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QUANTITATIVE STELLAR SPECTRAL CLASSIFICATION

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RESUMEN

Para espectros de rendija digitalizados de 487 estrellas, se compararon los anchos equivalentes de 19 líneas de absorción con sus respectivos índices de color $(B-V)$, sus magnitudes absolutas derivadas de paralajes del catálogo Hipparcos, y sus índices de metalicidad. Se desarrollaron algoritmos que permiten obtener la magnitud absoluta para todos los tipos espectrales con un error promedio de 0.26 magnitudes. Los colores $(B-V)$ se pueden reproducir con un error promedio de 0.018 magnitudes para las estrellas tempranas y, con un error promedio de 0.020 magnitudes, para las estrellas tardías. La metalicidad se recupera con un error promedio de 0.06 para estrellas tempranas y, con un error promedio de 0.07, para estrellas tardías.

ABSTRACT

Equivalent widths of 19 absorption lines in CCD slit spectra of 487 stars are compared with their respective $(B-V)$ colors, their absolute magnitudes derived from Hipparcos parallaxes, and with their metallicity indices. Algorithms are found which yield the absolute magnitudes for all spectral types with an average error of 0.26 magnitudes. The $(B-V)$ colors can be reproduced with an average error of 0.018 magnitudes for early type stars, and with an average error of 0.020 magnitudes for late type stars. The metallicity is recovered with an average error of 0.06 for early type stars, and an average error of 0.07 for late type stars.

Key words: **STARS: FUNDAMENTAL PARAMETERS**

1. INTRODUCTION

For the determination of the spatial distribution of different stellar populations, a minimum of two steps is required, namely (1) the complete and unbiased identification of members of the respective population in the field of interest, and (2) a fairly accurate distance determination for each of the members. A combination of spectral classification with photometry can provide the required data, whenever the spectral classification yields intrinsic colors and absolute magnitudes of adequate accuracy. The MK classification has been applied in this sense many times, but it is well known that in particular the precision of the predicted absolute magnitudes falls short of the desired goal.

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Objective prism spectra would be ideal for the mentioned type of galactic studies since they make it possible to reach faint magnitudes and at the same time provide data for many stars. Their normally rather low dispersion and hence spectral resolution permits only the use of strong absorption or emission features, of which for example, the MK classification makes no use. While so far most of the stellar spectral classification has been done by inspecting photographic plates, wide field arrays of CCDs on Schmidt telescopes now make it possible to base the classification on quantitative data and to include all detectable spectral features. In the blue spectral region which so far has been used more than any other region of the spectrum for classification purposes, it would be the Balmer lines, the Ca II - K line, the Ca I - line at 4226 Å, the G-band, and maybe a few Fe I - lines, which could be recognized and measured in spectra of a dispersion around 200 Å mm^{-1}. Objective prism spectra obtained with the CTIO Curtis Schmidt telescope equipped with a four-degree prism

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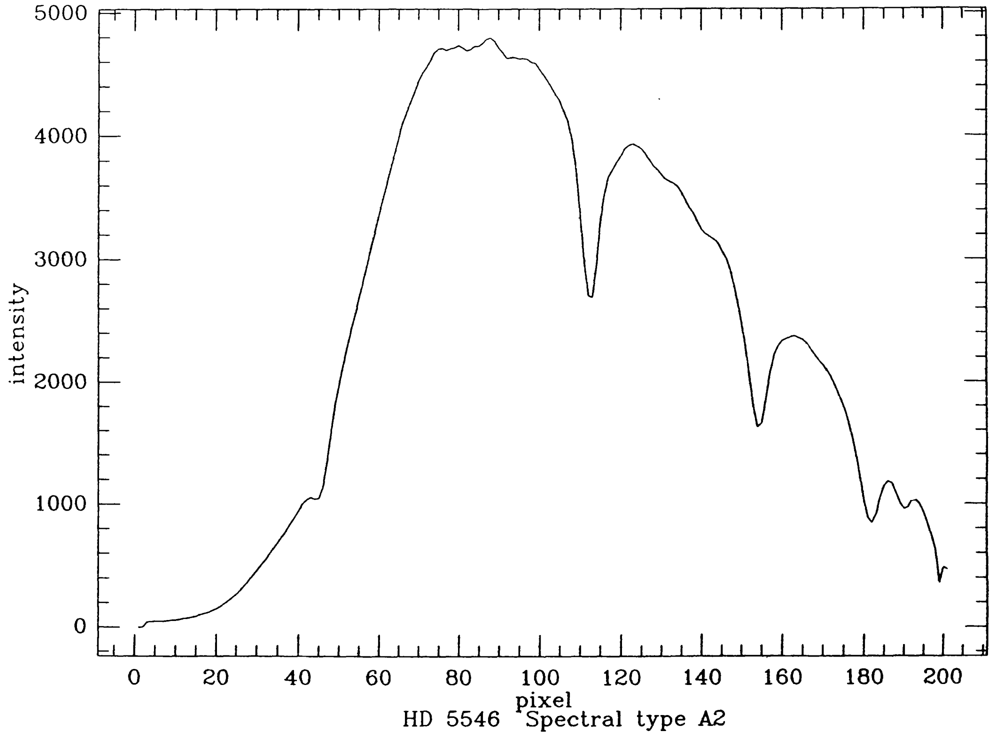

Fig. 1. An objective prism CCD spectrum observed through a Johnson B-filter. The prominent lines are, from left to right, Hγ, Hδ, and Hϵ.

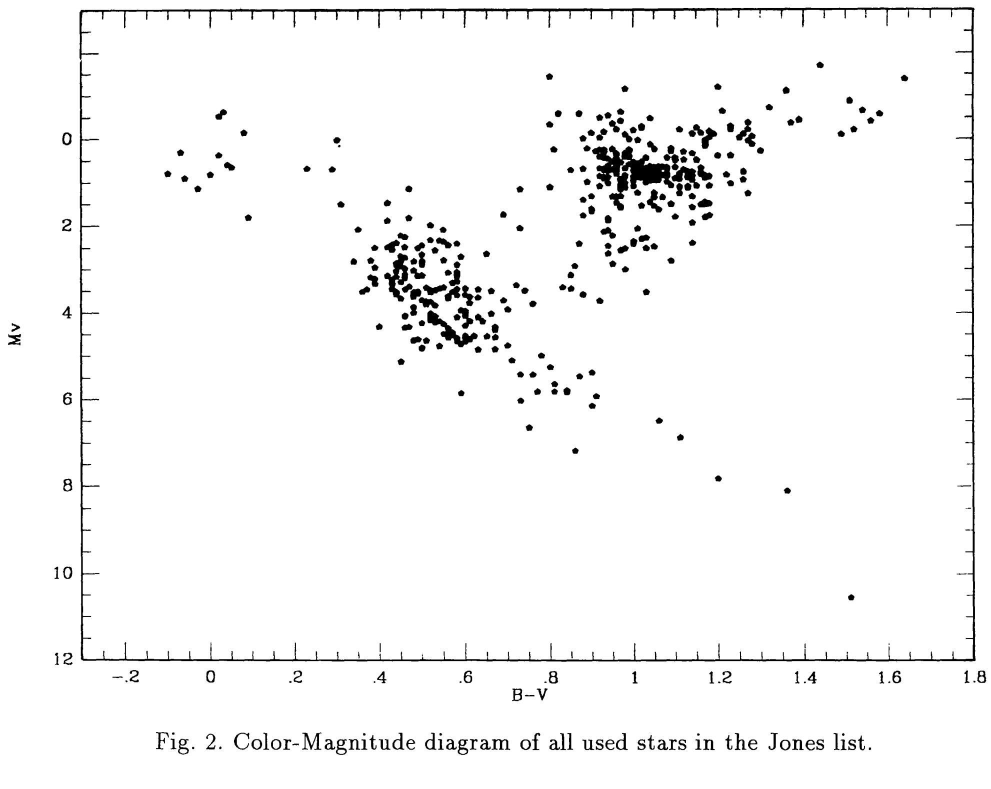

Fig. 2. Color-Magnitude diagram of all used stars in the Jones list.

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and a Johnson B-filter show that the above features can indeed be recognized and measured. An example is shown in Figure 1.

The more extensive tables which will carry roman numerals as well as the Annex I, will not be part of the printed text. They are available on our web-site http//www.cida.ve/~stock/paper1.

2. OBSERVATIONS

It is the purpose of this work, to test up to which point stellar physical parameters such as the luminosity or an intrinsic color can be predicted from measured spectral features. We shall not intend to reproduce the MK-classification. Our starting point is the Hipparcos Catalogue which provides accurate parallaxes for a large variety of stars. To this we add the library of CCD spectra of nearly 700 stars in the regions 3820 – 4500 Å and 4780 – 5450 Å, made available to the public by L. Jones.

The Jones library also contains B and V magnitudes as well as metallicity indices. Practically all of his stars are in the Hipparcos Catalogue. Figure 2 shows an Absolute Magnitude - Color diagram of all the stars of the Jones library which we have used in this work, while the histogram in Figure 3 shows the distribution of the metallicity indices of the same sample. The resolution of the Jones spectra is 0.6 Å, while the objective prism spectra mentioned above have a resolution of about 5.0 Å. In order to make them comparable with the objective prism spectra, the Jones spectra were smoothed with the IRAF GAUSS routine. An unsmoothed sample spectrum of the Jones library is shown in Figure 4. A total of 19 lines was selected in the smoothed spectra, all of which can be expected to be strong enough for certain spectral types to be measurable in objective prism spectra. The selected lines are listed in Table 1. For each line, an inner region and two outer regions were selected. The two outer regions, one on each side of the line —each at least several Angstroms wide— were used to determine a 'continuum' or 'pseudo-continuum', while the integration of the inner region yielded the equivalent width or pseudo equivalent width.

Table 1 also contains for each of the lines the limits of the three spectral regions. The wavelenghts given actually refer to the position of the first and last pixel. Pixel size is in all cases the original 0.62 Å. For the two continuum regions marked as Cont1 and Cont2 we averaged the fluxes and also calculated the wavelengths of their centers. A linear interpolation between these two continuum centers represented the continuum or pseudo-continuum, which then was used to integrate the contribution of each pixel within the range assigned to the spectral line under consideration to its total equivalent width. Our equivalent widths for the 19 lines and for every spectrum on our list are assembled in Table I (available electronically, see the end of § 1), together with some additional information.

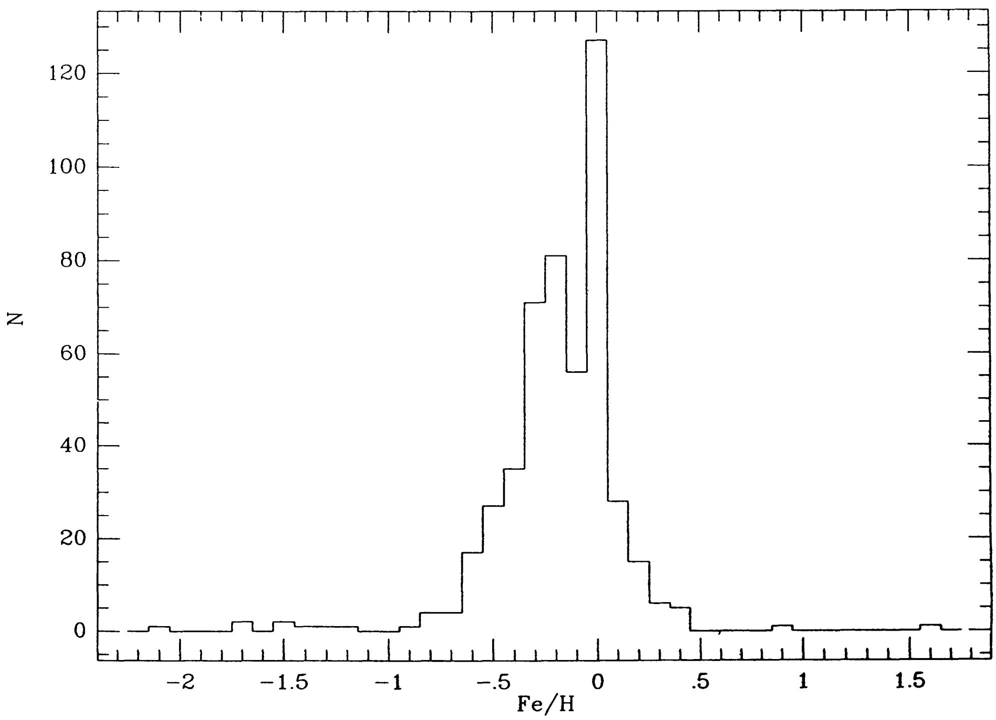

Fig. 3. Histogram of metallicities of all used stars in the Jones list.

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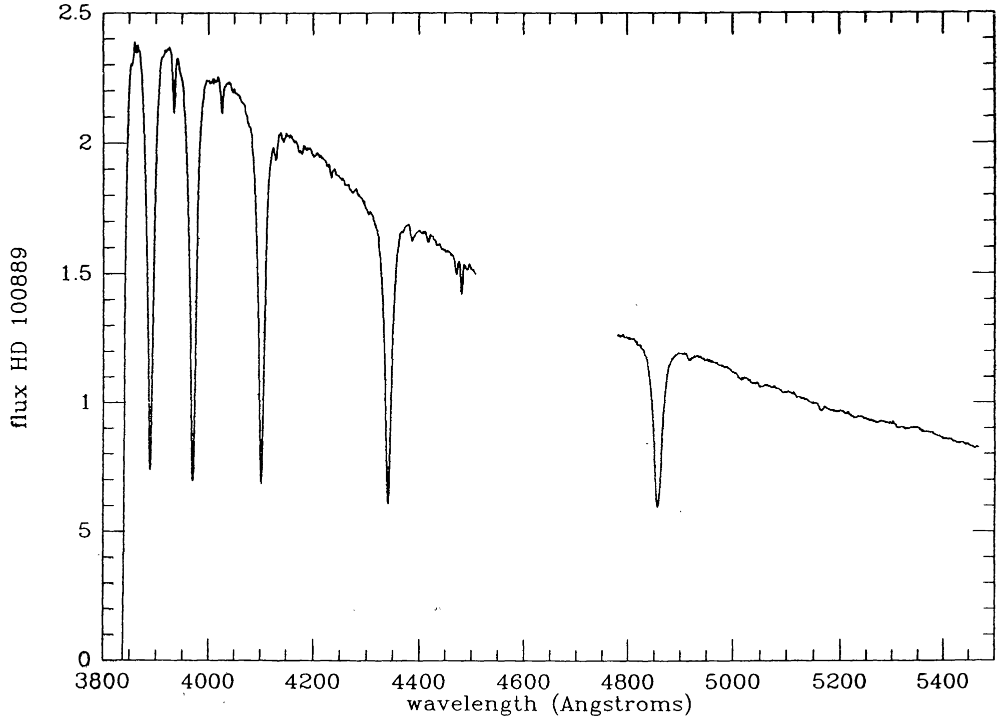

Fig. 4. An early-type spectrum of the Jones library.

TABLE 1

LIST OF ABSORPTION LINES

No.	Cont1		Line		Cont2		λ(Å)	Id.
1	3859.9	3865.5	3868.0	3917.8	3917.8	3925.3	3889	H
2	3912.8	3924.0	3924.0	3942.7	3946.4	3954.5	3933	Ca II *K*
3	3945.2	3953.9	3961.4	3980.1	3987.5	4000.0	3969	Ca II H + Hϵ
4	4038.0	4043.0	4043.0	4047.9	4047.9	4051.1	4045	Fe I
5	4082.2	4089.7	4088.4	4117.1	4117.1	4125.8	4101	Hδ
6	4214.9	4221.7	4221.7	4231.7	4231.7	4244.8	4226	Ca I
7	4279.0	4292.7	4292.7	4315.1	4315.1	4328.2	4305	*G*-band
8	4317.6	4321.4	4322.6	4328.2	4328.8	4335.1	4325	...
9	4311.4	4328.8	4328.8	4349.4	4349.4	4365.0	4340	Hγ
10	4378.0	4381.8	4381.8	4386.8	4386.8	4391.7	4383	...
11	4424.1	4445.9	4445.9	4473.3	4473.3	4487.6	4458	...
12	4816.1	4818.6	4818.6	4897.7	4897.7	4902.7	4861	Hβ
13	4898.3	4902.7	4902.7	4929.5	4929.5	4932.0	4923	...
14	4991.1	4994.9	4994.9	5027.9	5027.9	5032.2	5016	...
15	5057.1	5060.3	5060.3	5090.2	5090.2	5092.6	5079	...
16	5133.1	5156.2	5156.2	5190.4	5190.4	5217.8	5171	Mg I
17	5238.4	5251.5	5251.5	5286.3	5286.3	5294.4	5268	...
18	5302.5	5311.9	5311.9	5349.9	5349.9	5362.3	5327	...
19	5371.0	5386.6	5386.6	5419.0	5419.0	5441.4	5404	...

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We should mention here that L. Jones also gives equivalent widths for a number of absorption lines. However, his data were calculated on the basis of a few central pixels only, as reported to us by one of Jones' advisors (J. A. Rose), and thus can only be recovered with high resolution spectra. For early type stars where the true continuum is resolved the measured equivalent width is independent of the resolution. Thus for these stars, our equivalent widths are within the range of what they are known to be from other sources. The situation is different for late type stars where the true continuum hardly ever shows up between the large number of absorption features. As the resolution is lowered, the peaks on both sides of an absorption line which are used to define the pseudo-continuum are being lowered, while at the same time the entire line is being smoothed. It is mostly the lowering of the peaks which leads to a reduced equivalent width when the resolution is being lowered. Also one has to consider that part of a smoothed line may even fall outside of the bandpass assigned to it. On the other hand, for a spectrum with a given resolution the results are practically indifferent to the size and separation of the pixels with which they are observed, as long as both are small compared to the width of the spectral features one wishes to measure.

Our procedure is similar to that employed by Worthey et al. (1994). In fact, several of our lines coincide with their bandpasses. Our goal, though, is different. Here we want to make a clear distinction between 'observable' physical parameters such as absolute magnitudes or intrinsic colors, granted that these require the knowledge of the also observable parallax and the interstellar reddening, and 'derived' parameters such as the effective temperature or the surface gravity. Naturally, the derived parameters are obtained from the observable parameters by means of a theory. The purpose of our work is to determine whether and within which margin of accuracy it would be possible to obtain knowledge of the observable physical parameters through a quantitative measurement of spectral features. The usefulness of such a procedure is evident, as long as the ac-

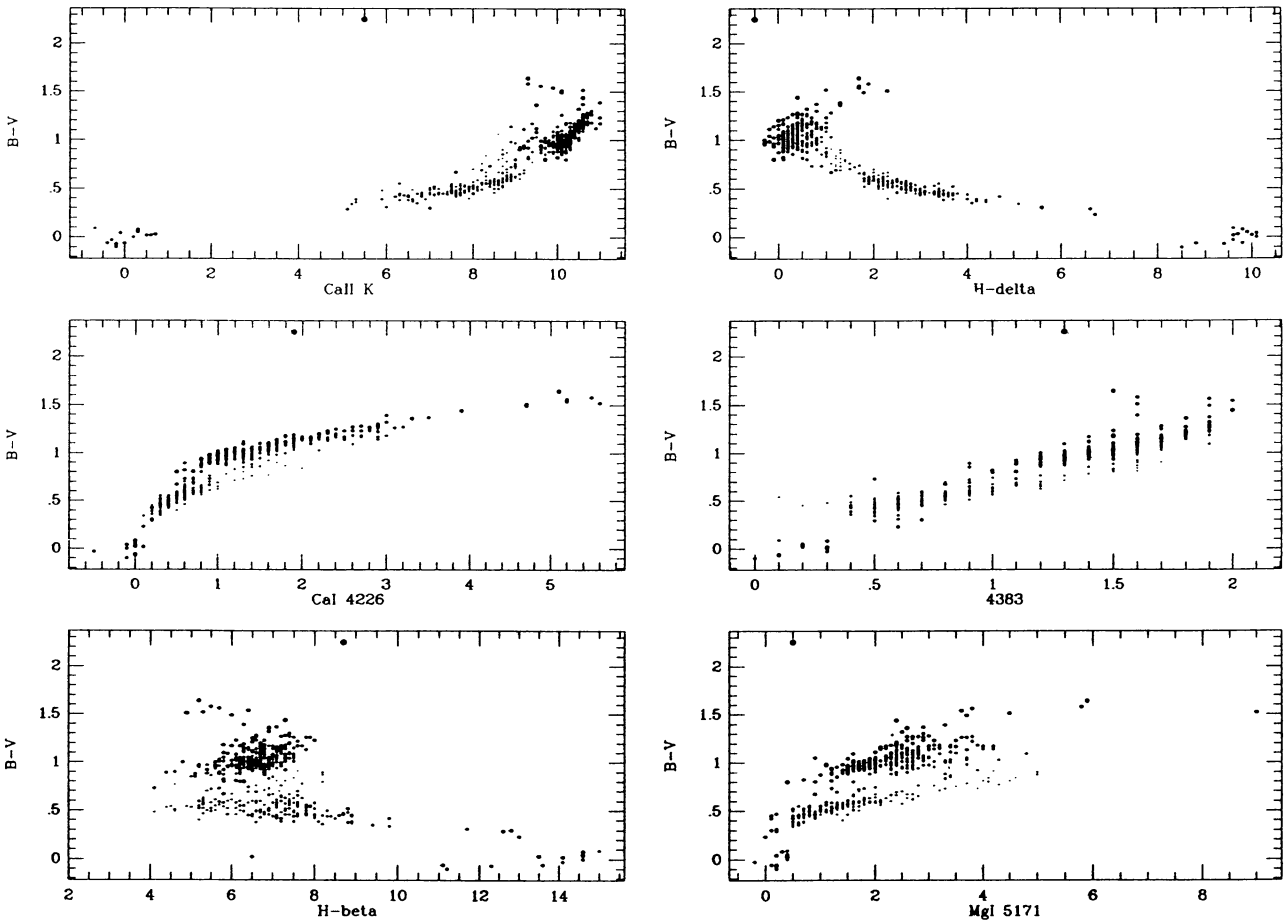

Fig. 5. Relation between the equivalent widths in Angstroms and the $(B-V)$ color for six different lines. The size of the symbols represents the luminosity of the objects.

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curacy of the parameters, in particular the predicted absolute magnitude, is adequate. We shall put special emphasis on low resolution spectra such that our results, if they turn out to be satisfactory, can also be applied to objective prism spectra.

The Jones library also provides B- and V-magnitudes, hence also $(B-V)$ colors. Combining the V-magnitude with the Hipparcos parallaxes, absolute V-magnitudes could be calculated. Stars with a parallax error greater than 20% were eliminated. Thus, practically no supergiants are left in the sample to be analyzed. Since all stars in the sample are rather bright, the effect of interstellar absorption will in most cases be small or even negligible. In Figure 5 we show several examples of the relation between the $(B-V)$ colors and the equivalent widths. The size of the symbols represents the luminosity of the star. Two things become apparent in these figures, namely (1) that in all cases the equivalent widths are functions of at least the luminosity and the intrinsic color and certainly of more physical parameters, and (2) that very early, early, late, and very late spectral types would require separate treatment. The first thing to achieve then, was to separate the stars into spectral type groups. Several of the lines, notoriously Hβ, give no handle to separate early and late type stars, while others are quite useful for deriving probabilities of belonging to either the early or the late type group.

The groups to be defined are: 'very early = 1', 'early = 2', 'late = 3', and 'very late = 4'. The number '0' is used for spectra which are to be deleted. Examples of the latter are HD 19445 and HD 116656, where the blue and the red spectrum evidently belong to different stars. For each group, starting with the very early one, a range of equivalent widths is defined for suitable lines. When for a given star a certain minimum number of lines falls within these ranges, the star is considered to be a member of the group and is removed from the list. This pro-

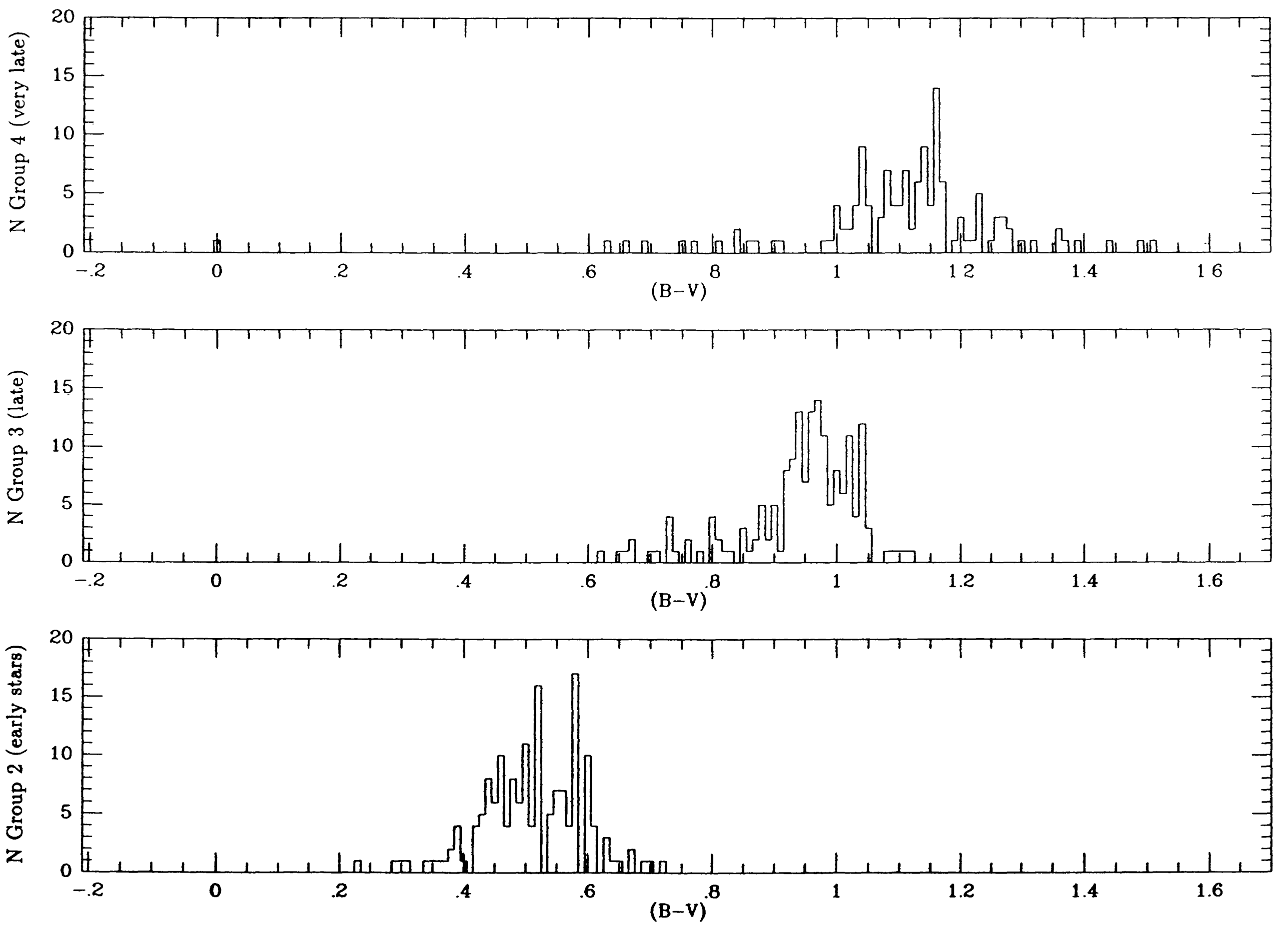

Fig. 6. Distribution of $B-V$ after separating the different groups on the basis of line strenght criteria.

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cess is carried out for the groups 1 to 3, and the remainig spectra are assigned to group 4. The respective ranges and minimum coincidences are listed in Annex I. To see how well this classification scheme works, we can analyze the content of either spectral types or of $(B-V)$-colors of each group since both these data are available. The histograms in Figure 6 show the color distribution per group.

3. ANALYSIS OF THE EQUIVALENT WIDTHS

Our next step is to represent the absolute magnitudes, as well as the colors and metallicities, as functions of a given set of equivalent widths, separately for the different groups. We first tried to recover the mentioned parameters by a second order polynomial with two lines as independent variables. From a set of 19 spectral lines for every spectrum a total of 171 different combinations can be formed. We tried all of them. Each time the respective six coefficients and their errors were determined by least squares. Spectra with residuals larger than 2.5 times the standard error were removed, and the process repeated until no more spectra had to be eliminated. In all cases, it was only a few spectra that had to be eliminated. Of the 171 solutions, we selected those which gave the smallest average residual. The respective combinations, their average residuals, and the coefficients with their errors are listed in Tables IIa-IIc.

We should point out here that the residuals which we have used to determine the performance of the

TABLE 2

SUMMARY OF THE BEST SOLUTIONS
ABSOLUTE MAGNITUDES

Two Lines											
Group 2				Group 3				Group 4			
L1	L2	rms	N	L1	L2	rms	N	L1	L2	rms	N
1	16	0.365	154	1	4	0.328	158	1	5	0.348	104
2	16	0.287	149	1	16	0.298	150	2	5	0.288	112
3	16	0.296	151	3	16	0.292	147	2	6	0.369	113
4	11	0.356	155	5	7	0.310	153	2	9	0.367	112
4	15	0.355	151	5	8	0.319	158	2	16	0.242	109
4	17	0.350	154	5	9	0.303	157	3	6	0.375	119
4	18	0.329	154	5	16	0.327	159	3	9	0.368	116
6	11	0.333	155	5	17	0.311	150	3	16	0.269	116
8	16	0.316	149	5	18	0.312	150	5	10	0.353	100
11	16	0.300	155	6	11	0.330	148	5	11	0.338	109
15	16	0.356	157	6	13	0.329	127	9	11	0.370	120
16	18	0.327	158	11	16	0.318	156	10	16	0.373	115
16	19	0.327	155	16	18	0.283	140	11	16	0.342	122

Three Lines														
Group 2					Group 3					Group 4				
L1	L2	L3	rms	N	L1	L2	L3	rms	N	L1	L2	L3	rms	N
1	2	16	0.261	150	1	2	16	0.249	161	1	2	4	0.261	112
2	11	16	0.273	153	1	3	16	0.226	155	1	3	16	0.277	120
2	14	16	0.273	151	2	3	16	0.250	156	2	5	12	0.274	115
2	16	19	0.266	152	2	5	7	0.244	155	2	8	16	0.275	116
5	16	17	0.271	154	2	5	8	0.234	155	2	9	16	0.258	115
5	16	18	0.264	156	2	5	9	0.215	158	2	16	17	0.275	118
5	16	19	0.266	152	2	5	16	0.228	159	3	5	16	0.263	120
7	16	17	0.271	153	2	16	18	0.233	162	3	8	16	0.253	121
7	16	18	0.256	154	2	16	19	0.239	156	3	15	16	0.282	122
7	16	19	0.260	154	3	5	9	0.213	154	3	16	17	0.263	121
8	16	19	0.266	153	3	12	16	0.244	147	3	16	19	0.240	117
9	16	18	0.274	157	3	16	17	0.250	155	5	6	16	0.266	112
10	11	16	0.257	149	3	16	18	0.238	161	5	9	11	0.261	112

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TABLE 3

SUMMARY OF THE BEST SOLUTIONS

$B-V$

Two Lines

Group 2				Group 3				Group 4			
L1	L2	rms	N	L1	L2	rms	N	L1	L2	rms	N
1	7	0.018	141	1	9	0.028	154	2	4	0.025	113
3	7	0.017	139	2	8	0.025	141	2	6	0.026	114
5	7	0.017	139	3	7	0.028	148	2	10	0.024	114
5	13	0.017	141	3	9	0.028	151	3	5	0.026	111
7	9	0.016	138	4	7	0.024	133	3	8	0.028	116
7	12	0.016	136	5	6	0.028	160	3	10	0.025	117
7	14	0.017	138	5	8	0.027	157	4	11	0.023	110
7	17	0.017	138	5	9	0.027	159	5	6	0.024	108
7	18	0.017	137	5	16	0.027	152	6	11	0.021	116
7	19	0.018	138	7	11	0.027	153	6	16	0.026	121
9	14	0.017	139	7	14	0.028	143	9	11	0.028	114
9	15	0.018	141	7	15	0.028	146	10	11	0.024	110
9	18	0.018	143	9	11	0.023	159	11	15	0.027	117

Three Lines

Group 2					Group 3					Group 4				
L1	L2	L3	rms	N	L1	L2	L3	rms	N	L1	L2	L3	rms	N
1	5	7	0.015	137	1	2	7	0.018	151	2	6	10	0.021	116
2	9	17	0.015	138	1	2	9	0.019	152	3	6	19	0.020	115
3	7	17	0.015	136	1	3	7	0.018	148	3	9	11	0.018	114
4	7	12	0.016	136	1	3	9	0.020	151	3	9	13	0.021	114
5	7	14	0.015	137	1	5	9	0.018	154	3	9	15	0.020	113
6	7	9	0.016	137	2	3	8	0.019	145	3	9	17	0.021	113
6	7	12	0.015	136	2	5	8	0.020	160	5	6	11	0.018	118
7	9	13	0.015	136	3	5	8	0.019	157	5	6	12	0.019	110
7	9	14	0.015	134	4	9	11	0.021	161	5	6	13	0.020	111
7	9	15	0.016	138	5	9	17	0.020	156	5	6	17	0.019	111
7	12	13	0.015	136	5	9	18	0.020	160	5	6	19	0.019	108
7	12	17	0.015	138	5	9	19	0.021	158	6	9	11	0.021	120

method we are suggesting contain a number of components, namely:

1. The errors of the equivalent widths which are affected by the noise in the spectra.

2. The errors of the coefficients. These could be improved if more spectra were available.

3. We do not expect that the intensities of spectral features such as the equivalent widths of absorption lines depend on only two basic physical parameters. Involved are the mass of the star, its surface temperature, its chemical composition, rotation, binary nature, etc. Thus a good part of the residuals will undoubtedly be due to the inadequacy of our function which does not contain enough independent variables and which may not have the most adequate mathematical form.

4. Errors in the data we are trying to recover. In the case of the $(B-V)$-colors observational errors of only a couple of hundredths of a magnitude, at the most, may be expected. On the other hand, the effect of interstellar reddening, in particular in the case of the more luminous stars, may not be totally negligible. The effect of the errors of the parallaxes may be more noticeable. In the sample we are using this error is restricted to 0.4 magnitudes, but will in most cases be considerably smaller.

5. Unresolved binaries. In the case of a binary system with two equal components our method would yield an absolute magnitude which corresponds to each single component. The photometrically calculated distance modulus would be in error by 0.75 magnitudes. The situation is far more complicated

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TABLE 4

SUMMARY OF THE BEST SOLUTIONS
Fe/H

Two Lines

Group 2				Group 3				Group 4			
L1	L2	rms	N	L1	L2	rms	N	L1	L2	rms	N
2	12	0.079	153	2	14	0.075	150	2	17	0.085	121
5	17	0.070	151	2	17	0.078	153	4	12	0.079	119
7	12	0.080	156	3	17	0.069	148	4	17	0.079	118
8	12	0.061	145	3	18	0.080	152	7	17	0.084	118
9	12	0.080	152	4	17	0.077	154	8	14	0.085	123
9	17	0.076	154	6	17	0.076	154	8	17	0.078	120
10	12	0.071	150	7	17	0.074	153	11	18	0.080	117
11	12	0.081	150	8	17	0.075	152	12	18	0.077	122
12	13	0.083	151	9	17	0.076	160	13	17	0.085	120
12	14	0.081	153	14	17	0.077	150	13	18	0.086	121
12	17	0.059	146	15	17	0.077	152	14	18	0.085	119
12	18	0.068	151	16	17	0.080	153	17	18	0.070	116
12	19	0.076	152	17	19	0.078	150	17	19	0.082	123

Three Lines

Group 2					Group 3					Group 4				
L1	L2	L3	rms	N	L1	L2	L3	rms	N	L1	L2	L3	rms	N
1	12	17	0.062	149	1	6	17	0.071	163	3	12	17	0.074	124
3	8	12	0.062	147	2	15	17	0.071	150	3	17	18	0.067	116
4	12	17	0.063	149	3	4	17	0.071	156	3	18	19	0.074	121
5	8	17	0.063	149	3	9	17	0.072	160	5	17	18	0.073	120
5	12	17	0.062	149	3	13	17	0.071	150	6	17	19	0.072	118
5	17	18	0.061	147	3	14	17	0.068	149	8	11	14	0.065	116
7	12	17	0.059	147	3	17	19	0.072	152	8	12	14	0.072	123
8	9	12	0.060	148	4	7	17	0.071	152	9	10	12	0.074	121
8	12	17	0.060	148	4	15	17	0.071	152	9	12	18	0.069	121
9	12	17	0.060	149	5	6	17	0.071	161	11	17	19	0.071	120
12	13	17	0.059	148	6	15	17	0.070	154	13	14	17	0.073	122
12	15	17	0.058	146	8	15	17	0.067	150	16	17	18	0.068	118
12	17	18	0.058	146	11	14	17	0.071	152	16	17	19	0.072	120

when the two components are different. A frequent combination is that of an early main sequence star with a late giant. If their magnitudes are similar, lines of both stars will be detectable in the spectra. Artificial combinations using Jones's spectra may give a clue as to whether such cases can be recognized.

Subsequently, we used a second order polynomial with three lines as independent variables. This leads to a total of 969 possible combinations. Data for the best combinations are given in Tables IIIa-IIIc. The criticism outlined above naturally applies to these solutions as well.

A summary of the best solutions with two or three independent parameters for the absolute magnitudes, the $(B-V)$ colors, and for the metallicities is given in Tables 2 to 4.

One rather convincing way to judge the performance of the above solutions is to look at a color-absolute magnitude diagram, with the residuals shown as arrows. This also gives an immediate and direct impression of the presence of systematic errors, depending on either absolute magnitude or color. A number of such diagrams is shown in the Figures 7*a* to 8*c*. It would be ideal to find three lines within a narrow wavelength range which give satisfactory results for all three physical parameters for all spectral types. This would make it possible to make use of a narrow band interference filter such as is done by Rose (1991), thus supressing considerably the sky background.

In the histograms in Figure 9 we show how often the different lines were made use of in the three-line solutions which gave the smallest average residuals.

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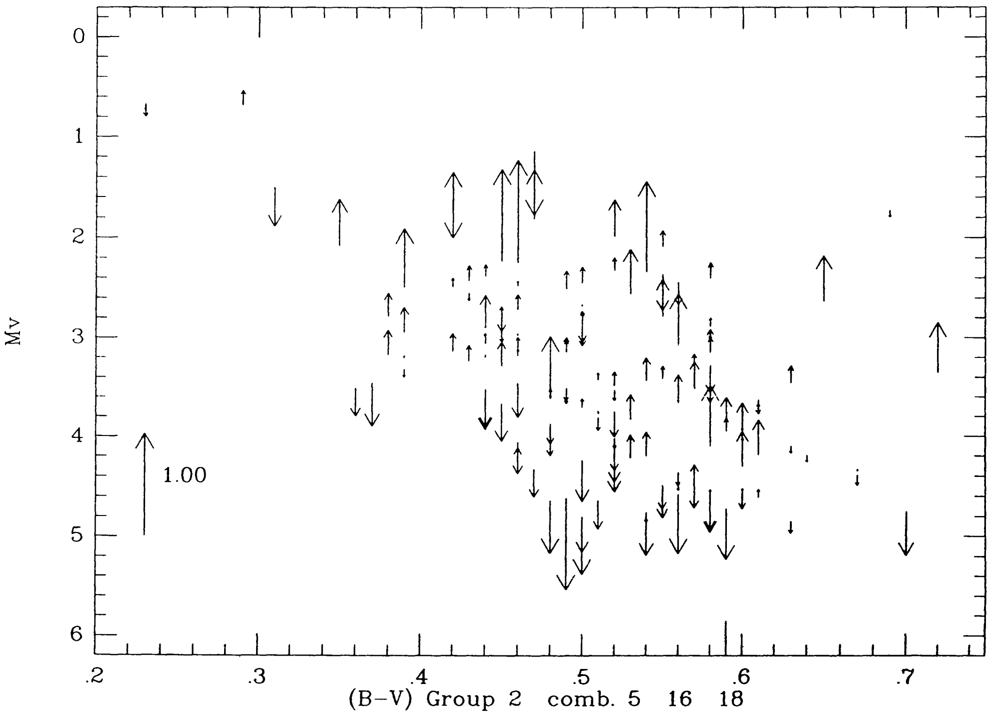

Fig. 7*a*. Residuals of the determination of the absolute magnitudes using a second order polynomial with three independent parameters (combination of lines 5, 16, and 18) for early type stars (Group 2).

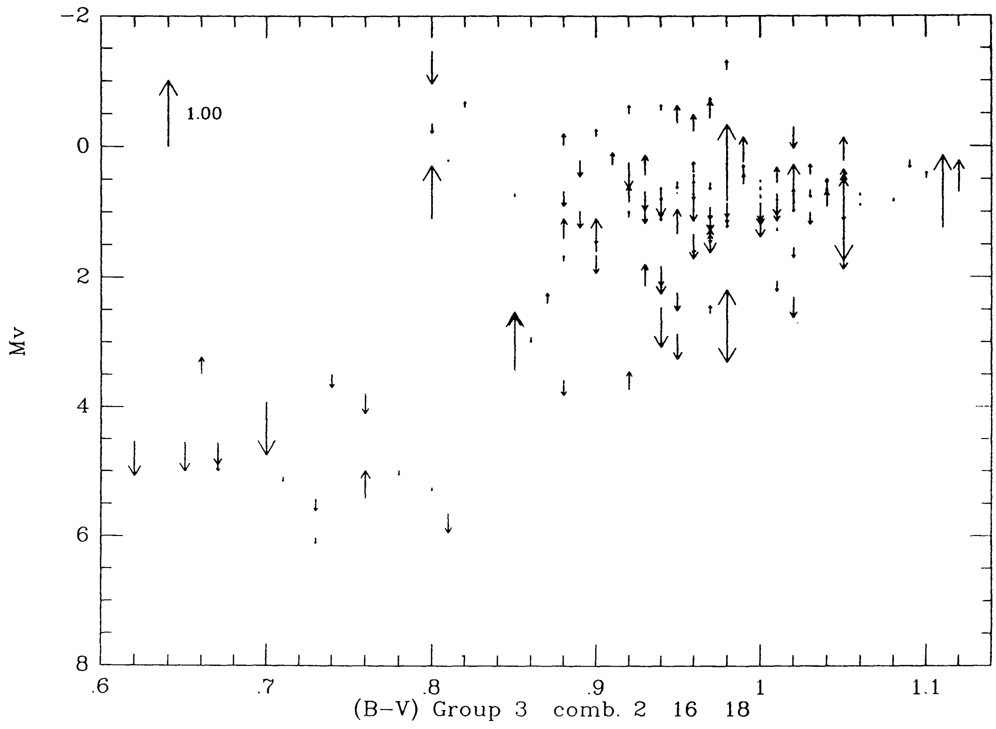

Fig. 7*b*. Residuals of the determination of the absolute magnitudes using a second order polynomial with three independent parameters (combination of lines 2, 16, and 18) for late type stars (Group 3).

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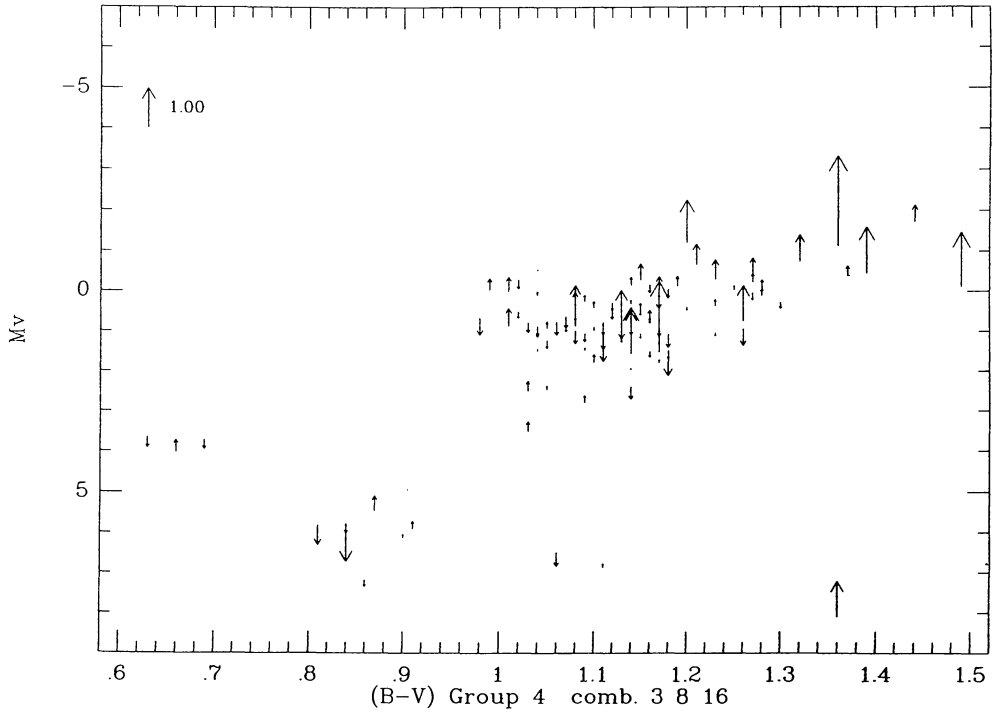

Fig. 7*c*. Residuals of the determination of the absolute magnitudes using a second order polynomial with three independent parameters (combination of lines 3, 16, and 18) for very late type stars (Group 4).

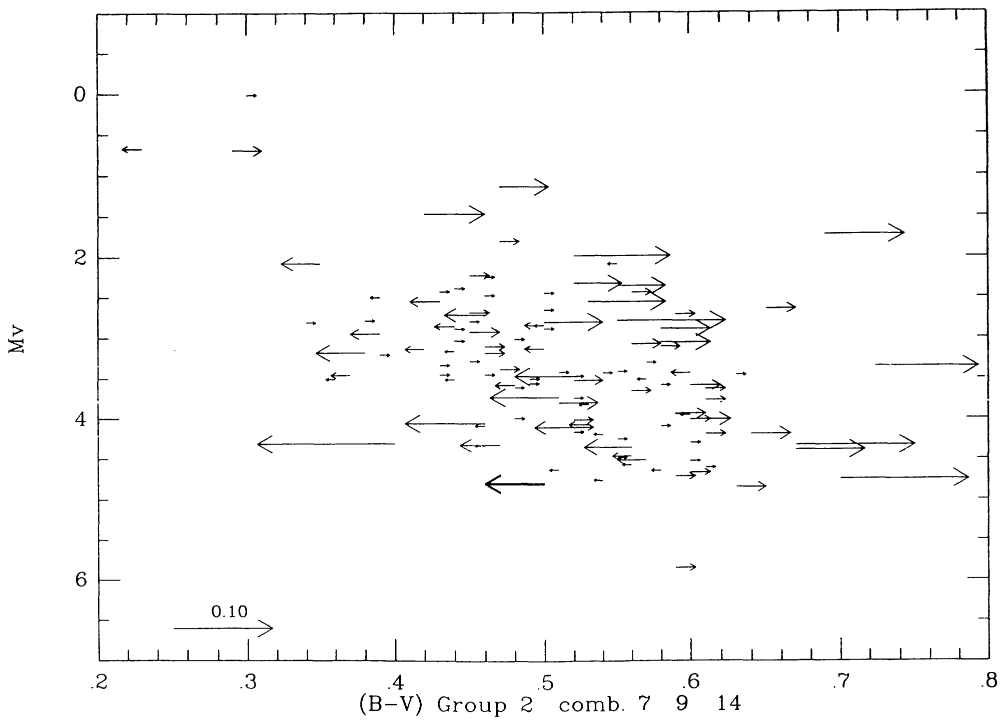

Fig. 8*a*. Residuals of the determination of the $B-V$ colors using a second order polynomial with three independent parameters (combination of lines 7, 9, and 14) for early type stars (Group 2).

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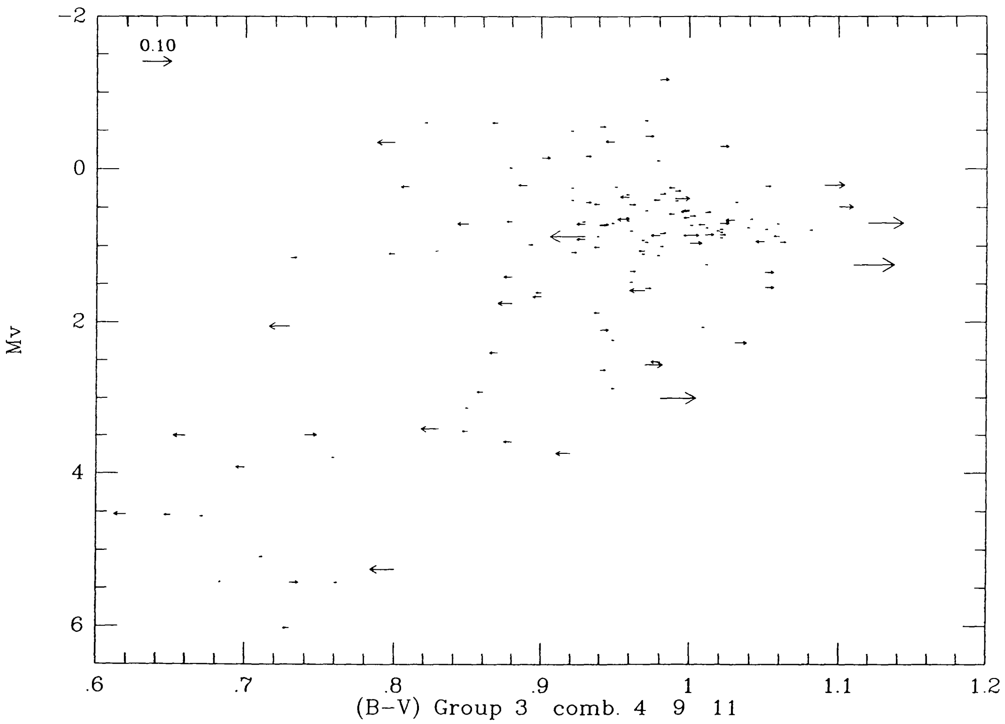

Fig. 8*b*. Residuals of the determination of the $B-V$ colors using a second order polynomial with three independent parameters (combination of lines 4, 9, and 11) for late type stars (Group 3).

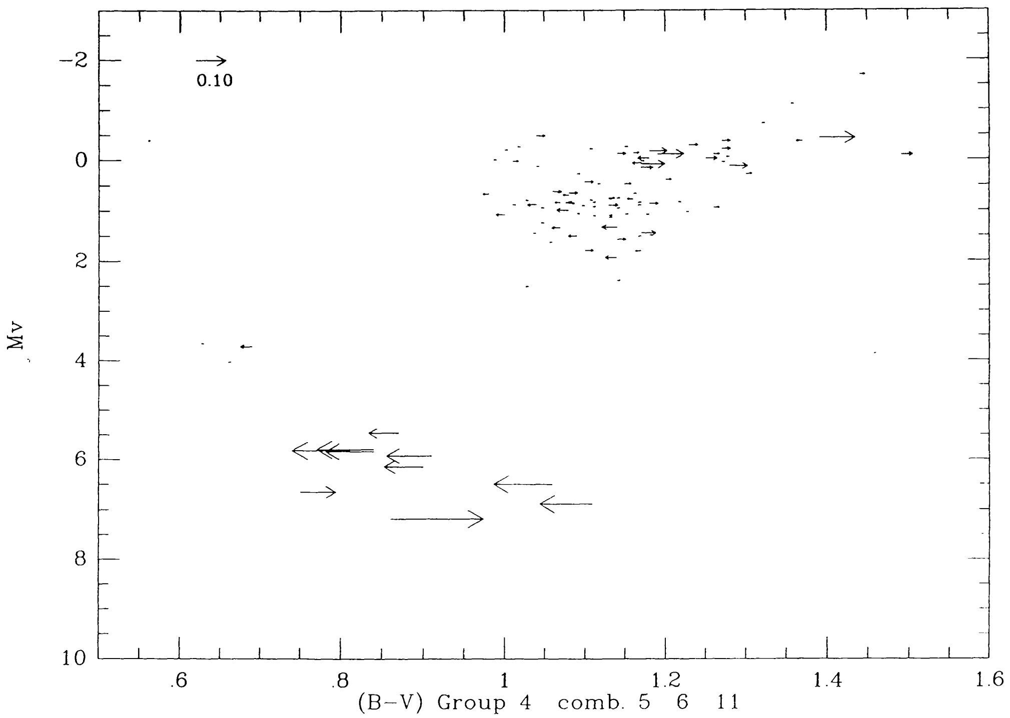

Fig. 8*c*. Residuals of the determination of the $B-V$ colors using a second order polynomial with three independent parameters (combination of lines 5, 6, and 11) for late type stars (Group 4).

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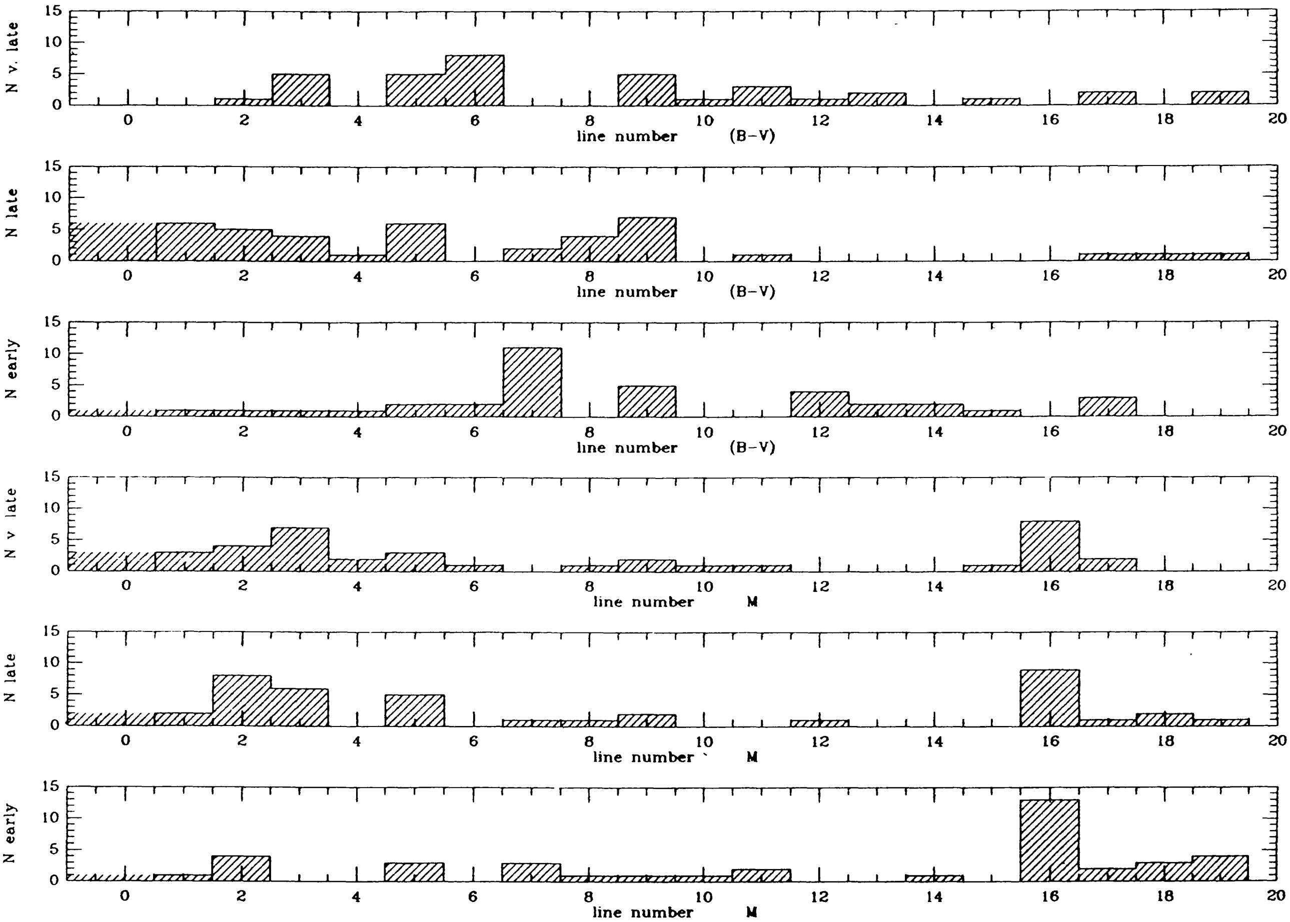

Fig. 9. The histograms show how often the 19 different lines were used for the 12 or 13 best solutions based on a combination of three lines. The upper three histograms are for the color solutions, the lower three for the absolute magnitude solution.

Line 16 (Mg I 5171) evidently plays a predominant role in the determination of the absolute magnitudes for all spectral types. It would have to be combined with lines in the blue part of the spectra. For the color solutions most of the best solutions are based on lines in the same part of the spectra.

4. CONCLUSIONS

We have shown that equivalent widths or pseudo equivalent widths of absorption lines derived from stellar spectra of intermediate resolution, can be used to predict basic stellar parameters for most types of stars with an accuracy which makes them useful for other types of investigations; in particular, galactic structure studies. A total of 19 different absorption lines was included in the analysis and it was found that the combination of a selected group of three of them, the combination depending on the intrinsic color or spectral type, serves to predict the absolute magnitude with an accuracy of 0.26 magnitudes which leads to an average error of the photometrically derived distance of about 12%. Such an accuracy is adequate to address for example, the problem of the scale height of the thin and the thick disk, as well as that of the extension of the galactic halo. Likewise the intrinsic color and hence the spectral type can be predicted with an accuracy which is adequate for the above studies, and the same is true for the metallicity index Fe/H.

Within the spectral range covered by our work we have chosen all absorption features (lines or blends) which are expected to be measurable in objective prism spectra, independent of whether they are already known to be sensitive indicators of one or the other stellar physical parameter, and we have tested the usefulness of all of them, in combination with one or two more lines, for their quantitative determination. Our results show that the Ca I line at 4226 Å

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and the *G*-band are of particular importance to indicate the intrinsic color, i.e., the spectral type or the temperature, while the Mg I line at 5171 Å is a very useful luminosity indicator practically across the entire HR-diagram. The line at 5268 Å, on the other hand, is very useful for the prediction of the metallicity index Fe/H. Thus, when selecting the most adequate telescope-prism-detector combination for this type of work, particular attention should be given to these lines.

Two important steps have to be taken before the system we are proposing can find wide application. First of all, one has to find out which resolution can be achieved with the limited number of telescope-prism-detector combinations available and which lines can really be detected and measured. Only actual observations can yield the answer.

Equally important, is to determine how sensitive the system is to changes in the resolution, for instance due to seeing variations. An answer to this question can be obtained by treating the same material we have used with a variety of different smoothing parameters.

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