Photometric determination of the [Fe/H] ratio for the globular cluster M 92[★]

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ABSTRACT

CCD observations of the northern globular cluster M 92 were obtained in the PXYVS colors of the Vilnius photometric system. The results for 230 stars in an area centered on the cluster and for 178 stars in an area west of the cluster down to $V = 17.0$ mag are presented. After a brief outline of the data pathway from observations to reduction via IRAF and a discussion of the photometric errors, the [Fe/H] ratio of the globular cluster M 92 is determined by multicolor PXYVS Vilnius photometry.

Key words. stars: fundamental parameters – stars: general – Galaxy: globular clusters: individual: M 92

1. Introduction

This paper is in continuation of a series of papers reporting CCD photometry in the Vilnius photometric system (hereafter VPS). Two fields in the direction of the very metal deficient globular cluster M 92 were investigated in five Vilnius colors PXYVS, with the purpose of producing CCD photometry for cluster members and of determining the [Fe/H] ratio of the cluster by a statistical approach.

Since the eighties, the CCD photometry technique progressively replaced the photoelectrically calibrated photographic plates, despite the small size of the field of view, relatively large pixels and surface imperfections, bringing a substantial improvement in sensitivity, linearity, and dynamic range. This “historical” change produced a dramatic reduction in the internal errors of the observational data, and also made systematic differences evident in respect to the previous works.

At the same time adequate software has been developed. In particular, the point-spread function technique permitted an improved signal-to-noise ratio and the deconvolution of overlapping images. These new techniques have shown their effective potential for studying the typically very crowded globular cluster fields. In fact, a complete survey of a globular cluster area, with this considerably increased accuracy, has produced significant improvement in our knowledge of the morphology of the color-magnitude diagrams (CMD).

Having decided to make CCD photometric observations, we devoted our attention to the choice of a multicolor photometric system. After the international photographic and photovisual systems that appeared in the twenties, in the second half of the last century a number of photometric systems were developed, starting with the *UBV* system introduced by Johnson & Morgan (1953). With the *RI* system, proposed by Cousins (1976, 1980), an extension was set up, called the *UBVRI* broadband system. The limitations and the evolution of these systems are

extensively described by Straižys (1992, 1999). Most CMDs for star clusters have been derived from the broad band *UBV* system and its extensions. But intermediate band systems (e.g. Strömgren and Vilnius) provide more accurate spectral information.

Hesser (1988) stressed the importance of using other multicolor photometric systems. He concluded that, despite the power of other systems to provide answers to many astrophysical problems, observational data on globular clusters obtained by multicolor photometric systems other than *UBVRI* are rather scarce in the literature. In general, this mainly depends on the necessary network of standards suitable for CCD photometry.

Bearing these arguments in mind, we started an observing program in the beginning of the nineties, in the VPS of regions in the direction of globular and open clusters. We had several aims in view: e.g., automated photometric classification of a wide variety of stars (Smriglio et al. 1986, 1988, 1990), CCD photometry in the Vilnius photometric system (Boyle et al. 1990a,b; Boyle et al. 1994; Dodd et al. 1996; Boyle et al. 1998; Smriglio et al. 1998; Smriglio et al. 2002), determination of interstellar extinction (Smriglio et al. 1991; Boyle et al. 1992; Janulis & Smriglio 1992), and the study of the cloudy structure of interstellar dust and the gas-to-dust ratio (Smriglio et al. 1994; Smriglio et al. 1995; Smriglio et al. 1996). The observations of globular clusters give the opportunity of calibrating photometric systems in terms of temperature, luminosity, and metallicity, since these parameters, and the interstellar reddening of the cluster stars can be measured with rather good accuracy. Moreover, the globular cluster population contains horizontal branch stars of different temperatures and metallicities, which are rather infrequent in the solar vicinity. Besides this, the morphology of the CMD is also very important for contributing to the knowledge of the age-metallicity relation.

In this paper we present CCD photometry in the VPS in the field of the globular cluster M 92, which is thought to be typical of very metal-deficient clusters. Furthermore we determine the [Fe/H] ratio for this cluster in a purely photometric way by use

[★] Appendix A, Figs. 1 and 2 are only available in electronic form at <http://www.aanda.org>

of a number of metallicity-sensitive color indices (Bartkevičius & Sperauskas 1983).

2. Observations

The observations were obtained using five Vilnius filters (P , X , Y , V , S), during two different observing runs in six nights in May and July 1996 with the 150 cm telescope of Bologna University situated at an altitude of about 3000 feet in Loiano (Northern Italy Apennines). A concise description of the VPS properties and the response functions of the Vilnius passbands are shown in a recent review of standard photometric systems (Bessel 2005). The U filter of the Vilnius system was not used, due to the very low ultraviolet efficiency of the presently available CCD camera; on the other hand, the U magnitude is not necessary for the photometric determination of metallicity using the technique described in the present paper. Also the observations in the Z band have been omitted because of the mediocre quality of the Z standard magnitudes available at that time.

Any light leaks outside the desired band were less than 1% of the transmission across a spectral region from 0.3 to 1.2 micron. A cryogenically-cooled CCD camera was used consisting of a Thomson TH 7896A CDA chip with 1024×1024 pixels, each 19μ square, operated at -130°C . The chip size corresponds to 9.6×9.6 arcmin on the sky at the $f/8$ Cassegrain focus of the telescope.

The observations were performed in two fields partially overlapping each other, and this overlap will be very valuable for estimating the accuracy of the photometry. The first one (hereafter M92C) was centered on the cluster at the coordinates $\text{RA} = 17^{\text{h}}17^{\text{m}}00^{\text{s}}$, $\text{Dec} = 43^\circ08'00''$ and the second one (hereafter M92W) was at $\text{RA} = 17^{\text{h}}16^{\text{m}}5^{\text{s}}$, $\text{Dec} = 43^\circ08'46''$ (epoch 1950). The common region has an extension of about 8.96×4.1 arcmin.

The exposure times for M92C were 30 min in P , 15 min in X , and 10 min in the rest of the filters. Similarly, the exposure times for M92W were 15 min in P , 7 min in X , and 5 min in the rest of the filters. The finding charts of both regions are shown in Figs. 1 and 2, respectively.

3. Reductions

The data were partially reduced at Wellington Victoria University (New Zealand) by one of us (A.K.D.) and at Rome University “La Sapienza”, using the crowded field photometry package DAOPHOT from IRAF in the point-spread function mode (Tody 1986, 1993; Stetson 1987).

The flatfielding was done using domeflat exposures. Flatfielded exposures in each filter were aligned by task *imalign* and then added in order to improve the signal-to-noise ratio (Newberry 1994). In the *imcombine* task we set “combine” = *average* and “reject” = *crreject*. In this rejection set-up the low pixels are ignored and only high pixels rejected to ensure that any star falling on a bad pixel or trap is rejected. This will also remove any star affected by cosmic rays.

We performed photometry on the combined images from each filter using tasks: *phot*, *psf*, *nstar*, *substar*, and *allstar* in this sequential order. The *psf* stars (photoelectric standards, as well as many bright and isolated stars) were selected using the *pstselect* procedure. The task *psf* was run interactively using the output list from *pstselect* and then accepting or rejecting a candidate as a *psf* star after inspecting the profile and the contour of the star. A good candidate *psf* star must have no neighbours within *fitrad* pixels and also must be free of cosmetic blemishes.

Table 1. The list of Vilnius photoelectric standard stars observed in the studied fields and used for calibration.

N.Zda	S66	M92C	V	$P - X$	$X - Y$	$V - S$
4	IX-13	38	14.00	0.58	0.88	0.75
8	X-49	2	12.21	0.91	1.22	0.90
9	III-65	7	12.47	0.89	1.28	0.91
6	IV-40	35	13.88	0.58	0.88	0.75
		M92W	V	$P - X$	$X - Y$	$V - S$
1	VI-7	10	13.50	0.60	0.81	0.59
2	VII-18	2	12.15	1.04	1.37	0.93
6	IV-40	15(35C)	13.88	0.58	0.88	0.72

Table 2. The fitting results in each pass-band for the stars common to both the observed fields.

band	mag.range	st.dev.	slope $\pm$ error	zero.p $\pm$ error
V	11.8–14.5	0.02	1.00 ± 0.01	-0.02 ± 0.10
P	13.4–16.0	0.02	0.99 ± 0.01	0.08 ± 0.10
X	12.9–15.5	0.03	0.99 ± 0.01	0.11 ± 0.20
Y	12.2–15.0	0.02	0.99 ± 0.01	-0.05 ± 0.17
S	11.4–13.3	0.02	0.99 ± 0.01	0.02 ± 0.12

The *fitrad* $\approx$ *FWHM* was set for each combined image per filter. The *FWHM* and *sky* σ were obtained from each combined image per filter, using task *imexamine*. These procedures were repeated until we had a good list of those *psf* stars that do not contain any non-stellar, multiple, or cosmetic blemishes. From this procedure the instrumental magnitudes for all the band-passes were obtained.

The instrumental magnitudes (m_{ccd}) for each band-pass were converted to the standard (m_{st}) ones of the VPS using a color equation (CE) of the form:

$$m_{\text{ccd}} = m_{\text{st}} + m_0 + m_1(Y - V)_{\text{st}} \quad (1)$$

where $(Y - V)$ is the color index most sensitive to temperature. The coefficient m_0 is the zero point shift and m_1 is the first-order color coefficient (slope). The values of these coefficients were obtained using task *fitparams* as described in IRAF.

Eight photoelectric standards from Zdanavičius (1992) were identified in the M92C observed area and other four standards in the M92W area, but only the stars listed in Table 1 were used for calibration. Unfortunately, this is due to the rather low (and in some cases very low) accuracy of 50% of these standards, as indicated by the author.

The first, second, and third columns of Table 1 list the identification numbers of the standards taken from Zdanavičius (1992), Sandage & Walker (1966) and this paper, respectively, and Cols. 4 to 7 show the V magnitude and color indices ($P - X$), ($X - Y$), ($V - S$) observed photoelectrically by Zdanavičius.

As already said in Sect. 2, an area of 8.96×4.1 arcmin. is common to both the observed fields, and 64 stars were identified in this area. For these stars two different sets of magnitudes and colors, obtained in two different runs, are available and their corresponding identification numbers, Nc for the M92C and Nw for M92W, are listed in Table A.3 (see Appendix).

These common stars give the opportunity for estimating the accuracy of our photometry. A comparison between the corresponding VPS magnitudes of these stars was performed by first degree polynomial fittings which give the results presented in Table 2. The fitting was performed with the stars in the range of magnitude indicated in Col. 2 for each pass-band. The slope and the zero-point with the corresponding errors are also shown. As an example, the result of the fitting for the Vilnius

Fig. 3. V magnitudes (V_w) of M92W versus V magnitudes (V_c) of M92C for stars that are common to both areas and brighter than $V = 14.5$.

V magnitudes of these common stars up to $V = 14.5$ is represented in Fig. 3.

From Table 2 we can see that for each pass-band the slope is systematically equal to 1 within a 1% rms error, while the errors for the zero-point are larger, due to the already-mentioned mediocre accuracy of the photoelectric standards. The standard deviation indicates a scatter within 2% for V , P , Y , and S colors and reaches 3% for X . For the magnitudes between $V = 15$ to 17, the scatter is larger than 3%, mainly due to the decreasing signal-to-noise ratio with increasing magnitudes by rule of photon statistics. Bearing in mind that the M92C area is affected by a background due to faint undetected stars and that it is relatively crowded compared to the western area, these results may be considered quite satisfactory for our purposes, as seen later.

In the absence of other photometric observations of the globular cluster M 92 in the VPS, we can try to get some information about the accuracy of our photometry by comparing our Vilnius V magnitude with the broad-band Johnson V magnitudes available in the two observed regions. For this purpose we identified 22 stars in M92C and an other 20 stars in M92W coincident with just as many standard stars observed by Sandage. They are listed in Tables A.4 and A.5, respectively (see Appendix). In these

Tables our identification numbers and the corresponding Sandage numbers are shown in Cols. 1 and 2. The V magnitudes are listed in Cols. 3 and 4. In Cols. 5 and 6 the $(B - V)$ color indices calculated from Vilnius colors and those measured by Sandage in the UBV broad-band Johnson system are shown. The $(B - V)$ in Col. (5) of each table has been calculated using the following relations between Vilnius and the UBV system (Straižys 1977, 1992):

$$(B - V) = 0.50[(X - V) + (Y - V)]$$

$$\text{for } [(X - V) + (Y - V)] \leq 2.26, \text{ or}$$

$$(B - V) = 0.48(X - V) + 0.02$$

$$\text{for } [(X - Y) + (Y - V)] > 2.26$$

where $(X - V)$ and $(Y - V)$ are the Vilnius color indices. These transformations can be applied both for reddened and unreddened stars.

The $(B - V)$ index was also corrected for a chemical composition effect by using the empirical relations between $(B - V)$ and

$(Y - V)$ color indices for metal poor stars of different metallicities, studied by Bartkevičius & Lazauskaitė (1992). But, with this sample and the present accuracy, we did not obtain significant differences, except for a slight second order effect for the brightest stars in the M92C field. On the contrary, a slightly larger, but also inconsequential, scatter of the data was observed in the color-magnitude diagram. This effect is certainly due to the errors introduced by these equations, which, according to the authors, can reach a value of 3%.

The comparison of our V magnitudes and $(B - V)$ color indices with those determined photoelectrically by Sandage & Walker (1966), listed in Tables A.4 and A.5 in the Appendix, was done by using a first degree least-square solution technique. The result for the V magnitude in the M92C area is given by the equation $V_c = (1.02 \pm 0.01)V_s - (0.27 \pm 0.22)$. For the M92W area we obtain $(V)_w = (1.00 \pm 0.01)V_s - (0.24 \pm 0.13)$, where the suffix “s” indicates Sandage’s values. In both the areas the standard deviation is <0.03 . Moreover, the result for the $(B - V)$ color index is given by the equation $(B - V)_c = (0.97 \pm 0.02)(B - V)_s - (0.01 \pm 0.01)$ in the M92C area and $(B - V)_w = (1.03 \pm 0.02)(B - V)_s - (0.01 \pm 0.01)$ in the M92W area. The standard deviation is 0.02 and 0.03, respectively.

On the basis of these results, it appears that the accuracy of this photometry remains within 2–3%, which in general cannot be considered as very accurate photometry. But considering the poor quality of the standards and of the high surface density of stars around the globular cluster, these results are acceptable. On the other hand, as we have already suggested in a previous paper (Smriglio et al. 1998), it is not excluded that the available broad band photometry can contain systematic errors. For testing this hypothesis, we identified a number of stars common to two different photoelectric observations in this region (see Table A.6 in Appendix), published by Sandage & Walker (1966) and Sandage (1969). The comparison between the V magnitude from Sandage & Walker (1966) (VS_{66}) and the V magnitude from Sandage (1969) (VS_{69}) gives the equation $VS_{69} = VS_{66}(1.06 \pm 0.03) - (0.93 \pm 0.46)$ with a standard deviation $SD = 0.04$. For this fitting the stars XI-11 and XII-6, rejected by the authors, were removed from the sample. These values confirm a probable presence of large scatter and also systematic differences in the UBV photoelectric photometry of globular cluster stars.

By applying the same technique, also the $(B - V)$ index $((B - V)_{S66})$ from Sandage & Walker (1966) and the corresponding index $((B - V)_{S69})$ from Sandage (1969) (Table A.6 in Appendix) were compared. The fitting gives the equation $(B - V)_{S69} = (B - V)_{S66}(1.05 \pm 0.08) - (0.01 \pm 0.01)$. This result shows a large rms error in the slope and, plotting the data in Fig. 4, we can also notice a systematically larger scatter for stars bluer than $(B - V) \approx 0.25$.

In conclusion, the broad-band photoelectric UBV observations, available in the M 92 region, do not allow any estimation of the external errors of our CCD photometry, because of the considerable scatter and the systematic differences existing in the published data.

4. Results

The Vilnius intermediate-band CCD photometry presented in the previous Sections has produced a catalogue of 344 stars brighter than $V = 17.5$ mag, the vast majority of them belongs to globular cluster M 92. For determining the metallicity of the cluster by a purely photometric technique, the stars brighter than $V = 14.8$,

for reasons described later, were selected. In this section the statistical procedure, followed for determining the [Fe/H] ratio of the studied cluster, and all the results are presented.

4.1. The catalogue

The final catalogue is presented in Table A.1 for the stars observed in the M92C field and in Table A.2 for the stars in the M92W field (see Appendix). In Table A.1, a list of 230 stars is complete in V magnitude from $V = 11.76$ (the brightest value in the field) to $V = 16.83$. Similarly, the list in Table A.2 contains 178 stars from $V = 11.72$ to $V = 17.47$ mag. In both tables, eight columns consecutively give (1) the sequential running number, (2) and (3) the coordinates X_c and Y_c , respectively, in pixels of the center of each star image, (4) the CCD V magnitude in the VPS, and (5) to (9) the Vilnius color indices $Y - V$, $P - V$, $X - V$, $V - S$, and Johnson $B - V$ color index. This last index was calculated from the Vilnius color indices ($X - V$) and ($Y - V$), as indicated in the previous section.

The stars of both samples are shown in order of increasing V magnitudes and, following a criterion already used in previous papers of the same series, can be easily identified in the finding charts in Figs. 1 and 2 by their coordinates X_c and Y_c , respectively.

4.2. Interstellar extinction

The interstellar reddening in the direction of the globular cluster M92 has been estimated in the course of time by several authors using a wide variety of methods. A concise, but in practice complete, list of color excess determination methods has been published by Webbink (1985). He grouped all the techniques available in the literature in six echelons, also giving an estimate of the accuracy of each method. The first-echelon technique relies on the intrinsic colors of the BHB stars, which are nearly independent of metallicity. With accurate photometry these measures can be accurate to $\pm 0^m.02$. The second and third-echelon measures rely on the intrinsic colors of the RR Lyrae stars and on the intrinsic flux distributions of individual red giants stars. The results are probably not very inferior to those of the first-echelon. The author relegates the asymptotic reddening of foreground field stars technique in the fourth position only, because these estimates are essentially statistical in nature and are normally significantly more uncertain than the higher-echelon measures. In fact, the measurement uncertainty in E_{B-V} increases in proportion to the reddening itself and, in the case of small-sized fields, it is typically $0.15 \times E_{B-V}$. The results are quite satisfactory in general for high-latitude clusters. For the sake of completeness we say that the fifth-echelon measures employ the blue and red edges of the RR Lyrae instability strip and the sixth-echelon can be obtained by comparing of integrated photometry of the cluster in question with the intrinsic colors of clusters of a similar spectral type. Their accuracy is comparable to that of second and third-echelons. In the absence of a color-excess determination by one of the above methods, one can resort to the cosecant-law, but the accuracy cannot be better than $\pm 0.4 \times E_{B-V}$. The color-excesses E_{B-V} for the cluster M92 are diffusely quoted in the literature and an extended selection, used in this paper, is listed in Table 3.

The measure by Sandage (1969) was performed by using the two-color diagram of blue horizontal branch stars, which is a first-echelon technique for determining the reddening of a globular cluster (Webbink 1985). According to this author, in the case

Table 3. A selection of the color-excess E_{B-V} of M 92 from several authors in the literature (in order of publication).

References	E_{B-V}
Sandage (1969) (quoted by Webbink 1985)	0.02
Sandage (1970)	0.02
Harris & Racine (1979)	0.01
Zinn (1980a)	0.02
Zinn (1985)	0.02
Reed et al. (1988)	0.02
Smriglio et al. (1998)	0.01

Fig. 4. Comparison between the $(B - V)$ color-index by Sandage (1969) and the same color-index observed by Sandage & Walker (1966) for 17 stars.

of very accurate photometry, the error could be better than $0^m.02$, but, after our photometric test (see Sect. 3, Fig. 4), this condition could not be achieved sufficiently. Both Harris & Racine (1979) and Zinn (1980a) have taken weighted means of the available reddening estimates in the literature and, while these averages are identical, they found differences of up to 0.03 mag for many clusters on their list. The reddening has been measured recently by Vilnius photometry (Smriglio et al. 1998) using seven suspected non-member foreground stars (Sandage & Walker 1966) of solar metallicity. The metal abundance of these stars is also confirmed by the color-color diagrams in the VPS.

From the available data, it is evident that $E_{B-V} = 0.02$ is the most probable value for the reddening of M 92, but we also think that it is comparable to, or smaller than, the photometric errors obtainable by all these techniques. Consequently, we have decided not to apply any reddening correction to the observed color indices.

4.3. The color-magnitude diagram

Plotting the stars of one of the two fields (e.g. M92W) in the color-magnitude diagram [V , $B - V$], (CMD, shown in Fig. 5), we can select a sample of stars able to be used for the photometric determination of the [Fe/H] ratio of M 92.

For reasons that will be justified in the next paragraphs, the stars brighter than about 14.8 V -magnitude have been selected. By chance, they are the brightest of the catalogue and then affected by smaller errors. These objects are marked in Fig. 5 by open circles. The stars fainter than this limit are indicated by empty squares. On the whole, two samples of about 40 stars in M92W and 80 stars in M92C are available.

Fig. 5. The color-magnitude diagram for the stars observed in the field M92W: the empty circles indicate the stars brighter than $V = 14.8$; the empty squares the stars fainter than this value; filled circles and filled squares are photoelectric standards by Sandage & Walker (1966) and Sandage (1970), respectively. The measured $[\text{Fe}/\text{H}]$ ratio for three stars is indicated (see text)

Moreover, the CMD diagram gives the opportunity of making an immediate and simple comparison of our photometry with that of Sandage & Walker (1966). In fact, the filled circles indicate 37 photoelectric standards, observed in the region of M 92 and identified by these authors as members of this cluster. Likewise, the filled squares indicate six other photoelectric standards, fainter than $V = 16$ mag, later observed by Sandage (1970). It is evident that, within the 2–3% accuracy of this photometry, the distribution of CCD stars does not show any significant systematic effect with respect to the UBV photometry. In any case, the presence of some small systematic effect in the $(B - V)$ index, calculated from VPS color indices, would not influence the determination of metallicity, which is obtained directly from Vilnius color indices.

4.4. The photometric determination of $[\text{Fe}/\text{H}]$ ratio

The efficiency of photometry in the VPS for distinguishing metal deficient stars (MD) and for determining their abundances and luminosities has been extensively shown by V. Straižys and his group in the seventies and eighties. A new technique for determining all these parameters and, in particular, the $[\text{Fe}/\text{H}]$ ratio for MD stars was published by Bartkevičius & Sperauskas (1983) and is applied in the present work.

In a few words, it is possible to observe the ultraviolet excess for MD stars by their position on color-color diagrams by plotting a color index that is sensitive to metal deficiency as a function of a color index that mainly depends on the temperature. In the VPS the $(Y - V)$, $(V - S)$, and $(Y - S)$ indices are the best indicators of the effective temperature for F-M type MD stars, while $(P - X)$, $(X - Y)$, and $(P - Y)$ are the indices most sensitive to the metallicity. The $(U - P)$ index is indispensable for determining luminosities of all MD stars and for distinguishing peculiarities as carbon-rich stars (CH, barium, and R stars) and red horizontal branch (RHB) stars. From these color-color diagrams it is possible to define a metallicity index δ (CI), that is nearly independent of temperature (Bond 1980), for each star and also, to calibrate it directly in terms of $[\text{Fe}/\text{H}]$. For estimating the amount of variation of the abundance-sensitive color indices as a function of the metallicity, the two-color diagram $(P - X)$ vs.

$(Y - V)$, calibrated in metallicities (Straižys 1982), can be used. In this diagram the unreddened stars of normal chemical composition of spectral types G0-K2 and luminosities IV-III, and G5-K2 for supergiants, form a single sequence and $\delta(P - X)$ “is a function of the metallicity only”. This diagram is calibrated in $[\text{Fe}/\text{H}]$ using values of metallicity measured by spectroscopy. The variation $\delta(P - X)/0.1[\text{Fe}/\text{H}]$ dex is on the order of 1% for G0-G5 and 1.5–1.8 % for K0-K2 types and does not show any luminosity effect. The amount of variation obtained by other combinations of filters appears to be on the same order of magnitude.

In our case the color-color diagrams $(P - V)$, $(Y - V)$ and $(X - V)$, $(Y - V)$ where plotted in Figs. 6a–d. In these figures the continuous line represents the main sequence, while the sequence of G-K giants of solar metallicity is shown by a dashed line. The arrow gives the slope of the interstellar reddening line and its length corresponds to $E_{Y-V} = 0.20$.

Figure 6a shows the $(P - V)$, $(Y - V)$ diagram, plotted for the 230 stars observed in M92C field (Table A.1 in Appendix), as are the stars brighter than $V = 15$ mag. The analogous diagram for the 178 stars observed in M92W field (Table A.2 in Appendix) is plotted in Fig. 6b.

From these diagrams, noticeable color excesses $\delta(P - V)$ and $\delta(X - V)$ due to differential line blanketing are evident. The distribution of dots in Figs. 6a–c show that the scatter depends essentially on the stars fainter than the 15th V -magnitude and also that it is obviously larger in the more crowded region M92C.

In particular, stars fainter than 15th V -magnitudes have been omitted in Fig. 6c to show the fairly good sequence of the MD stars more clearly. This sequence, as already shown by Smriglio et al. (1998), displays a good fit with the sequence of a sample of field stars, with same metallicity and luminosity and after dereddening of their color indices. Again in this figure, six suspected foreground stars of solar metallicity and two suspected RHB stars are present, as their measured metallicity afterwards confirmed.

4.5. Results

The method for statistically determining the $[\text{Fe}/\text{H}]$ ratio of a globular cluster consists in measuring the metallicity of a properly selected sample of cluster members. An accurate statistical analysis of these data permits a mean value of $[\text{Fe}/\text{H}]$ ratio to be determined with its rms error.

In the case of M 92, we decided to select the stars brighter than about 14.8 V -magnitudes. These stars are mainly red giants (RG). But a few stars of the red end of the horizontal branch (RHB), some stars of the asymptotic branch and some sub-giants are included in this sample. It is known that the RHB stars have either no ultraviolet excess or only a slight one relative to solar metallicity stars. The explanation is that the deblanketing due to low metal abundance nearly compensates for the gravity effect (e.g., Johnson & Morgan 1953; Eggen & Sandage 1964). Also some field star could appear in the same range of color and magnitude. But these objects show a relatively high value of metallicity (apparent or real) and then they could pollute the mean metallicity of the sample from a statistical point of view. For instance, in Fig. 5, the value of measured metallicity has been indicated for the stars scattered around the giant branch sequence. It is evident that they appear to be metal rich or slightly richer than the actual metal abundance of the cluster. On the other hand, we estimate that only a relatively small number of RHB stars can be present in this sample. Bearing in mind that this globular cluster is extremely metal-poor, we think

Fig. 6. The color-color diagrams $(P - V)$ vs. $(Y - V)$ and $(X - V)$ vs. $(Y - V)$ in both cluster and west fields. The continuous line represents the main sequence, and the dashed line the sequence of the normal G-K giants. The stars, observed in the fields M92C (a) and c) and M92W (d)), are plotted by dots. The encircled dots are the stars brighter than about $V = 15$ th magnitude. In c) only the stars brighter than this limit are represented (see text).

that the usual 3σ statistical cleaning of the data is an efficient technique for excluding nearly all of these relatively metal-rich objects. In case of 1% photometry, that is to say, a more accurate measurement of the metallicity, an individual elimination could also be performed on the basis of their measured $[\text{Fe}/\text{H}]$ value, followed finally by the statistical cleaning. In all cases, a more effective removal of these RHB stars from the sample will probably reduce the dispersion of the measured $[\text{Fe}/\text{H}]$ ratios and/or some systematic effect.

The metallicity for each star was determined from the three color excesses $\delta(X - Y)$, $\delta(P - Y)$ and $\delta(P - X)$. On the whole, six different sets of values have been obtained. The final sample of stars, selected for our purpose, and the measured metallicity are shown in Tables A.7 and A.8 for the two fields M92C and M92W, respectively (see Appendix).

At this point, it is important to notice that the values of metallicity reported in these tables can only be used for statistical analysis. In fact, a single value could show a large difference compared to the mean, and it would be meaningless to use it as a measurement of metallicity for a single star. Obviously, the information about the metallicity of the cluster is contained in the whole set of measurements and must be extracted by statistical treatment. The $[\text{Fe}/\text{H}]$ values, listed in Tables A.7 and A.8, have been plotted in histograms and the resulting six histograms are shown in Fig. 7. The bell-shaped distribution of data can be studied with a Gaussian fit and, for each set of data, the mean value $[\text{Fe}/\text{H}]$ with its rms error σ_i is obtained. The results are listed in Table 4.

This statistical treatment requires some justification: for a normal distribution of a set of measurements, the probability that a single value is affected by a given error must be absolutely

random, which is to say that the error must be independent of the measurement itself. In the case of astronomical photometry, this may not be completely true, because of the dependence of the photon statistical errors on the apparent magnitudes. This effect gives a contribution to the final observational error, making it dependent on the magnitude, and its influence by degrees significantly increases with the magnitude itself. But in our case all the stars of the selected samples are brighter than $V \approx 14.5$ mag and the signal-to-noise ratio errors remain confined within 0.5% up to $V \approx 14$ mag and within 1% for stars fainter than $V \approx 14$ – 14.5 mag. Then, remembering that the estimated final errors, in this range of magnitudes, are on the order of 2–3%, we can assume that this systematic effect is actually negligible.

Considering that the distributions shown in Fig. 7 at first sight appear to follow a normal distribution, with a more or less good approximation, some statistical parameters were determined for testing the normal distribution. The features to be considered are the median, the *skewness* (the degree of symmetry of a distribution, hereafter SKN), and the *kurtosis-excess* (the degree of peakedness, hereafter KRX).

In Table 5, the SKN and the KRX are shown in Cols. 3 and 5, respectively, for each set of data in both regions M92C and M92W. The values given in Cols. 4 and 6 are obtained by multiplying the standard deviations of the SKN and the KRX by 2.6. This is known to be a rapid test for estimating the symmetry and the shape of a Gaussian distribution: it can be shown that, when they are smaller than their correspondent limit, the SKN and the KRX are significantly near to zero.

From Table 5, it is evident that the values of SKN and the KRX indicate a symmetric and *mesokurtic* normal

Fig. 7. The histograms of the six sets of [Fe/H] ratios measured in both fields cluster (in **a**, **c**, **e**) and west (in **b**, **d**, **f**), obtained from the three color excesses $\delta(X - Y)$, $\delta(P - Y)$ and $\delta(P - X)$. The Gaussian fittings for each distribution are also shown.

Table 4. The [Fe/H] ratios measured for each color excess in both fields M92C and M92W with the corresponding rms error and the number of stars involved in computing each value.

UV excess	[Fe/H] cluster	Nc	[Fe/H] west	Nw
$\delta(P - X)$	-2.90 ± 0.57	65	-2.07 ± 0.63	31
$\delta(P - Y)$	-2.24 ± 0.26	78	-1.90 ± 0.25	34
$\delta(X - Y)$	-1.98 ± 0.34	71	-2.13 ± 0.50	34

distribution for each set of data, with only the exception of the [Fe/H]*clusterPY*. In fact, both the SKN and the KRX are positive for this set, and larger than their own limits, that is, the normal distribution is slightly asymmetric on the right side with more concentration around its mean value (*leptokurtic*). This effect is also indicated in Fig. 7 and is more evident in Fig. 7c. On the other hand, the symmetry of these normal distributions is also confirmed by the fact that the mean and the median are coincident within the same bin (Tables 4 and 5). In conclusion, the statistical approach by a Gaussian fitting to the determination of metallicity seems to be correct and fairly justified.

The final value of metallicity $\overline{[Fe/H]}$ is obtained by calculating the weighted mean of the six mean values in Table 4; that is, $\overline{[Fe/H]} = \sum_i p_i [Fe/H]_i / \sum_i p_i$ and assuming as weight $p_i = 1/\sigma_i^2$, where σ_i , with i from 1 to 6, is the rms error of each [Fe/H] determination in Table 4. The rms error of the mean is given by the known formula: $\sigma_f = 1/\sqrt{\sum_i (1/\sigma_i^2)}$. This statistical

Table 5. The results of the statistical analysis. The values of median, skewness, kurtosis-excess are indicated for each set of metallicity measurements, in each field (C for M92C and W for M92W). The values listed in Cols. 4 and 6 give the limit for the skewness and the kurtosis-excess to be considered significantly equal to zero (see the text).

UV excess	median	sk.	lim _{sk}	k-ex.	lim _{ku}
$\delta(X - Y)C$	-1.97	0.16	0.22	0.20	0.87
$\delta(P - Y)C$	-2.26	0.36	0.20	2.30	0.80
$\delta(P - X)C$	-2.94	0.16	0.23	-0.05	0.91
$\delta(X - Y)W$	-2.08	0.00	0.46	0.83	1.80
$\delta(P - Y)W$	-1.88	0.12	0.46	-0.15	1.80
$\delta(P - X)W$	-2.12	0.92	0.50	0.15	2.01

procedure provided the value $\overline{[Fe/H]} = -2.11 \pm 0.14$. It is interesting that the rms error, obtained with the present 2–3% photometry, is lower than (0.15–0.20) dex, which is the value of the accuracy obtained, with a 1% Vilnius photometry, for the [Fe/H] measurement of a single star (Straižys 1999).

5. Discussion and conclusions

The main aim of the present work is the statistical determination of the [Fe/H] ratio of the globular cluster M 92 by Vilnius photometry and an estimate of the accuracy of the method. Multicolor stellar photometry in the band-passes PXYVS of the Vilnius system has been carried out in two fields, 9.6×9.6 arcmin each, in the direction of the globular cluster M 92. The two fields overlap each other and the common area has an extension of about 9×4 arcmin. The *U* Vilnius filter band-pass was not used, due to the very low UV efficiency of the CCD camera then available at the Loiano 152 cm telescope. Also, the observations in the *Z* band have been omitted because of the mediocre quality of the *Z* standard magnitudes available in the literature. However, the band-passes *U* and *Z* are not required for a photometric determination of metallicity by using the quoted method. Moreover, no classification of stars is necessary, because the reddening in the direction of M 92 is already known and is negligible within the present accuracy.

In a previous paper, Smriglio et al. (2002) have shown that, with a 1.5-m class telescope, the rms error of the CCD photometry is generally less than 2% up to 16.5 *V*-magnitude. The rms error for the present photometry ranges between 2% and 3%, which is not very accurate. But, in spite of this mediocre accuracy, it has been possible to well determine the metallicity for this cluster fairly, due to the measurement of the [Fe/H] ratio for a large number of cluster members and to a statistical analysis of these data.

In fact, taking the 64 stars common to both fields into account, a catalogue of 344 stars on the whole has been obtained up to about 17.5 *V*-magnitude. Of these objects, a sample of about 120 stars brighter than $V \sim 14.8$ mag has been selected.

The final result obtained by the statistical method presented in this paper gives the value $\overline{[Fe/H]} = -2.11 \pm 0.14$ for the metallicity of the globular cluster M 92. In order to compare this result with those measured by other authors, a short random selection of M 92 metal abundances, published in different times, is reported here without any claim to completeness.

The main techniques followed for investigating the metal abundances of globular clusters are based on spectroscopic or photoelectric photometry observations and are applied both to integrated and individual cluster members. Spectroscopic observations in the blue region of the integrated spectra by

Table 6. Some [Fe/H] determinations of the globular cluster M 92 measured by different authors in different epochs.

Reference	[Fe/H] _{dex}	error _{dex}
Wallerstein & Helfer (1966)	-2.1	
Harris & Racine (1979)	-2.12	±0.2
Zinn (1980a)	-2.19	±0.1
Zinn & West (1984)	-2.24	±0.08
Harris (1996)	-2.28	
Gratton et al. (1997)	-2.16	±0.07
Smriglio et al. (this paper)	-2.11	±0.14

Morgan (1956, 1959), Kinman (1959) and van den Bergh (1969) have shown rather good efficiency in ranking the globular cluster by metal abundance. In the seventies a number of observers obtained similar results by observations of individual cluster stars (e.g., Osborn 1973; Butler 1975; Canterna 1975; Hesser et al. 1977; Cooley et al. 1978; Searly & Zinn 1978; Cohen 1978, 1979), but much less sensitivity in distinguishing small metallicity differences among very metal-poor globular clusters (i.e., [Fe/H] < -1.5) was pointed out by Zinn (1980a). Photoelectric photometry observations in the same spectral region were also successfully used by several authors (e.g., van den Bergh & Henry 1962; Gascoigne & Koelher 1963; McClure & van den Bergh 1968; Johnson & McNamara 1969; Faber 1973; Harris & Canterna 1977).

A number of metallicity determinations, measured or averaged from the results of different authors, and the respective accuracy (when available) are listed in Table 6. The Harris & Racine (1979) [Fe/H] value in Table 6 is based on the average of abundance estimates from individual cluster giants, published in the seventies (for related references see their paper). The typical internal errors in [Fe/H] estimated by these authors, are ±0.2 dex. The Zinn (1980a,b) [Fe/H] value in Table 6 is obtained by photoelectric photometry of the cluster's integrated colors. These measurements and the measurements by other investigators have yielded estimates of [Fe/H] with an average precision of ±0.1 dex for a total of 84 clusters.

Later on, Zinn & West (1984) derived the metallicity of M92 as a weighted mean of the following determinations: [Fe/H]_{IR} = -2.01 and [Fe/H]_{T_e} = -2.14, both from the effective temperature T_e of the giant branch (Frogel et al. 1983); [Fe/H]_{ΔS} = -2.34, from the ΔS parameter, which relies on strength of Ca II K line in the spectra of RR Lyrae variables; [Fe/H]_{BG} = -2.4, by Bell & Gustafsson (1983) from comparison of scans of red giants with synthetic spectra, [Fe/H]_{DDO} = -2.27, from Hesser et al. (1977) DDO photometry of red giants; and [Fe/H]_{Q₃₉} = -2.12, from the photometric integrated light index Q₃₉. The standard error of each measurement, as assumed by the authors, is ±0.2 dex, except for [Fe/H]_{Q₃₉} whose limiting accuracy has been estimated to be ±0.15 dex. The resulting weighted average gives the value [Fe/H] = (-2.24 ± 0.08 dex). This standard deviation was calculated by propagating the σs of the individual measurements; but, as pointed out by the authors themselves, this value represents the precision with which the clusters are ranked on Cohen's metallicity scale and not the accuracy, in absolute terms, of the value of [Fe/H]. Moreover, this value of metallicity depends on a particular procedure for determining the mean. In fact, the straight mean of the data gives a value of metallicity $\overline{[Fe/H]}$ = (-2.21 ± 0.15) dex, where the error indicates the standard deviation obtained from the scatter of the measurements themselves.

On the basis of high-resolution, high signal-to-noise spectra of bright red giants, a value of [Fe/H] = -2.16 has been measured for the M92 metallicity by Gratton et al. (1997). They show that the availability of a homogeneous set of high-quality abundances provides a standard error of ~0.07 dex and also pointed out that Carretta & Gratton abundances (1997) for metal-poor and metal-rich clusters agree quite well with Zinn & West values (1984). Moreover, a direct estimate of the accuracy in abundance measurements by using multicolor photometry in comparison with high dispersion analysis has been made by these authors and the errors, derived from the rms scatter of differences between Strömgren intermediate band *uvby* photometry and high dispersion metallicity, are on the order of 0.13 dex.

From the data reported in this sample, it seems reasonable to derive the following conclusions:

- the values of metallicity are spread out over a range of about 0.2 dex. This depends on the different techniques used for the measurements and on zero-point offsets of different scales. The latter is mainly due to different assumptions about the solar abundances in the high-dispersion analysis originally used in calibration. This is the typical value for zero-point offset, but, in some cases, a maximum zero-point difference of about ≤0.4 dex has been observed (Zinn & West 1984). This problem has now been solved by the ability of Kurucz model to reproduce most of the solar observations to the level of accuracy of the high dispersion spectral analysis (Gratton et al. 1997).
- Some nonlinearity may also be present on different scales. For example, the Zinn & West scale (1984) appears slightly nonlinear when calibrated against the best modern measurements of [Fe/H] (see Carretta & Gratton 1997; Rutledge et al. 1997), but this effect seems to be very small or absent for metal-poor clusters (which is the case of M92).
- The accuracy of the measurements on a particular metallicity scale achieved a value of ±0.08 dex (e.g. Zinn & West 1984) or, more recently, ±0.07 dex (e.g. Gratton et al. 1997). On the other hand, in some cases (e.g. Zinn & West 1984), when the [Fe/H] ratio is obtained from a number of metal abundances measured by different techniques and/or different authors, it has been shown that the error is on the order of ±0.15 dex. Moreover, a direct comparison between Strömgren multicolor photometry and high-dispersion spectroscopy measurements gives an rms error of 0.13 dex, and the accuracy with which the index Q₃₉ can predict [Fe/H] is limited to ±0.15 dex.

In conclusion, on the understanding that the high dispersion spectroscopy of individual giants provides the most accurate results, we can conclude that the statistical method presented in this paper, based on CCD observations in the VPS and using crowded field photometry package DAOPHOT from IRAF in the point-spread function mode (Tody 1986, 1993; Stetson 1987), can achieve a precision that is typical of intermediate band photometry (e.g. *uvby* of Strömgren's system). Moreover, the accuracy seems to be better than achieved by using the photometric integrated light index Q₃₉.

We can say that this simple method can be useful for determining the [Fe/H] ratio for globular clusters from PXYV Vilnius photometry alone. We also think that better accuracy can be achieved by more accurate CCD photometry (i.e. using a more efficient CCD chip in the UV, establishing standards with accuracy better than 1%, using appropriate instrumental procedure to reduce effects due to scattered light on flat-fielding, etc.) and by improving the statistics, i.e. increasing the number of

independent observations, as well as the number of cluster members involved in the statistical process.

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Fig. 1. The finding chart of the M92C field. The central pixel ($X_c = 1044$; $Y_c = 1022$) is at RA $17^{\text{h}}17^{\text{m}}00^{\text{s}}.7$, Dec $+43^{\circ}08'00''$ (1950.0). The X, Y pixel coordinates, with their respective origins in the East and South, correspond to those in Table 1A (see Appendix).

Fig. 2. The finding chart of the M92W field. North is up, east to the left. The central pixel ($X_c : 1042$; $Y_c : 1024$) is at RA $17^h 16^m 25^s.7$, Dec $+43^\circ 08' 46''$ (1950.0). The X, Y pixel coordinates, with respective origins in the East and South, correspond to those in Table 2A (see Appendix).

Appendix A:**Table A.1.** CCD photometry in M92C.

Nr	Xc	Yc	V	Y – V	P – V	X – V	V – S	B – V
1	1235	740	11.76	0.45	1.62	1.11	0.39	0.45
2	907	750	12.25	1.00	3.19	2.33	0.90	1.34
3	1056	995	12.33	0.90	2.43	1.89	0.55	1.07
4	1114	1028	12.34	0.99	3.10	2.28	0.87	1.31
5	957	1360	12.35	0.97	2.98	2.20	0.88	1.26
6	970	1007	12.40	1.04	3.78	2.42	0.92	1.40
7	1223	940	12.49	0.96	2.99	2.21	0.88	1.26
8	1000	1187	12.50	0.98	3.02	2.22	0.88	1.27
9	902	1211	12.51	0.94	3.01	2.20	0.88	1.24
10	895	1065	12.54	0.88	2.84	2.09	1.03	1.16
11	1261	1172	12.58	0.94	2.90	2.16	0.87	1.22
12	1149	929	12.60	0.89	2.77	2.05	0.83	1.14
13	987	919	12.70	0.91	3.01	2.18	0.94	1.22
14	784	655	12.88	0.87	2.67	1.98	0.78	1.10
15	1124	827	12.90	0.86	2.63	1.98	0.80	1.09
16	1090	766	12.92	0.66	2.57	1.83	0.68	0.92
17	868	830	12.97	0.86	2.63	1.96	0.80	1.08
18	1020	1178	13.10	0.88	2.60	1.96	0.76	1.09
19	1050	1265	13.11	0.83	2.53	1.87	0.79	1.02
20	735	1060	13.34	0.81	2.41	1.82	0.76	0.99
21	1005	1317	13.34	0.81	2.47	1.85	0.77	1.00
22	727	973	13.44	0.77	2.30	1.74	0.74	0.93
23	1154	1279	13.47	0.80	2.39	1.77	0.76	0.96
24	903	1161	13.49	0.75	2.25	1.70	0.74	0.90
25	1004	1266	13.65	0.82	2.32	1.80	0.70	0.98
26	925	967	13.70	0.79	2.31	1.75	0.76	0.94
27	713	653	13.79	0.74	2.22	1.66	0.71	0.87
28	1085	1004	13.82	0.56	2.41	1.36	0.89	0.63
29	796	1180	13.82	0.70	2.03	1.55	0.68	0.80
30	1097	811	13.83	0.74	2.33	1.73	0.76	0.91
31	967	888	13.84	0.79	2.29	1.76	0.73	0.95
32	1164	1434	13.86	0.72	2.13	1.59	0.70	0.83
33	1160	693	13.87	0.74	2.25	1.64	0.74	0.86
34	1336	852	13.88	0.71	2.09	1.52	0.68	0.79
35	1022	858	13.88	0.72	2.06	1.56	0.62	0.81
36	1039	1208	13.94	0.70	2.01	1.51	0.63	0.78
37	1248	572	13.98	0.73	2.25	1.59	0.69	0.83
38	1025	1188	13.98	0.71	2.26	1.68	0.80	0.87
39	1060	1139	13.99	0.69	2.06	1.55	0.67	0.79
40	704	986	13.99	0.74	2.19	1.66	0.72	0.87
41	1123	976	14.01	0.69	2.02	1.49	0.64	0.76
42	1276	936	14.03	0.80	1.92	1.43	0.59	0.79
43	1261	677	14.07	0.73	2.21	1.60	0.70	0.84
44	747	945	14.07	0.73	2.19	1.67	0.70	0.87
45	848	1300	14.09	0.70	2.06	1.56	0.69	0.80
46	1003	909	14.09	0.71	2.19	1.61	0.79	0.83
47	927	1065	14.10	0.59	1.87	1.49	0.68	0.71
48	1171	1177	14.10	0.74	2.22	1.67	0.71	0.88
49	1367	770	14.10	0.69	2.06	1.48	0.66	0.76
50	802	879	14.11	0.74	2.18	1.66	0.68	0.87
51	1030	859	14.14	0.69	2.04	1.51	0.71	0.77
52	966	1136	14.15	0.87	2.11	1.71	0.25	0.96
53	754	1287	14.16	0.74	2.17	1.61	0.63	0.85
54	1037	789	14.19	0.73	2.17	1.64	0.71	0.86
55	1350	864	14.19	0.73	2.13	1.62	0.70	0.85
56	1051	756	14.21	0.73	2.10	1.59	0.69	0.83
57	1405	1035	14.24	0.52	1.77	1.23	0.49	0.55
58	938	1098	14.30	0.75	2.22	1.59	0.68	0.84
59	1084	901	14.32	0.65	2.14	1.57	0.83	0.78
60	727	1352	14.34	0.70	2.14	1.62	0.69	0.83
61	935	789	14.36	0.63	1.94	1.40	0.66	0.69
62	993	1342	14.37	0.63	1.82	1.34	0.60	0.66
63	1173	1046	14.38	0.64	1.88	1.38	0.60	0.68
64	711	890	14.44	0.64	1.85	1.41	0.63	0.70

Table A.1. continued.

Nr	Xc	Yc	V	Y - V	P - V	X - V	V - S	B - V
65	1242	1291	14.46	0.67	1.90	1.39	0.65	0.70
66	847	811	14.47	0.67	2.55	1.82	0.67	0.92
67	1499	954	14.47	0.70	1.98	1.52	0.68	0.78
68	1180	847	14.47	0.63	1.76	1.34	0.57	0.66
69	1178	869	14.49	0.69	2.08	1.59	0.71	0.81
70	738	808	14.50	0.61	1.77	1.34	0.58	0.65
71	633	1427	14.52	0.47	1.64	0.97	0.15	0.39
72	1016	1194	14.53	0.59	1.70	1.22	0.62	0.58
73	726	814	14.54	0.65	1.84	1.41	0.64	0.70
74	719	1465	14.55	0.70	2.08	1.55	0.67	0.80
75	1240	938	14.58	0.71	2.08	1.55	0.68	0.80
76	1064	946	14.59	0.52	1.66	1.25	0.74	0.56
77	851	670	14.61	0.70	2.04	1.51	0.65	0.78
78	566	1487	14.62	0.69	2.01	1.52	0.62	0.78
79	1251	648	14.63	0.68	2.02	1.55	0.67	0.79
80	801	754	14.63	0.70	2.01	1.55	0.67	0.80
81	783	1177	14.66	0.69	1.96	1.55	0.67	0.79
82	1107	852	14.66	0.70	2.05	1.60	0.64	0.82
83	958	1093	14.67	0.63	1.68	1.16	0.25	0.57
84	951	1231	14.69	0.23	1.28	0.60	0.11	0.09
85	1137	853	14.70	0.58	1.71	1.22	0.53	0.57
86	1417	812	14.72	0.70	2.08	1.54	0.67	0.79
87	1247	806	14.72	0.71	2.06	1.56	0.64	0.81
88	902	1054	14.72	0.78	1.94	1.44	0.57	0.78
89	1511	588	14.73	0.68	2.02	1.47	0.64	0.75
90	953	1096	14.74	0.77	2.13	1.48	0.41	0.80
91	1181	913	14.74	0.70	2.05	1.56	0.72	0.80
92	1049	922	14.76	0.63	2.04	1.49	0.78	0.73
93	1083	869	14.77	0.69	2.13	1.69	0.66	0.86
94	581	1240	14.78	0.67	2.03	1.49	0.65	0.75
95	1163	1137	14.79	0.57	1.78	1.18	0.38	0.55
96	681	637	14.81	0.54	1.62	1.13	0.51	0.51
97	940	877	14.81	0.67	1.94	1.50	0.65	0.76
98	1188	1052	14.85	0.65	1.94	1.56	0.77	0.78
99	724	1039	14.86	0.67	2.01	1.50	0.66	0.76
100	705	1104	14.87	0.67	1.95	1.48	0.68	0.75
101	574	888	14.88	0.68	1.92	1.49	0.60	0.76
102	916	937	14.95	0.68	1.99	1.55	0.68	0.79
103	776	954	14.97	0.25	1.04	0.50	0.03	0.05
104	1170	967	14.97	0.70	2.07	1.58	0.71	0.81
105	864	1101	14.98	0.47	1.71	1.01	0.32	0.41
106	814	1368	15.04	0.24	1.38	0.65	0.15	0.12
107	1093	1039	15.05	0.53	1.68	1.40	0.94	0.64
108	555	804	15.10	0.31	1.42	0.72	0.21	0.19
109	994	812	15.10	0.29	1.40	0.71	0.14	0.17
110	1154	1059	15.13	0.40	1.56	0.79	0.05	0.27
111	1409	1184	15.16	0.31	1.28	0.60	0.10	0.13
112	1402	828	15.17	0.67	2.00	1.46	0.65	0.74
113	922	721	15.17	0.66	1.81	1.43	0.62	0.72
114	1165	1290	15.18	0.33	1.40	0.77	0.28	0.22
115	1006	610	15.18	0.28	1.40	0.69	0.23	0.16
116	1354	1126	15.19	0.32	1.46	0.76	0.28	0.21
117	940	1252	15.20	0.67	2.01	1.51	0.66	0.76
118	905	807	15.21	0.66	1.96	1.39	0.62	0.70
119	902	972	15.21	0.32	1.38	0.75	0.13	0.21
120	1180	1100	15.21	0.74	1.99	1.59	0.55	0.84
121	1154	1000	15.21	0.44	1.38	0.76	0.10	0.27
122	952	1150	15.22	0.68	1.94	1.53	0.64	0.78
123	729	923	15.22	0.31	1.32	0.77	0.26	0.21
124	1035	1501	15.23	0.26	1.30	0.64	0.25	0.12
125	864	932	15.23	0.59	1.74	1.19	0.44	0.56
126	968	923	15.23	0.71	1.94	1.45	0.69	0.75
127	1410	1263	15.24	0.68	1.83	1.43	0.67	0.73
128	1046	1309	15.25	0.66	1.91	1.44	0.67	0.72
129	600	1106	15.25	0.25	1.32	0.65	0.14	0.12
130	911	932	15.25	0.67	1.95	1.50	0.63	0.76
131	732	1160	15.26	0.24	1.38	0.67	0.24	0.13

Table A.1. continued.

Nr	Xc	Yc	V	Y - V	P - V	X - V	V - S	B - V
132	579	1011	15.28	0.27	1.33	0.64	0.14	0.13
133	883	907	15.28	0.16	1.13	0.56	0.29	0.03
134	1334	739	15.28	0.29	1.31	0.59	0.10	0.11
135	1111	1048	15.29	0.47	1.74	0.94	0.26	0.38
136	562	824	15.29	0.23	1.32	0.60	0.16	0.09
137	959	849	15.30	0.20	1.12	0.59	0.47	0.07
138	1452	667	15.30	0.65	1.90	1.38	0.64	0.69
139	1165	903	15.32	0.25	1.37	0.61	0.16	0.10
140	770	1050	15.33	0.66	1.93	1.51	0.66	0.76
141	1124	1368	15.33	0.30	1.37	0.67	0.14	0.16
142	1081	756	15.33	0.25	1.32	0.62	0.13	0.11
143	930	1039	15.34	0.57	1.90	1.45	0.87	0.68
144	940	770	15.34	0.21	1.52	0.59	0.25	0.07
145	781	1112	15.35	0.50	1.52	1.07	0.57	0.46
146	1171	944	15.36	0.67	1.96	1.47	0.65	0.74
147	1439	596	15.37	0.29	1.41	0.55	0.13	0.09
148	1031	917	15.38	0.25	1.45	0.67	0.18	0.13
149	1076	762	15.39	0.30	1.42	0.68	0.12	0.16
150	826	1018	15.39	0.65	1.80	1.44	0.68	0.72
151	925	1505	15.40	0.47	1.54	1.02	0.45	0.42
152	1214	1100	15.40	0.31	1.35	0.62	0.00	0.14
153	991	877	15.40	0.26	1.45	0.70	0.27	0.15
154	1482	965	15.42	0.30	1.40	0.63	0.14	0.14
155	561	1098	15.42	0.66	1.95	1.40	0.65	0.70
156	1227	917	15.43	0.27	1.49	0.69	0.18	0.15
157	1027	800	15.43	0.28	1.28	0.64	0.13	0.13
158	1013	628	15.44	0.29	1.35	0.61	0.13	0.12
159	912	1367	15.46	0.62	1.80	1.48	0.66	0.72
160	1129	946	15.48	0.69	2.01	1.43	0.60	0.73
161	1071	817	15.48	0.18	1.35	0.57	0.24	0.05
162	1266	1012	15.48	0.19	1.36	0.53	0.13	0.03
163	971	646	15.51	0.31	1.33	0.64	0.09	0.15
164	854	1402	15.51	0.65	1.76	1.33	0.59	0.66
165	865	1073	15.52	0.20	1.17	0.50	0.14	0.02
166	885	837	15.52	0.66	1.77	1.40	0.58	0.70
167	831	1027	15.54	0.52	1.71	1.34	0.50	0.60
168	1008	1395	15.56	0.65	1.94	1.43	0.66	0.71
169	1043	855	15.59	0.24	1.40	0.49	0.33	0.04
170	895	584	15.61	0.61	1.78	1.41	0.65	0.68
171	847	732	15.63	0.67	1.88	1.43	0.66	0.72
172	1070	1211	15.63	0.62	1.93	1.49	0.67	0.73
173	919	762	15.64	0.17	1.19	0.51	0.19	0.01
174	1146	804	15.64	0.69	1.90	1.38	0.56	0.71
175	1094	836	15.65	0.27	1.51	0.59	0.19	0.10
176	1326	1044	15.65	0.61	1.86	1.35	0.74	0.65
177	758	1200	15.66	0.64	2.04	1.53	0.69	0.76
178	932	823	15.66	0.22	1.25	0.56	0.11	0.06
179	868	802	15.68	0.67	1.89	1.39	0.65	0.70
180	650	920	15.70	0.34	1.27	0.67	0.09	0.18
181	938	1147	15.70	0.65	1.90	1.23	0.65	0.61
182	1201	978	15.71	0.24	1.24	0.50	0.13	0.04
183	1313	1199	15.71	0.66	1.80	1.32	0.69	0.66
184	842	1028	15.72	0.74	1.82	1.44	0.52	0.76
185	955	794	15.73	0.35	1.45	0.64	0.05	0.17
186	789	1421	15.75	0.63	1.72	1.34	0.67	0.66
187	628	1208	15.77	0.63	1.71	1.33	0.64	0.65
188	791	668	15.77	0.61	2.24	1.51	0.55	0.73
189	878	1355	15.78	0.39	1.15	0.65	0.07	0.19
190	1184	929	15.78	0.30	1.41	0.63	0.08	0.14
191	1195	930	15.80	0.24	1.14	0.58	0.18	0.08
192	817	610	15.81	0.61	1.70	1.32	0.57	0.64
193	807	994	15.83	0.58	1.84	1.32	0.71	0.62
194	1484	839	15.84	0.35	1.23	0.56	0.08	0.13
195	972	692	15.85	0.32	1.19	0.61	0.11	0.14
196	793	1134	15.86	0.22	1.13	0.50	0.17	0.03
197	887	926	15.87	0.59	1.94	1.47	0.75	0.70
198	920	1196	15.87	0.30	1.26	0.62	0.12	0.13

Table A.1. continued.

Nr	Xc	Yc	V	Y - V	P - V	X - V	V - S	B - V
199	925	1228	15.90	0.67	1.93	1.48	0.63	0.75
200	738	722	15.90	0.40	1.29	0.67	0.08	0.21
201	1137	712	15.94	0.30	0.96	0.51	0.11	0.08
202	573	626	15.97	0.45	1.16	0.69	0.06	0.24
203	1120	947	15.97	0.64	1.68	1.43	0.72	0.71
204	1348	934	15.98	0.64	1.86	1.32	0.67	0.65
205	582	949	16.01	0.28	1.01	0.57	0.15	0.10
206	1328	1025	16.02	0.24	0.98	0.54	0.13	0.06
207	835	798	16.02	0.66	1.73	1.29	0.60	0.65
208	1170	1144	16.03	0.22	1.10	0.51	0.17	0.04
209	895	1390	16.04	0.62	1.88	1.37	0.67	0.67
210	1121	867	16.08	0.61	2.10	1.43	0.82	0.69
211	774	855	16.09	0.20	0.96	0.52	0.11	0.03
212	1291	994	16.14	0.20	0.87	0.44	0.26	0.00
213	1228	1011	16.16	0.48	1.48	1.04	0.69	0.43
214	1307	726	16.16	0.28	1.11	0.55	0.18	0.09
215	1306	847	16.17	0.67	1.93	1.39	0.65	0.70
216	1188	872	16.17	0.58	1.71	1.38	0.83	0.65
217	859	1067	16.20	0.19	0.76	0.46	0.17	0.00
218	1428	590	16.22	0.32	1.07	0.52	0.16	0.09
219	828	1483	16.23	0.40	1.07	0.64	0.17	0.19
220	1130	1013	16.26	0.62	1.89	1.35	0.85	0.66
221	898	886	16.33	0.32	0.99	0.63	0.14	0.15
222	1197	991	16.39	0.28	0.96	0.50	0.18	0.06
223	787	1097	16.42	0.33	0.93	0.57	0.06	0.12
224	739	899	16.43	0.37	0.93	0.62	0.03	0.17
225	749	701	16.44	0.30	0.89	0.47	0.11	0.06
226	857	1033	16.48	0.25	1.11	0.52	0.35	0.06
227	858	853	16.53	0.33	0.95	0.54	0.19	0.11
228	1258	806	16.58	0.30	0.85	0.59	0.10	0.12
229	1141	1142	16.72	0.16	0.78	0.38	0.41	-0.10
230	1052	1242	16.83	0.45	1.00	0.67	0.15	0.23

Table A.2. CCD photometry in M92W.

Nr	Xw	Yw	V	Y - V	P - V	X - V	V - S	B - V
1	653	632	11.72	0.46	1.64	1.08	0.37	0.44
2	1049	703	12.13	1.03	3.44	2.36	0.93	1.37
3	641	832	12.41	0.95	3.02	2.14	0.86	1.22
4	679	1064	12.48	0.92	2.98	2.13	0.81	1.20
5	567	821	12.56	0.83	2.79	1.99	0.87	1.08
6	797	1201	12.76	0.88	2.72	1.94	0.75	1.08
7	541	720	12.81	0.93	2.70	1.94	0.74	1.11
8	1261	1199	13.09	0.69	2.48	1.70	0.62	0.87
9	572	1172	13.39	0.82	2.41	1.73	0.71	0.95
10	1223	1093	13.49	0.65	2.06	1.47	0.58	0.73
11	1115	854	13.65	0.75	2.24	1.62	0.70	0.86
12	1045	976	13.71	0.75	2.18	1.61	0.71	0.85
13	578	585	13.74	0.81	2.30	1.61	0.00	0.88
14	754	745	13.80	0.70	2.13	1.53	0.66	0.79
15	582	1327	13.80	0.65	2.15	1.52	0.70	0.76
16	541	1073	13.91	0.77	2.26	1.61	0.71	0.86
17	785	662	14.00	0.69	2.07	1.49	0.62	0.76
18	678	569	14.00	0.70	2.22	1.56	0.72	0.80
19	590	1070	14.01	0.77	2.27	1.62	0.63	0.87
20	694	828	14.06	0.68	2.15	1.48	0.64	0.75
21	768	756	14.11	0.73	2.19	1.60	0.66	0.84
22	659	929	14.12	0.73	2.22	1.61	0.69	0.84
23	755	906	14.18	0.73	2.21	1.60	0.67	0.84
24	824	927	14.19	0.53	1.80	1.25	0.46	0.56
25	1035	1375	14.27	0.69	2.21	1.51	0.50	0.77
26	591	939	14.32	0.58	1.91	1.27	0.62	0.60
27	596	761	14.37	0.66	2.07	1.52	0.70	0.76
28	660	1184	14.38	0.63	1.94	1.36	0.63	0.67

Table A.2. continued.

Nr	Xw	Yw	V	Y - V	P - V	X - V	V - S	B - V
29	591	922	14.38	0.69	2.15	1.51	0.65	0.77
30	598	740	14.41	0.62	1.88	1.27	0.55	0.62
31	917	847	14.45	0.70	2.08	1.53	0.66	0.79
32	1386	816	14.46	0.69	2.68	1.80	0.67	0.92
33	668	540	14.48	0.71	2.13	1.49	0.60	0.77
34	1116	599	14.51	0.67	2.36	1.62	0.53	0.82
35	581	926	14.52	0.68	2.10	1.47	0.63	0.75
36	658	831	14.55	0.64	2.02	1.46	0.69	0.72
37	697	1174	14.57	0.68	2.06	1.47	0.66	0.75
38	554	745	14.60	0.55	1.72	1.15	0.47	0.52
39	599	806	14.60	0.70	2.08	1.50	0.63	0.77
40	606	945	14.65	0.67	2.05	1.50	0.64	0.76
41	835	705	14.66	0.69	2.07	1.49	0.65	0.76
42	929	480	14.68	0.63	2.00	1.42	0.71	0.70
43	665	698	14.68	0.65	2.06	1.45	0.64	0.72
44	588	859	14.78	0.69	2.06	1.49	0.63	0.76
45	591	1013	14.89	0.66	2.06	1.49	0.66	0.75
46	1290	571	14.94	0.57	1.95	1.33	0.60	0.62
47	558	925	14.97	0.28	1.47	0.67	0.20	0.15
48	1072	780	15.06	0.66	2.00	1.44	0.62	0.72
49	569	764	15.07	0.65	1.96	1.44	0.60	0.72
50	820	720	15.08	0.65	2.01	1.44	0.61	0.72
51	583	1183	15.10	0.33	1.48	0.69	0.22	0.18
52	827	1077	15.13	0.19	1.24	0.48	0.08	0.00
53	773	1018	15.15	0.34	1.49	0.71	0.23	0.20
54	751	631	15.16	0.20	1.29	0.50	0.04	0.02
55	581	1030	15.17	0.54	1.59	1.08	0.46	0.48
56	588	709	15.18	0.20	1.41	0.55	0.13	0.05
57	583	795	15.19	0.26	1.46	0.60	0.08	0.10
58	829	1155	15.20	0.67	2.01	1.43	0.62	0.72
59	869	560	15.21	0.65	1.97	1.40	0.63	0.70
60	1332	923	15.23	0.26	1.47	0.64	0.17	0.12
61	598	992	15.25	0.67	2.00	1.46	0.61	0.74
62	589	836	15.25	0.66	1.98	1.38	0.60	0.69
63	769	1128	15.25	0.24	1.44	0.61	0.14	0.10
64	780	1051	15.26	0.24	1.43	0.62	0.13	0.10
65	645	809	15.26	0.24	1.44	0.61	0.06	0.10
66	542	1261	15.26	0.21	1.35	0.49	0.11	0.02
67	542	1022	15.28	0.23	1.39	0.56	0.10	0.07
68	1047	1241	15.29	0.23	1.38	0.57	0.14	0.07
69	572	892	15.30	0.16	1.20	0.44	0.07	0.00
70	613	1089	15.30	0.19	1.24	0.48	0.06	0.00
71	545	1002	15.32	0.65	1.96	1.40	0.60	0.70
72	856	489	15.32	0.14	1.29	0.45	0.11	0.00
73	555	759	15.33	0.67	2.01	1.43	0.62	0.72
74	685	904	15.34	0.19	1.32	0.51	0.06	0.02
75	554	979	15.35	0.20	1.38	0.55	0.12	0.05
76	921	1019	15.37	0.64	1.98	1.43	0.64	0.71
77	1125	1251	15.38	0.60	2.12	1.46	0.54	0.70
78	632	993	15.39	0.20	1.30	0.51	0.11	0.03
79	901	857	15.39	0.21	1.35	0.54	0.09	0.05
80	553	1092	15.42	0.63	1.91	1.34	0.58	0.66
81	686	1056	15.43	0.64	1.89	1.36	0.66	0.67
82	542	701	15.49	0.76	2.42	1.70	0.86	0.90
83	558	885	15.49	0.20	1.26	0.50	0.10	0.02
84	745	936	15.51	0.66	1.94	1.42	0.61	0.71
85	776	1280	15.55	0.17	1.09	0.40	0.05	0.00
86	602	821	15.55	0.19	1.27	0.48	0.00	0.00
87	541	1008	15.61	0.62	1.95	1.33	0.59	0.65
88	707	1052	15.62	0.66	1.92	1.40	0.59	0.70
89	553	938	15.63	0.62	1.97	1.34	0.64	0.65
90	613	823	15.63	0.20	1.15	0.49	0.10	0.02
91	564	696	15.65	0.62	1.91	1.31	0.58	0.64
92	554	1016	15.65	0.18	1.13	0.44	0.07	0.00
93	582	916	15.66	0.56	1.81	1.35	0.59	0.63
94	539	760	15.70	0.68	1.89	1.36	0.55	0.69
95	575	830	15.70	0.60	1.94	1.34	0.62	0.64

Table A.2. continued.

Nr	Xw	Yw	V	Y - V	P - V	X - V	V - S	B - V
96	632	753	15.73	0.64	1.85	1.39	0.63	0.69
97	579	863	15.73	0.69	1.92	1.33	0.56	0.68
98	548	906	15.74	0.66	1.91	1.30	0.57	0.65
99	1205	680	15.81	0.63	1.87	1.42	0.62	0.70
100	582	1068	15.81	0.66	1.90	1.34	0.58	0.67
101	606	765	15.82	0.61	1.81	1.35	0.56	0.65
102	1363	605	15.82	0.59	1.92	1.36	0.53	0.65
103	902	731	15.82	0.16	1.10	0.42	0.07	0.00
104	550	1316	15.87	0.60	1.83	1.38	0.58	0.66
105	555	604	15.87	0.12	0.84	0.34	0.09	-0.10
106	774	1160	15.87	0.66	1.92	1.39	0.60	0.70
107	790	914	15.88	0.62	1.80	1.42	0.59	0.69
108	965	1217	15.88	0.14	1.01	0.42	0.08	0.00
109	540	860	15.90	0.22	1.04	0.49	-0.01	0.03
110	766	826	15.92	0.63	1.87	1.40	0.58	0.69
111	646	904	15.92	0.51	1.65	1.14	0.43	0.50
112	588	1036	15.94	0.18	1.03	0.45	0.04	0.00
113	541	929	15.95	0.73	1.92	1.47	0.60	0.77
114	562	956	15.95	0.64	1.86	1.37	0.57	0.68
115	709	886	15.96	0.17	0.92	0.42	0.07	0.00
116	599	1001	16.01	0.20	0.98	0.33	0.09	0.00
117	724	740	16.04	0.63	1.77	1.37	0.57	0.67
118	613	1247	16.05	0.65	1.87	1.37	0.58	0.68
119	594	898	16.05	0.62	1.95	1.36	0.55	0.66
120	967	1039	16.09	0.61	1.84	1.36	0.59	0.66
121	725	619	16.10	0.18	1.06	0.39	0.02	0.00
122	702	1031	16.11	0.16	0.93	0.43	0.10	0.00
123	586	783	16.11	0.57	1.88	1.21	0.61	0.56
124	981	801	16.13	0.67	1.83	1.36	0.58	0.69
125	703	743	16.13	0.63	1.83	1.29	0.58	0.63
126	746	917	16.14	0.13	0.89	0.37	0.12	0.00
127	846	482	16.15	0.11	0.89	0.32	0.06	-0.10
128	557	1004	16.17	0.20	0.90	0.44	0.06	0.00
129	826	767	16.17	0.59	1.91	1.37	0.58	0.65
130	563	1058	16.20	0.60	1.94	1.31	0.59	0.63
131	574	902	16.21	0.60	1.81	1.16	0.55	0.55
132	631	889	16.22	0.62	1.89	1.41	0.60	0.69
133	1317	1318	16.22	0.66	1.81	1.29	0.58	0.65
134	618	834	16.22	0.18	0.96	0.42	0.11	0.00
135	559	859	16.23	0.50	1.73	1.24	0.57	0.54
136	1088	1365	16.23	0.61	1.91	1.35	0.59	0.65
137	1321	807	16.30	0.63	1.93	1.40	0.54	0.69
138	661	713	16.31	0.62	1.85	1.24	0.54	0.60
139	626	853	16.33	0.59	1.80	1.39	0.57	0.66
140	792	1011	16.34	0.14	0.91	0.42	0.08	0.00
141	667	909	16.34	0.64	1.85	1.36	0.56	0.67
142	560	1034	16.34	0.17	0.93	0.39	0.05	0.00
143	675	817	16.35	0.74	2.56	1.71	0.72	0.90
144	1133	1162	16.36	0.62	1.83	1.30	0.66	0.63
145	600	699	16.39	0.60	1.84	1.28	0.57	0.61
146	739	968	16.40	0.59	1.75	1.35	0.57	0.64
147	675	891	16.43	0.59	1.78	1.30	0.53	0.62
148	675	699	16.46	0.14	0.78	0.35	0.06	0.00
149	683	1145	16.48	0.17	0.83	0.32	-0.01	0.00
150	573	1031	16.49	0.55	2.02	1.41	0.59	0.65
151	603	1053	16.54	0.20	0.85	0.40	-0.02	0.00
152	563	1353	16.54	0.62	1.68	1.22	0.58	0.59
153	567	678	16.54	0.65	2.02	1.40	0.53	0.70
154	588	961	16.55	0.62	1.79	1.49	0.57	0.73
155	580	1119	16.56	0.17	0.77	0.35	0.02	0.00
156	1282	549	16.57	0.54	1.94	1.18	0.48	0.53
157	605	1101	16.60	0.59	1.91	1.27	0.54	0.60
158	614	1131	16.61	0.63	1.88	1.36	0.59	0.67
159	608	967	16.62	0.18	0.80	0.36	0.13	0.00
160	707	530	16.62	0.58	1.84	1.30	0.53	0.61
161	930	551	16.64	0.54	1.82	1.16	0.53	0.52
162	1249	999	16.66	0.61	1.97	1.28	0.61	0.62

Table A.2. continued.

Nr	Xw	Yw	V	Y - V	P - V	X - V	V - S	B - V
163	849	1096	16.68	0.62	1.86	1.43	0.63	0.70
164	751	703	16.69	0.57	1.77	1.28	0.59	0.60
165	561	804	16.70	0.54	1.61	1.13	0.48	0.51
166	602	960	16.72	0.60	2.00	1.23	0.60	0.59
167	549	990	16.75	0.28	1.56	0.72	0.00	0.17
168	544	888	16.79	0.86	1.80	1.26	0.43	0.73
169	708	1181	16.79	0.65	1.95	1.27	0.50	0.63
170	763	862	16.80	0.57	1.68	1.30	0.54	0.61
171	629	976	16.82	0.67	1.90	1.30	0.59	0.66
172	737	914	16.83	0.67	1.76	1.34	0.57	0.68
173	546	1040	16.93	0.63	2.03	1.34	0.52	0.66
174	690	786	16.95	0.69	1.58	1.37	0.50	0.70
175	637	856	16.96	0.62	1.81	1.34	0.55	0.65
176	702	912	17.01	0.52	1.77	1.25	0.48	0.56
177	626	608	17.12	0.58	1.62	1.32	0.46	0.62
178	559	911	17.47	0.60	1.45	0.93	0.23	0.44

Table A.3. The identification numbers Nc and Nw for the 64 stars common to both the observed regions M92C and M92W. The corresponding numbers are taken from Tables A.1 and A.2.

Nc	Nw	Nc	Nw	Nc	Nw	Nc	Nw
1	1	35	14	66	30	89	42
7	3	42	20	67	31	90	39
11	4	44	18	69	27	95	55
12	5	48	19	75	36	97	40
15	7	54	21	80	33	103	44
23	9	57	24	85	38	111	52
32	15	63	26	87	43	113	50
33	13	65	28	88	41	114	51
116	53	146	62	190	86	213	111
118	61	147	72	191	90	214	121
120	69	152	78	194	103	215	101
127	58	154	79	201	105	216	117
134	54	157	65	204	110	218	127
137	59	163	74	206	126	220	98
139	57	173	84	208	112	228	148
142	66	175	91	212	115	229	142

Table A.4. In Cols. 1 and 2 the identification numbers of M92C stars Nc and the corresponding Sandage & Walker numbers (1966) Ns. In Cols. 3 and 4 the Vc and Vs magnitudes and in Cols. 5 and 6 the $(B - V)$ color indices. The color-index $(B - V)$ in Col. 5 is determined by transformations of linear combinations of Vilnius color-indices (see text).

Nc	Ns	Vc	Vs	$(B - V)_c$	$(B - V)_s$
57	VI-74	14.24	14.25	0.55	0.56
60	II-39	14.34	14.35	0.83	0.70
74	II-24	14.55	14.54	0.80	0.78
96	XI-13	14.81	14.81	0.51	0.51
106	II-66	15.04	15.02	0.12	0.09
108	XII-9	15.10	15.12	0.17	0.15
111	VI-55	15.16	15.25	0.13	-0.04
115	X-22	15.18	15.13	0.16	0.20
116	VI-67	15.19	15.14	0.21	0.23
124	IV-27	15.23	15.20	0.12	0.18
132	XII-26	15.28	15.27	0.13	0.10
136	XII-10	15.29	15.22	0.09	0.15
147	VIII-19	15.37	15.36	0.09	0.11
154	VII-36	15.42	15.38	0.14	0.09
158	X-23	15.44	15.40	0.12	0.05
194	VII-46	15.84	15.81	0.13	-0.03
200	XI-23	15.90	15.82	0.21	-0.03
202	XI-11	15.97	15.90	0.24	0.02
205	XII-24	16.01	15.94	0.10	-0.07
218	VIII-18	16.22	16.11	0.09	0.01
219	III-27	16.23	16.15	0.19	-0.12

Table A.5. In Cols. 1 and 2 the identification numbers of M92W stars Nw and the corresponding Sandage & Walker numbers (1966) Ns. In Cols. 3 and 4 the V_w and V_s magnitudes and in Cols. 5 and 6 the $B - V$ color indices. The color-index ($B - V$) in Col. 5 is determined by transformations of linear combinations of Vilnius color-indices (see text).

Nw	Ns	V_w	V_s	$(B - V)_w$	$(B - V)_s$
2	VII-18	12.13	12.12	1.37	1.31
8	VI-6	13.09	13.16	0.87	0.84
10	VI-7	13.49	13.54	0.73	0.70
12	VI-18	13.71	13.73	0.85	0.82
24	VI-74	14.19	14.25	0.56	0.56
32	VII-1	14.46	14.58	0.92	0.89
34	VII-12	14.51	14.67	0.82	0.72
52	VI-55	15.13	15.17	0.00	-0.03
53	VI-67	15.15	15.14	0.20	0.23
60	VI-10	15.23	15.24	0.12	0.13
63	V-55	15.25	15.30	0.10	0.16
64	VI-61	15.26	15.31	0.10	0.14
68	VI-3	15.29	15.32	0.07	0.08
72	VIII-19	15.32	15.36	0.00	0.11
77	VI-2	15.38	15.45	0.70	0.68
79	VII-36	15.39	15.38	0.05	0.09
85	V-36	15.55	15.58	0.00	-0.02
103	VII-46	15.82	15.81	0.00	-0.03
108	V-23	15.88	15.87	0.00	0.02
127	VIII-18	16.15	16.11	-0.08	0.01

Table A.6. The V magnitudes and the $(B - V)$ color-indices of 17 stars observed by Sandage & Walker (1966) and re-observed by Sandage (1969).

N	V_{66}	V_{69}	$(B - V)_{66}$	$(B - V)_{69}$	remarks
I-10	15.48	15.47	0.02	0.01	
II-40	15.82	15.86	-0.08	-0.08	
III-27	16.15	16.14	-0.12	-0.10	
IV-17	15.51	15.50	0.03	0.02	
IV-27	15.20	15.19	0.18	0.17	
V-23	15.79	15.89	0.02	-0.03	
V-36	15.58	15.60	-0.02	-0.05	
V-55	15.30	15.30	0.16	0.16	
VI-3	15.33	15.32	0.09	0.08	
VI-10	15.24	15.24	0.13	0.13	
VI-55	15.25	15.18	-0.04	-0.02	
VI-61	15.31	15.31	0.14	0.14	
XI-1	16.04	16.12	-0.04	-0.09	
XI-11	15.90	16.02	0.02	-0.13	reject
XII-1	15.11	15.11	0.16	0.19	
XII-6	15.84	15.92	-0.01	-0.10	reject
XII-24	15.94	15.93	-0.07	-0.06	

Table A.7. In Col. 1 are the id. numbers of the sample of stars selected in the M92C field. In Cols. 2–4 the measured values of [Fe/H] are shown.

Nr.	$\delta(X - Y)$	$\delta(P - Y)$	$\delta(P - X)$
2	-2.36	-2.30	-2.73
3		-1.97	
4	-2.45	-2.35	-2.90
5	-2.53	-2.60	-3.00
6	-2.51		
7	-2.36	-2.49	-2.94
8	-2.57	-2.56	-2.95
9	-2.14	-2.27	-2.65
10	-1.82	-3.07	-2.63
11	-2.32	-2.55	-3.05
12	-2.15	-2.33	-2.88
13	-1.82	-2.33	-2.36
14	-2.21	-2.21	-2.93
15	-2.07	-2.36	-3.12
17	-2.17	-2.36	-2.99
18	-2.45	-2.41	-3.30
19	-2.18	-2.36	-5.41
20	-2.14	-2.42	
21	-1.97	-2.27	
22	-1.92	-2.33	
23	-2.25	-2.40	
24	-1.79	-2.32	-2.97
25	-2.40	-2.50	
26	-1.98	-2.48	
27	-1.86	-2.15	-2.80
28	-1.84	-2.32	-3.09
30	-1.41	-2.05	-2.48
31	-2.15	-2.50	
32	-1.96	-2.24	-2.77
34	-2.17	-2.07	-3.10
35	-2.26	-2.18	-2.41
36	-2.13	-2.14	-2.91
37	-1.13	-2.26	-2.32
38	-2.15	-1.83	-1.90
39	-1.64	-2.05	-2.75
40	-1.86	-2.32	-3.04
41	-2.10	-2.06	-2.57
43	-1.61	-2.11	-3.03
44	-2.08	-2.03	-2.30
45	-1.77	-2.26	-2.91
46	-1.62	-2.46	-2.32
47		-1.95	
48	-1.80	-2.15	-2.88
49	-2.18	-2.00	-2.12
50	-1.86	-2.12	-3.12
51	-1.95	-2.35	-2.57
53	-2.20	-1.88	-2.80
54	-1.94	-2.33	-3.11
55	-1.81	-2.24	-2.95
56	-2.15	-2.39	-3.11
58	-2.50	-2.07	-2.35
59		-2.30	-1.77
60	-1.33	-1.95	-2.73
67	-2.06	-2.52	-3.27
69	-1.34	-2.19	-2.94
74	-1.84	-2.07	-2.64
75	-2.04	-2.22	-2.75
77	-2.13	-2.12	-2.64
78	-1.87	-1.99	-2.94
79	-1.84	-2.35	-3.27
80	-1.43	-2.12	-3.06
81	-1.64	-2.46	
82	-1.48	-2.03	-3.36
86		-2.87	
87	-1.97	-2.08	-3.0
88	-1.91	-2.07	-2.56
89	-2.06	-1.96	-2.30

Table A.7. continued.

Nr.	$\delta(X - Y)$	$\delta(P - Y)$	$\delta(P - X)$
90	-1.77	-2.47	-3.00
91		-1.13	
92		-2.18	-1.77
93		-1.73	-3.40
94	-1.69	-1.88	-2.30
96	-1.61	-2.25	-3.30
98		-2.71	-3.86
99	-1.61	-2.02	-2.59
100	-1.77	-2.36	-2.99
101	-1.90	-2.18	
102	-1.43	-2.29	-3.35
103	-1.62	-2.33	-3.00

Table A.8. In Col. 1 are the id. numbers of the sample of stars selected in the M92W field. In Cols. 2–4 the measured values of [Fe/H] are shown.

Nr.	$\delta(X - Y)$	$\delta(P - Y)$	$\delta(P - X)$
2	-2.64	-1.96	-1.62
3	-2.53	-2.22	-2.31
4	-2.19	-1.85	-2.30
5	-1.56	-1.98	-4.38
6	-2.54	-1.97	-2.45
7	-3.20	-2.41	-2.88
9	-2.79	-2.23	
10	-1.40	-1.17	-1.56
11	-2.31	-2.11	-2.42
12	-2.37	-2.40	-2.81
13	-3.32	-2.24	
14	-1.99	-1.82	-2.04
15		-1.51	-1.16
16	-2.72	-2.30	
17	-2.10	-1.75	-2.12
18	-1.77	-1.83	-1.53
19	-2.66	-1.78	
20	-1.98	-1.45	-1.21
21	-2.08	-1.87	-2.46
22	-2.01	-1.94	-2.30
23	-2.08	-1.85	-2.30
25	-1.95		-1.08
27	-1.22	-1.90	-2.09
29	-1.95	-1.60	-1.59
31	-1.99	-2.02	-2.47
33	-2.48	-1.59	-1.83
35	-2.06	-1.59	-1.56
36	-1.25	-1.86	-1.77
37	-2.06	-1.91	-1.93
39	-2.21	-1.86	-2.21
40	-1.61	-1.75	-2.20
41	-2.10	-1.91	-2.12
43	-1.57	-1.52	-1.36
44	-2.10	-1.84	-2.21
45	-1.47	-1.72	-1.89