains the space motion vector V in the direction of galactic rotation.

The stars in Table I are in order of decreasing metal/hydrogen values. They are all high-velocity stars, and the detailed analysis performed on them has changed for all of them either their spectral types or their luminosity class, or both spectral type and luminosity.

In Table I by spectral type 'from detailed analysis' we mean the spectral type of a population I star having the same effective temperature and the same gravity as the analyzed star.

Using the data of Table I a diagram has been drawn: luminosity class vs spectral type (Figure 10). In the diagram, three kinds of symbols have been employed: open circles stand for metal-poor stars by factors ranging from 100 to 500 with respect to the Sun; crosses stand for metal-poor stars by factors from 10 to 60; filled circles, for metal-poor stars with factors from 7 to 3. On this diagram the arrows connect the two classifications (columns 4 and 5 of Table I) given for each star. The diagram shows clearly that the most metal-deficient stars have been the most shifted.

The fact that these stars have been misclassified is easy to understand. In the MK classification the spectra have been inspected in the blue-region which shows very weak lines. These stars have therefore seemed to be of an earlier spectral type than they are in reality. The most deficient halo-giants have also been misclassified in luminosity. It is well known, that for the same spectral type, but not luminosity class, the spectra of highly luminous stars have more enhanced ionized lines than the spectra of the corresponding dwarfs. Therefore the astronomers responsible for the MK classification were completely

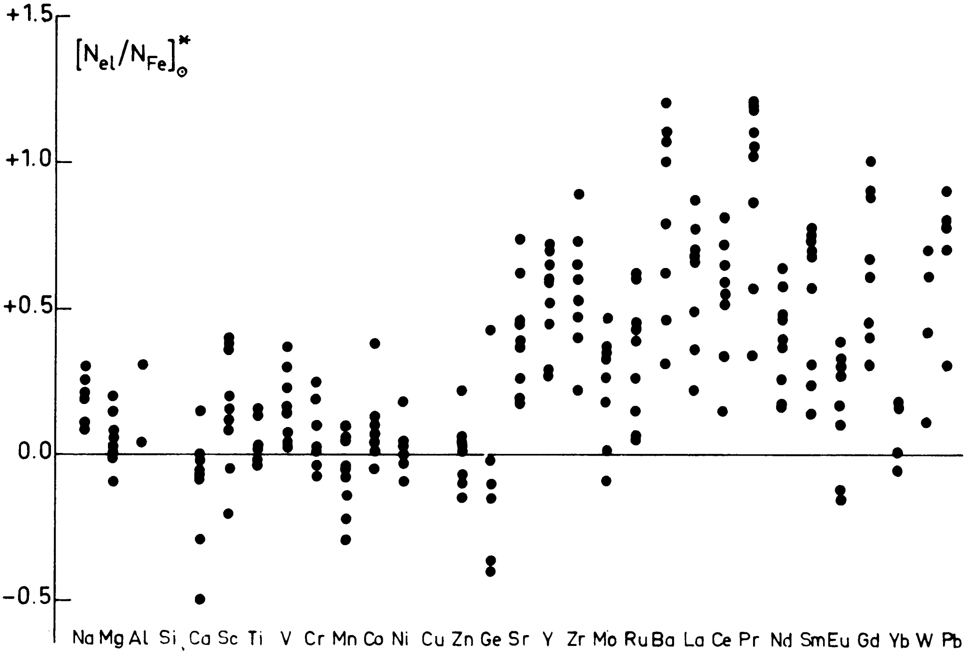

Fig. 9. Logarithmic abundances $\left[\frac{N_{el}}{N_{Fe}}\right]^{*}_{\odot}$ of the elements measured in the Barium stars.

right in judging the blue region for such kinds of stars, with weak lines and enhanced ionized lines, as belonging to much less advanced (sometimes more than by a spectral class) dwarfs.

There is another much more subtle problem of slightly incorrect classification. Chiefly it concerns the late F and G type stars. In the catalogue many of them have been classified as dwarfs. Many of them belong to Woolley's catalogue of stars nearer than 25 parsecs (Woolley *et al*, 1970). It was easy to put these stars on an (M_{bol} $-\log T_{eff}$) diagram (see Figure 2 in Cayrel de Strobel, 1974). In this diagram filled circles represent dwarfs and open circles subgiants. It is easy to see that many filled circles (dwarfs) seem to be already evolved subgiants.

TABLE I

Change of spectral type for very metal-deficient stars

HD	V(km^{-1})	[Fe/H]$^*_\odot$	Sp.T. from Catalogue	Sp.T. from detailed analysis
122563	−206	−2.70	GO IV	K3 II
165195	− 99	−2.70	(G5)	K4 III
221170	−139	−2.70	G2 IV	K4-5 III-II
140283	−107	−2.15	A8 V	F8 VI
128279	–	−2.05	GO V	G7 IV-III
M92 III-13	–	−2.00	–	K4-5 III-II
19445	−122	−1.75	A4p	F9 VI
25329	−184	−1.64	K1 V	K3 V
2665	+ 56	−1.56	G5 III	KO II
103095	−150	−1.50	G8 Vp	G9 VI
201626	− 72	−1.45	–	G9 III
219617	−258	−1.40	F8 IV	GO VI
232078	−392	−1.30	K3 IIp	K4-5 III-II
M13 140	–	−1.20	–	K4-5 III-II
6755	−344	−1.04	F8 V	G8 III
6833	−203	−0.85	G8 III	K2-3 II
26	−372	−0.67	G4 Vp	KO II
180928	−206	(−0.60)	–	K5 III
41312	−130	−0.60	gK3	K4 II
175329	− 70	−0.58	K1 III-IV	K5 II
5780	−206	−0.43	K4 III	K5 II

5. Comparison between Observed and Theoretical M_{bol} −log T_{eff} Diagrams

Apart from this discussion of problems of classification, we should like to illustrate the application of well-determined chemical and physical parameters of nearby stars to the construction of HR diagrams in the (M_{bol} −log T_{eff}) plane.

On the (M_{bol} −log T_{eff}) diagram which we have already considered (Cayrel de Strobel, 1974) we can see that many of the observed points towards the bottom fall below the main-sequence. The question was: either the abscissae and the ordinates of these stars are not well-determined, or the slope of the observational main-sequence is different from the theoretical one. On Figure 12 an (M_{bol} −log T_{eff}) diagram has been plotted composed only of stars with normal (solar) metal abundances having both good bolometric magnitudes and good effective temperatures. On the second diagram of Figure 12 the stars of the observational main-sequence fall almost all on a theoretical zero-age-main-sequence calculated by Hejlesen for normal metal/hydrogen abundances (X = 0.70, Z= 0.02) (Hejlesen *et al.*, 1974).

This seems to indicate that the lower observational main-sequence has the same slope as the theoretical main-sequence of Hejlesen.

The broken lines in Figure 12 represent Hejlesen's grid of evolutionary tracks for (X=

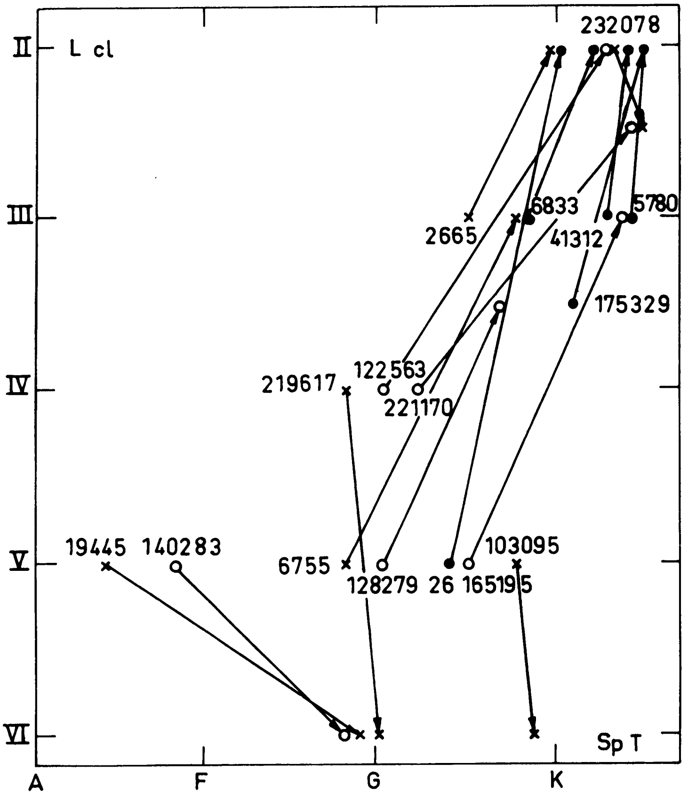

Fig. 10. In this luminosity class vs spectral type diagram arrows connect the two classifications given for each star in columns 4 and 5 of Table I. Open circles, crosses and filled circles respectively stand for stars with the following deficiencies:

$$\circ \quad -2.70 \leqslant \left[\frac{N_{Fe}}{N_H}\right]^*_\odot \leqslant -2.0$$

$$\times \quad -1.75 \leqslant \left[\frac{N_{Fe}}{N_H}\right]^*_\odot \leqslant -1.00$$

$$\bullet \quad -0.85 \leqslant \left[\frac{N_{Fe}}{N_H}\right]^*_\odot \leqslant -0.43$$

0.70 and Z= 0.03) and the solid lines represent a grid of isochrones. The diagram of Figure 12 confirms that of Cayrel de Strobel (1974) concerning the state of evolution of stars classified as dwarfs in our catalogue. On Figure 12 we can see that many of them (filled circles) are already in the subgiant region.

On the ($M_{\rm bol}$ −log $T_{\rm eff}$) diagram of Figure 13 we have placed nearby metal-deficient stars having good bolometric magnitudes and effective temperatures. Comparing this diagram with a theoretical one calculated by Hejlesen for about the same metal deficiency (X= 0.70 Z = 0.004), we can see that the nearby metal-deficient stars fall already in the evolved subgiant region of the HR diagram with the exception of the cool subdwarf Groombridge 1830. Two well-known subdwarfs lie on this diagram: HD 19445 and HD

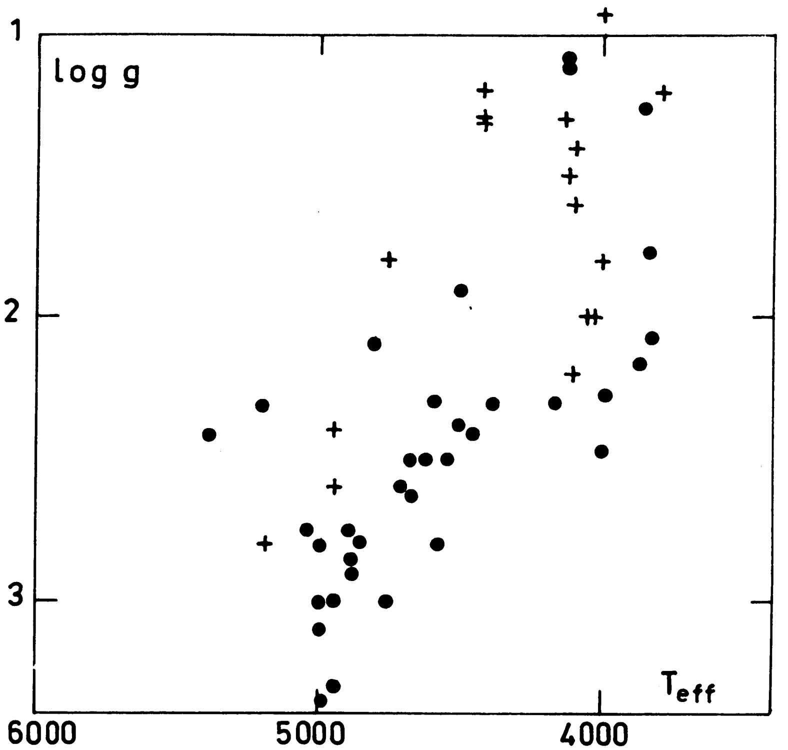

Fig. 11. In this $\log g$ vs T_{eff} diagram filled circles stand for population I giants with spectral type between G5 to K5. Crosses stand for metal-deficient stars contained in Table I and falling in the same range of temperature and gravities as the population I giants. Here it is visible that the temperatures of the metal-deficient stars correspond to late G and early K stars, their gravities being on average smaller than those of population I yellow giants.

140283. These stars are more metal-deficient than $Z = 0.004$, nevertheless even on this mild metal-deficient theoretical HR diagram HD 19445 and HD 140283 have already passed the turn-off point as suggested by R. Cayrel (1968).

The nearby subgiants on the HR diagrams of Figures 12 and 13 can be used also to test the age of the stars in the solar neighbourhood.

6. Conclusion

We said in the introduction that a metal/hydrogen abundance catalogue of stars could be useful to astronomers in their work.

We have shown the metal abundance diagrams of individual elements, but we leave the interpretation of these diagrams to astronomers interested in nucleosynthesis or in diffusion problems.

Note, that the problem of the Hyades remains acute since the high dispersion analyses

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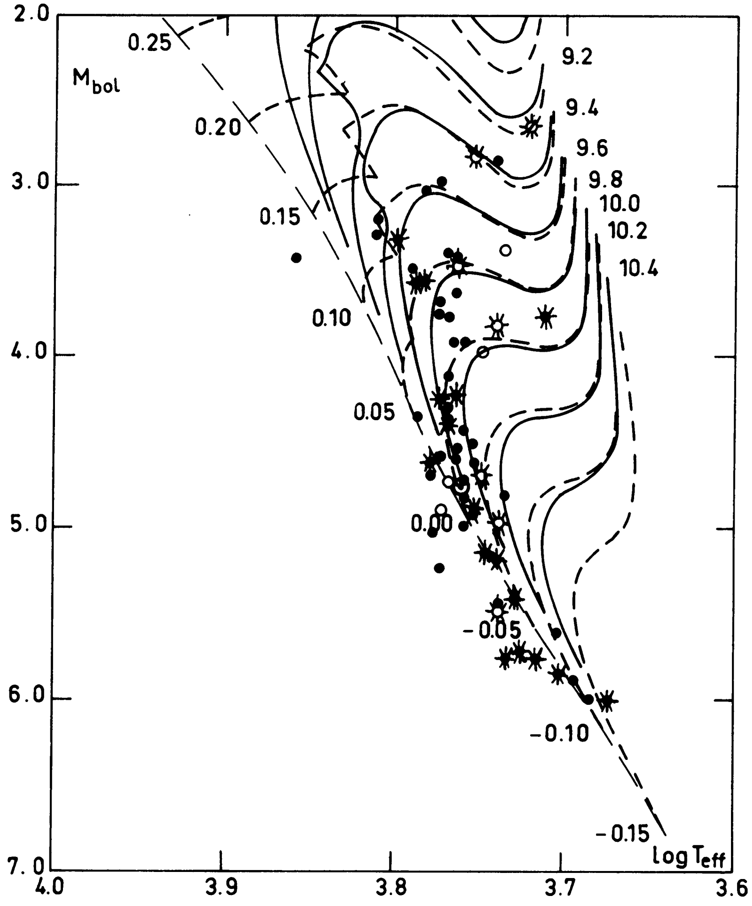

Fig. 12. The (M_{bol} – log T_{eff}) diagram showing the evolutionary tracks (broken lines) and isochrones (continuous lines) computed by Hejlesen for normal metal abundances ($X = 0.70$, $Z = 0.03$) together with the positions of stars with normal metal abundances, good bolometric magnitude and good effective temperature determinations. The full circles in the diagram are stars classified as dwarfs, in the catalogue, the open circles are stars classified as subgiants. Full circles with asterisks and open circles with asterisks are stars having very well-determined bolometric magnitudes. The open dotted circle shows the position of the Sun. The ages are given in log years; the masses in log $M/M_\odot$.

lead to normal metal abundances in contradiction with the results of Strömgren's, Gyldenkerne's, Geneva and other photometries, which give to the Hyades a metal/hydrogen abundance which is approximately twice the value of the normal 'solar' one.

Let us conclude this introduction to the metal/hydrogen catalogue with the following remarks.

Out of 343 stars contained in this catalogue with spectral types more advanced than F5 only 6 have metal-deficiency factors greater than 100, with respect to the sun. Five were discovered some twenty years ago by Greenstein and co-workers. Since then many

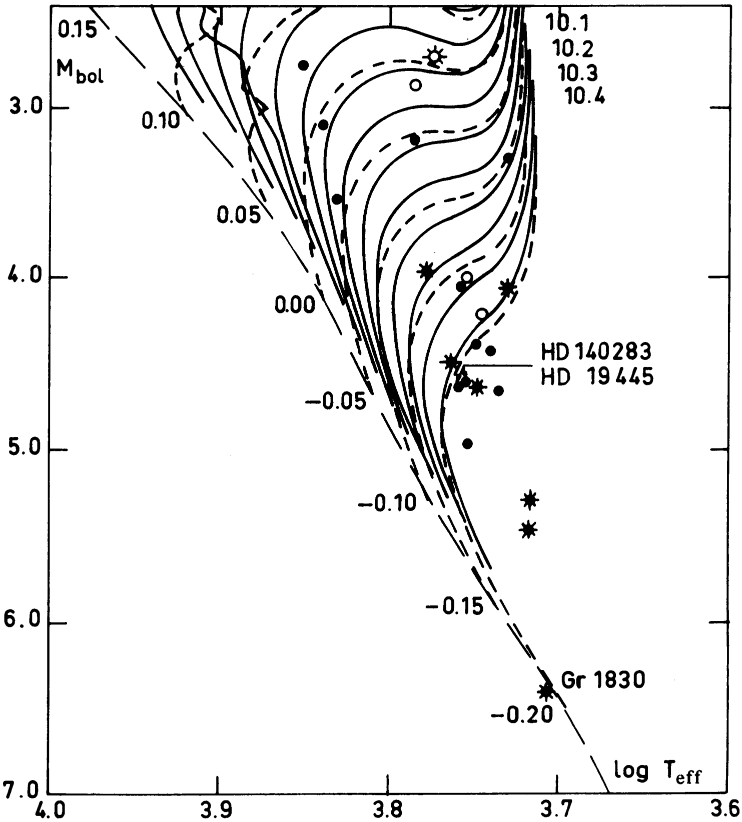

Fig. 13. The (M_{bol} – log T_{eff}) diagram showing the evolutionary tracks (broken lines) and isochrones (continuous lines) computed by Hejlesen for weak metal abundances (X = 0.70, Z = 0.004) together with the positions of stars with weak metal abundances, good bolometric magnitude and good effective temperature determinations. Full circles, full circles with asterisks, open circles and open circles with asterisks have the same meaning as in Figure 12.

high-velocity stars have been investigated, only one of them has been found as metal-deficient as the Greenstein stars (this star was discovered by the Spites at ESO Observatory two years ago). Many of the high-velocity stars have been found only slightly metal-deficient.

This is an important result and it leads to the conclusion that the halo is probably considerably less metal-deficient than is currently assumed. The photometry of Steinlin (1975) (Becher's system) in Basle contradicts this statement. This discrepancy is likely explainable by the difference in the criteria used to define a 'halo' star. Our definition based on the modulus of the space velocity (U, V, W) includes stars which may belong to the disk population and which should be better described as 'high velocity stars', whereas Steinlin has a very pure sample of halo stars, on the ground of their distance to the galactic plane.

It would be extremely interesting to carry out a detailed analysis of a sample of Steinlin stars of magnitudes $\simeq$ 15 to 16. That does not seem to be out of reach of modern observational techniques. I hope that a second generation 'Catalogue of iron/hydrogen determinations' will contain a large sample of faint stars.

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DISCUSSION

Bidelman: With respect to the spectral-type vs the *I-K* colours, where are the types from? Are they all MK types, or partly HD?

Also, is it not possible that some of the scatter in this diagram is due to the effect of interstellar reddening? Many of the stars in the *Caltech Catalogue* are barely interstellar-reddened. Perhaps, however, your stars are sufficiently near that there is no problem here.

Cayrel: The stars of the diagram have mostly all MK types. I do not think that the scatter is due to interstellar reddening; the stars are all sufficiently near to permit us to exclude the interstellar-reddening as the cause of the scatter. This scatter could be attributed partially to global abundance effects – or to peculiar abundances effects.

Walborn: The difference between *I-K* scatter for stars with spectral types and with quantitative analysis *could* be due to reddening, as pointed out by Dr Bidelman, particularly if the quantitatively analyzed stars are systematically brighter. If discrepancies exist when only reliable, homogeneous types are used, and reddening is corrected for, then one may be finding interesting objects, with infrared excesses or some other real colour-spectrum discrepancy.

Müller: In the table you showed us you had two columns concerning spectral types, one was the spectral types given in catalogues, the other was derived from 'detailed analysis'. (1) How certain are you of the spectral type derived from detailed analysis? (2) 'Detailed analysis' means 'differential curve of growth' analysis? If so, then this is rather dangerous to do as Dr Baschek already pointed out this morning.

Cayrel: (1) I do not derive spectral types from detailed analysis. By spectral type from detailed analysis I mean the spectral type of a Population I star, with normal 'solar' metal content, having the same effective temperature and the same gravity as the analyzed Population II star.

(2) Yes, detailed analysis means here differential curve of growth analysis. The older iron abundance results: $\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right]^{\mathrm{star}}_{\mathrm{standard}}$, come mostly from differential curve of growth analysis relying upon the one-layer approximation, the recent results rely upon appropriate model-atmosphere computation.

C. Jaschek: Since the Jaschek-Jaschek catalogue was mentioned several times I would like to explain what we did. We chose from the existing literature what we considered the 'best' classification, in the case several classifications were available; in the case only one existed, this single one was taken. The 'best' classification was considered the one made either by Morgan or Keenan, or one of his associates. Objective prism classifications were discarded, if possible. The classifications are therefore definitely not homogeneous.

One very important point is that the spectral classification used be homogeneous; those in the catalogue are definitely not homogeneous. Therefore one should be very critical where large discrepancies appear between these classifications and theory.

Cayrel: (1) Considering *only* in the catalogue a sample of homogeneous spectral MK classification of metal-deficient stars, we have even so found inconsistency between spectral classification and atmospheric parameters.

(2) The differences of the values of the atmospheric parameters between different authors for a given very metal-deficient star are always small when compared to the differences between the spectral type deduced from MK classification and the spectral type attributed to the star from its atmospheric parameters.

Baschek: Which are, in detail, the criteria for luminosity used for the column 'catalogue'?

Bidelman: The criteria of luminosity in the G and K stars are mainly atomic lines – Sr II, Ti II, Fe II, and the hydrogen lines. The molecular bands are not used because they are known to be subject to non-understood variations.

Baschek: Is it possible that a large part of the scatter in luminosity is due to deviations of the solar relative abundances when strontium, cyanogen, iron, ... is involved in the criteria?

Cayrel: Yes, this could be very possible and I answered in this way to Dr Bidelman.

Hack: I agree that a detailed analysis is necessary for reliable spectral classification because it is obviously meaningless to try to fit stars in a two-dimensional classification when the chemical composition is appreciably different from the solar one.

Keenan: The effect of the choice of criteria and the variation of abundances in producing the scatter in Mme Cayrel's diagrams can be judged better after some of the later papers, and can be better discussed then.

Garrison: To illustrate with an example: HD 122563 has an extreme difference between types given by spectral classification and Mme Cayrel's type. It puzzles me because the H lines for a K star are very markedly weaker than a GO star. Therefore the classifier would have to affix a 'peculiar' to the classification of a star with metal lines that weak, because, unless it is He rich, the H weakness and the metals weakness are inconsistent.

Walborn: It appears that a number of features in several of the diagrams could be due to systematic errors in the bolometric corrections, absolute-magnitude scale, and/or effective-temperature calibration for late-type stars.

Metal deficiencies as large as those in your table should be detected in careful spectral classification, for instance as discrepancies between the G-band-to-hydrogen ratio and the metal-to-hydrogen ratios. It is important not to take spectral types uncritically from large compilations without regard for their sources or quality.

Cayrel: Yes, metal deficiencies can be detectable in other careful spectral classifications, but they have not been detected in 'careful' MK classifications just because the blue spectral region of a metal-deficient star looks very much like the blue spectral region of a hotter metal-normal star.

C. Jaschek: The most probable error is the one in parallaxes – one is not sure that the errors of the parallaxes are smaller than 10%; and if this is not true, the absolute magnitudes may be off by large amounts.

Cayrel: The stars shown on diagrams Figure 12 and Figure 13 of my paper are all nearby stars with very good parallaxes.

Spinrad: Since most stars near the sun are M dwarfs and most of the mass of the Universe is in M dwarfs, it is a pity that the Catalogue does not include any. We badly need to study the physics and abundances of M dwarfs – and with the astrophysical capability of the 1970s this should be possible.

Cayrel: There are two causes which even in the 1970s have excluded M dwarfs from a catalogue of iron/hydrogen determinations, based on high dispersion spectra and on model atmospheres analyses:
(a) The iron lines are badly blended and the non-existing continuum prevents equivalent widths measurements.
(b) Consistent model atmospheres for M dwarfs, taking into account appropriate molecular blanketing and appropriate convection, do not exist.

Kandel: As a theoretician (Commission 36) I am inclined to accept an observer's spectral classification. Has one attempted to synthesize a Population II spectrum corresponding to a specific T_{eff} and g, and present it to an observer in a form (tracing, or better still photographic plate, synthesized with the appropriate resolution) such that classification can be made? Is it true in fact that a predicted Population II spectrum could be classified with so much 'error'?

Cayrel: Such a synthetic spectrum, as you describe it, has not been realized. Even so, the blue spectral region of a very metal-deficient Population II synthetic star would appear as a blue spectral region of a much less advanced Population I star to a trained eye of a spectral MK classifier.

In the name of the Organizing Committee, *C. Jaschek* explained briefly the reasons for having a discussion on standard stars. Dr. *A. Maeder* suggested that 'it would be important to discuss the set-up of a list of standard stars, to be used for the calibration of the different photometric and spectrophotometric procedures used to derive abundance of groups of elements'.

Because of this suggestion, a Committee was appointed to set up such a list, of which Mrs *G. Cayrel* became the chairman.

A list of standard stars was proposed by Mrs *Cayrel.*

In the discussion which followed, the following points were raised:
(a) no very bright stars should be included in the list because of the difficulty of observing them photometrically
(b) stars whose peculiarity is not firmly established should be avoided.

As a result of the discussion, it was agreed that the following list could be provisionally used:

886	B2IV
10307	G2V
27749	Am
28068	G1V
28344	G2V
61421	F5 IV–V
62509	KOIII
90537	G8 III–IV
103095	G8Vp
113226	G8III
122563	GOIV
149438	BOV
172167	AOV
182572	G8IV
214680	O9V
219134	K3V

It was further recommended that any additional suggestions should be sent to Mrs *Cayrel* before the end of 1975 and that a discussion on this point should be made at the next meeting of IAU Commission 45, if possible in connection with Commission 29.