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Synthesis of the integrated spectrum of metal-rich globular clusters using the HR diagram and a stellar library*

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Abstract. An average integrated spectrum of the nearly–solar metallicity globular clusters NGC 6528, NGC 6553 and NGC 6440 is synthesized in the range $3500 < \lambda < 9750$Å with a library of stellar spectra and constraints provided by the observed colour–magnitude diagram (CMD) of NGC 6553. In order to account for the CMD parts below the observational cut-off, we employ a power law mass function with slopes x =-0.5, 1.35 and 2.5. We conclude that the MS contribution amounts to ≈15% of the integrated light at 5870Å and this minor contribution makes the integrated spectrum basically insensitive to these x values. The dominant components are the Red Giant Branch and the Horizontal Branch with respectively ≈60% and ≈20% of the flux at λ5870Å. The residuals of the observed integrated spectrum with respect to the model suggest that [Fe/H] is slightly subsolar in these globular clusters, whereas [CNO/Fe] is slightly above the solar ratio.

Key words: Galaxy: globular clusters – stars: abundances – stars: HR diagram

1. Introduction

Globular cluster properties have been intensively studied with techniques which measure their individual stars such as spectroscopy and colour–magnitude diagrams, and with integrated photometry and spectroscopy. They have provided fundamental information on the stellar evolution theory and on the chemical enrichment of the Galaxy (for reviews see e.g. Renzini & Fusi Pecci 1988; Kraft 1985). On the other hand the combination of integrated and individual star techniques for the synthesis of globular cluster integrated spectra using a library of stellar spectra has not been as much explored. Santos et al. (1990, hereafter SBD90) have applied this synthesis approach to the study of the rich open cluster M 11. The importance of the application of the method to globular clusters resides on the possibility of decomposing the integrated light in terms of its stellar components. In principle, one might access information on subjects such as the main sequence faintest stars and the mass function slope. By comparing the observed and model spectra one may infer on differences between the physical parameters of the involved stellar populations; the present work explores the latter possibility.

The globular clusters NGC 6528, NGC 6553 and NGC 6440 are among the most metallic ones in the Galaxy, as indicated by integrated photometry and integrated spectral studies (Zinn 1980, 1985; Bica & Pastoriza 1983; Bica & Alloin 1986). Indeed atomic and molecular features in their integrated spectra are substantially stronger than those in 47 Tucanae, which is traditionally considered as a reference metal–rich globular cluster. The CMDs of NGC 6528, NGC 6553 and NGC 6440 are very similar in $V\times(V-I)$, and they differ morphologically from that of 47 Tucanae by the presence of a more curved and extended giant branch and a very red horizontal branch (Ortolani et al. 1990, 1995; Ortolani et al. 1992, hereafer OBB90, OBB95 and OBB92 respectively; Bica et al. 1994). A high dispersion spectral analysis of a giant star in NGC 6553 indicated a nearly solar metallicity ([M/H]=-0.2) and an overabundance of Nitrogen (Barbuy et al. 1992).

The objective of the present work is to synthesize the mean integrated spectrum of NGC 6528, NGC 6553 and NGC 6440 using an essentially solar metallicity library of stars, together with constraints provided by the relative number of stars in different parts of the observed CMDs. The resulting model spectrum when compared to the observed one can provide clues on the abundance of different elements from the analysis of the residuals of metallic features and of the continuum blanketing.

In Sect. 2 we describe the integrated spectra and CMDs of the clusters and their preparation for the synthesis. In Sect. 3 we describe the stellar library used for the synthesis. The synthesis is made in Sect. 4, where the results are also discussed. The concluding remarks of this work are given in Sect. 5.

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* Based on data collected at the European Southern Observatory, La Silla, Chile.

Table 1. Properties of stellar groups

Group	$(B-V)$	$(V-R)$	$(V-I)$	m_v	M_v	$W(KCaII)$	$W(CaT)$	$\log g$	Θ_{eff}	$M/M_\odot$	Observations
F02V	0.33	0.25	0.43	-2.46	3.2	6.30	6.31	4.18	0.72	1.5	
F36V	0.46	0.35	0.64	-2.42	3.5	10.27	6.84	4.34	0.78	1.3	
F7G0V	0.57	0.43	0.73	-2.37	4.3	13.46	6.7	4.36	0.83	1.1	
G23V	0.64	0.46	0.86	-2.36	4.7	15.58	6.88	4.45	0.86	0.99	
G46V	0.73	0.51	0.86	-2.35	5.4	16.94	7.06	4.49	0.88	0.92	
G89V	0.80	0.50	0.82	-2.35	5.8	21.80	6.71	4.49	0.93	0.84	CN strong
K01V	0.79	0.58	0.98	-2.30	5.9	17.03	7.51	4.49	1.00	0.78	
K34V	1.05	0.92	1.40	-2.17	7.0	23.22	8.05	4.53	1.07	0.71	
M01V	1.39	1.17	2.10	-2.03	8.6	17.94	5.97	4.60	1.34	0.53	
G5IV	0.72	0.47	0.84	-2.37	3.1	18.17	7.95	4.40	0.86	1.00	
B89III	-0.08	-0.05	-0.06	-2.59	-1.0	0	0	3.50	0.43	5	
F01III	0.26	0.23	0.36	-2.45	1.3	6.19	7.36	4.00	0.68	2	
G8K0III	1.00	0.67	1.17	-2.27	0.7	21.54	8.34	2.80	1.02	1.1	
G8K0III.MP	0.84	0.66	1.20	-2.28	0.85	16.19	7.40	2.40	1.02	1.1	metal–poor
K13III	1.21	0.83	1.36	-2.19	0.50	23.77	9.74	2.20	1.13	1.1	
K45III	1.45	1.00	1.76	-2.13	-0.10	25.95	10.42	2.00	1.28	1.2	
K67III	1.55	1.07	2.14	-2.03	-0.40	24.29	7.97	1.50	1.31	1.2	
M3III	1.54	1.01	2.58	-1.95	-0.60	24.51	13.62	1.40	1.43	1.3	
M5III	1.46	0.92	3.58	-1.82	-0.30	20.06	14.64	1.40	1.51	1.3	
G02I	0.90	0.56	0.95	-2.31	-6.30	19.94	13.85	1.40	0.95	10	
G68II	1.03	0.76	1.24	-2.23	-6.10	21.70	8.84	3.00	0.99	5	
M2I	1.71	0.94	2.29	-2.05	-5.60	22.20	13.46	0.70	1.46	20	

2. The spectral and CMD data for the clusters

In studies of integrated spectra in the visible, near–infrared and near–ultraviolet ranges (respectively Bica & Alloin 1986, 1987 and Bica et al. 1994, hereafter BA86, BA87 and BAS94), the clusters NGC 6553, NGC 6528 and NGC 6440 presented very similar properties, forming a distinct class with stronger absorption features with respect to other metal–rich globular clusters such as 47 Tuc. In order to increase the signal to noise ratio of the spectrum to be synthesized, we adopt the average of those of the three very metal–rich globular clusters. The spectra were obtained with the 1.52m telescope at ESO, La Silla with resolutions in the range ≈ 12–16Å; for details on the observations and reductions see BA86, BA87 and BAS94. The average spectrum of NGC 6553, NGC 6528 and NGC 6440 will be hereafter designated G1 template, of which the visible and near-infrared parts were previously used in the visualisation of population syntheses of galaxy nuclei in Bica (1988). The averages were made with the cluster spectra corrected for reddening using a normal law (Seaton 1979) and E$(B-V)$ values as in BA86, BA87 and BAS94.

The distribution of stars in the CMD and their proportions are part of the synthesis procedure. We use the $V\times(V-I)$ diagram of NGC 6553 from OBB90 which contains 1306 stars. This CMD was obtained from CCD images collected with the Danish 1.54m at ESO, La Silla under good seeing conditions; for details on the observations and calibrations see OBB90. The CMDs of NGC 6528 and NGC 6440 are very similar to that of NGC 6553 (OBB92, OBB95). We adopted the CMD of NGC 6553 because the cluster is much less concentrated than NGC 6528 and NGC 6440, and consequently its CMD should be less affected by crowding effects, which might affect the relative number of stars in different parts of the CMD. We preferred the $V\times(V-I)$ CMD rather than $V\times(B-V)$ because the stellar sequences are better defined in the former, mainly owing to the weaker effects of differential reddening and blanketing at longer wavelengths.

3. The spectral library

In the application of the synthesis method to the open cluster M 11 (SBD90) the stellar library of Gunn & Stryker (1983, hereafter GS83) was employed. This library spans the range $\lambda\lambda$3160–10620Å and has a resolution of 20Å for $\lambda <$ 5740Å and 40Å for $\lambda >$ 5740Å. These resolutions are lower than those employed for the star cluster spectra in BA86, BA87 and BAS94 (typically of 12–16Å). In SBD90 the integrated spectrum of M 11 had to be degraded for the comparison with the synthetic spectrum based on GS83's library. As in the present study we are particularly interested in a metallicity analysis based on spectral line residuals, we decided to use stellar spectra with a higher resolution. The stellar library of Jacoby et al. (1984, hereafter JHC84) is suitable for our purposes since it has a resolution of ≈5Å, but it is limited to the range $\lambda\lambda$3510–7427Å. We complemented it with a near–infrared library of stars, which was used for detailed studies of the CaII triplet and other features (Alloin & Bica 1989). The latter library has a resolution of ≈3Å and spans the range $\lambda\lambda$7200–10230Å; it mostly contains stellar types F and later, thus particularly suitable for population synthesis of old stellar populations, which is the case of the clusters in the present work. In the organization of the present stellar library, we basically followed SBD90's procedures employed for

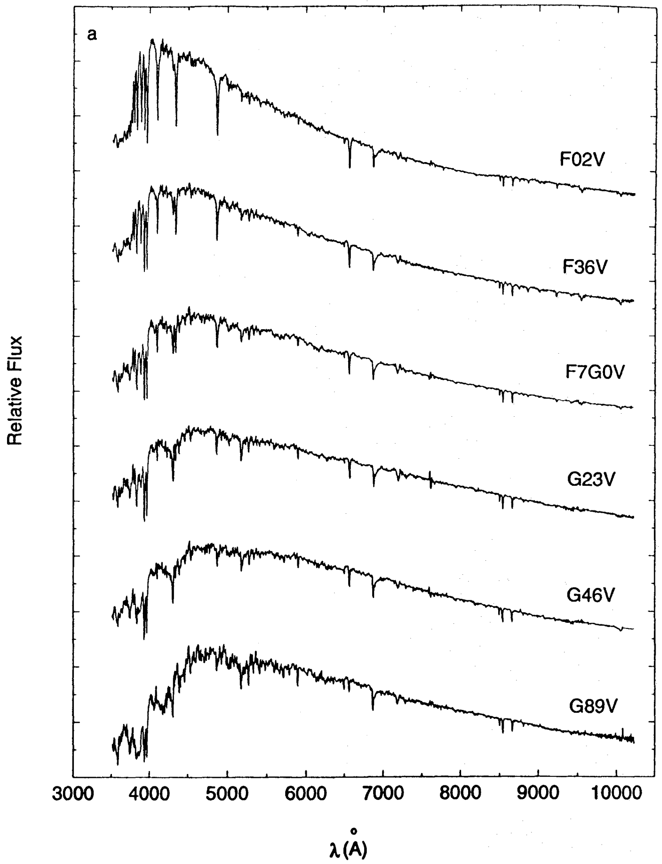

Fig. 1a. Examples of stellar spectral types resulting from the connection of visible (Jacoby et al. 1984) and near–infrared spectra (Alloin & Bica 1989) for luminosity class V. Spectra are in F_λ units, normalized at λ5870Å and shifted by an additive constant when necessary for clarity purposes

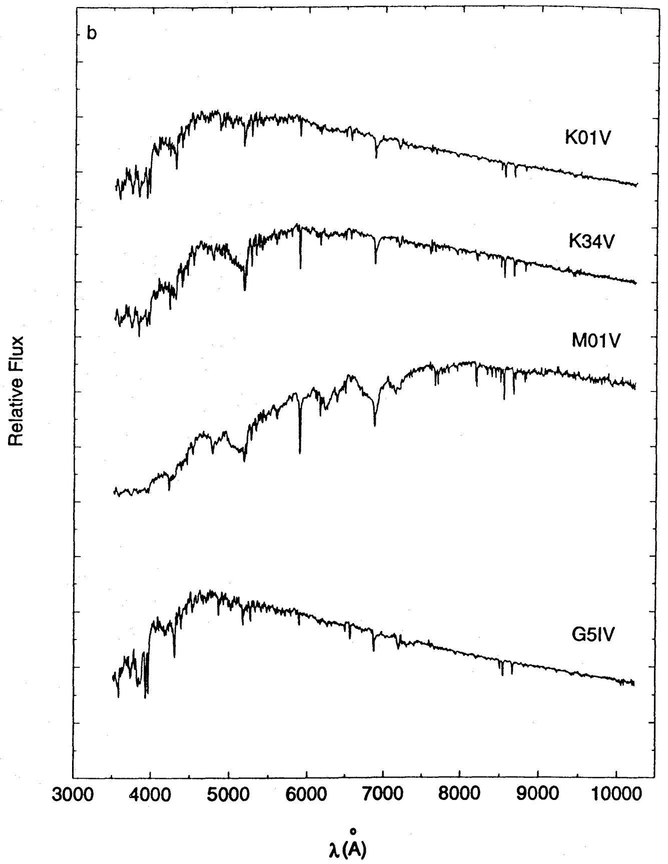

Fig. 1b. As Fig. 1a for luminosity classes V and IV

the definition of stellar groups from GS83's spectra of individual stars. In order to define groups of similar spectral type, luminosity class and metallicity we used the information on the individual stars in JHC84 and in Alloin & Bica (1989), together with colours, absolute magnitudes and metallicities available for individual stars and/or average stellar types (Cayrel de Strobel et al. 1985; Schmidt–Kaler 1982). However, the spectral resemblance was the ultimate criterion for averaging or not the spectra. As a first step we obtained 67 stellar groups with JHC84's library and 27 with the near–infrared library. We subsequently combined similar spectral groups between the two libraries. The wavelength for connecting them was around 7300Å. We ended up with 22 visible/near–infrared spectral groups whose properties are condensed in Table 1. The Table contains $BVRI$ colours, m_v (a parameter explained in Sect. 4.1), M_v (absolute V magnitude), equivalent width of K CaII and that resulting from the sum of the CaII triplet lines in the near–infrared, parameters related to gravity, temperature and mass based on data in Schmidt–Kaler (1982), Jones et al. (1984) and Pickles (1985).

Examples of resulting spectra for Main Sequence and Giant groups are shown in Fig. 1. The continuum distribution and features of these spectral groups were also compared to those from the library of Silva & Cornell (1992), which has an average resolution of 11Å, with good agreement. From the available information on metallicity of individual stars (Cayrel de Strobel et al. 1985), and from colours of individual stars and groups when compared to those predicted for different metallicities (Cameron 1985), the groups in Table 1 are compatible with the solar metallicity, except G8K0III.MP which is metal deficient. Since the stars in the libraries are essentially all from the solar neighbourhood, we will assume that the groups in Table 1 (except the metal deficient one) are representative of the solar metallicity for each spectral and luminosity class. A more detailed analysis of these spectral libraries, their constructions, internal degeneracy and metallicity differences are provided in Santos (1993).

4. The synthesis and discussion

4.1. Synthesis of the observed CMD

The observed $V\times(V-I)$ CMD of NGC 6553 was corrected for reddening E$(B-V)$=0.80 (which converts to E$(V-I)$=0.84), and a distance modulus $(m-M)$=15.7 (BA86, OBB90, Demarque & Lee 1992). The cluster sequences in the $M_v\times(V-I)_o$ diagram were divided into six boxes as shown in Fig. 2. The fainter stars in the boxes 1, 2 and 3 belong to the giant branch, and are at a brightness level which is basically not affected by

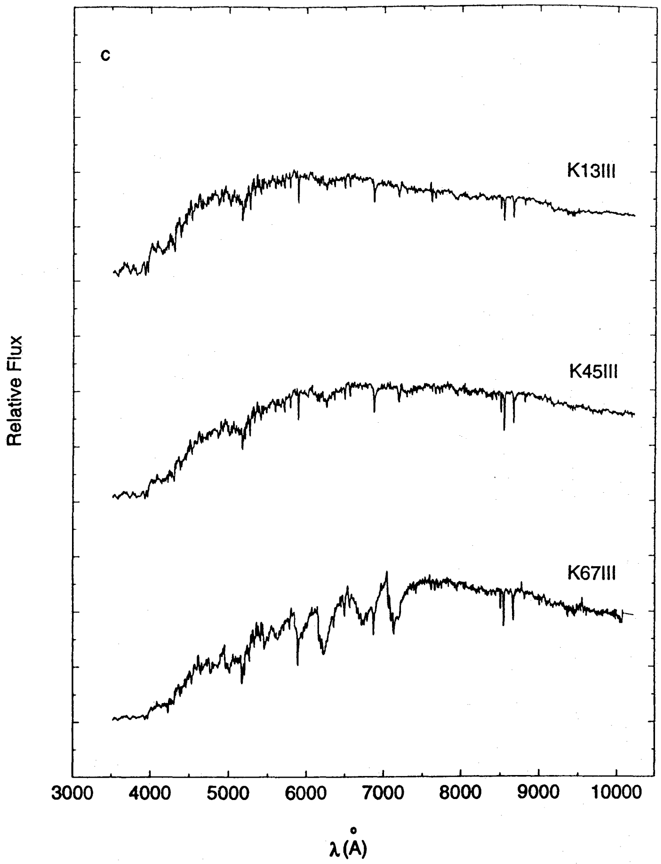

Fig. 1c. As Fig. 1a for K giants

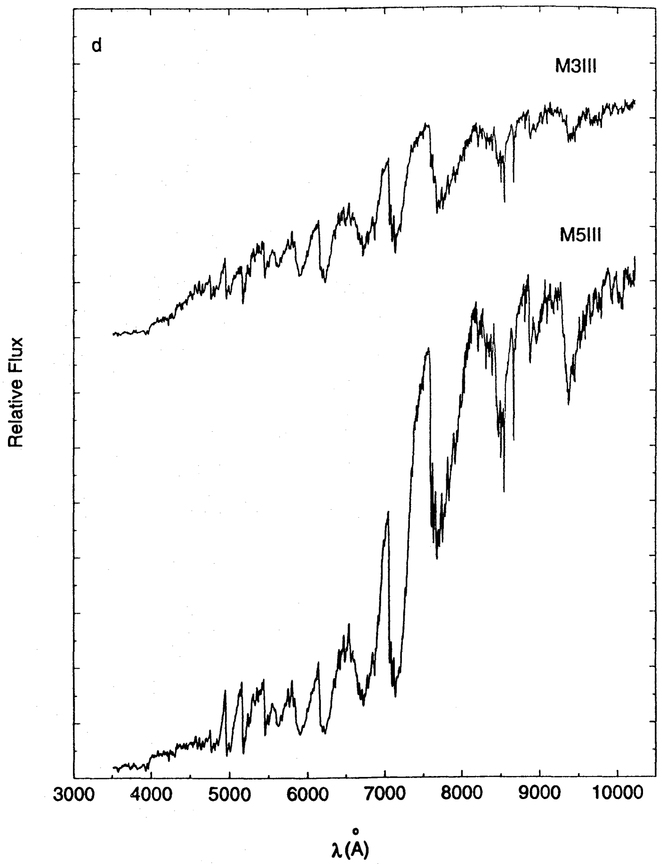

Fig. 1d. As Fig. 1a for M giants

crowding or observational cutoff effects. The association of the library spectral types to the boxes in Fig. 2 was made by means of the $(V-I)_o$ colour. Since the CMDs of OBB90 are in the Cousins system, the colours of the stellar groups in the Johnson system (Table 1) were transformed by means of the equations in Bessell (1979). The synthesis technique follows SBD90; each stellar type spectrum contributes to the synthetic spectrum with a weight which is proportional to the total V flux of the stars in the corresponding box. Thus, the contribution of the j spectral type at the adopted reference wavelength λ=5870Å is given by

$$C_j = n_j 10^{-0.4(<M_v>_j - m_{vj})}$$

where n_j is the number of stars of type j, m_{vj} is the result of the convolution of the spectrum j normalized at 5870Å with the V filter, and $< M_v >$ is the mean absolute V magnitude of the n stars in the box associated to the spectral type j,

$$< M_v > = -2.5 \log[(\sum_{i=1}^{n} 10^{-0.4 M_{vi}})/n]$$

We show in Table 2 the spectral types associated to the boxes from Fig. 2, together with their respective values for n_j, $< M_v >_j$ and C_j.

The synthetic spectrum is obtained with

$$\mathscr{F}_\lambda = \sum_{j=1}^{N} C_j f_{\lambda\, j}$$

for the N=6 spectral types in Table 2, where $f_{\lambda\, j}$ stands for the spectrum j.

The synthetic spectrum for the 6 boxes of Fig. 2, resulting from the new stellar library of Sect. 3, is compared in Fig. 3 to that resulting from the stellar groups based on GS83's library as defined in SBD90. The improvement in spectral resolution is considerable. The similar absorption features and continuum distribution indicate that the two libraries are equivalent. This is an additional evidence that the stellar types in the new library of Sect. 3 are basically of solar abundance, since GS83's stars are better documented in terms of metallicities, having 15 stars in common with the catalogue of Cayrel de Strobel et al. (1985) and 24 stars in open clusters with metallicity estimates in Janes (1988) and Sandage (1988), which on the average provide [Fe/H]≈0.

We compare in Fig. 4 the synthetic spectrum for the 6 boxes in Fig. 2, using the new stellar library of Sect. 3, with the G1 template. Notice the similarity of the two spectra, which indicates that the integrated light of the clusters are dominated by the brighter stellar sequences of the CMD. The synthetic spectrum is slightly redder than the G1 template, which suggests that among the fainter spectral types not yet taken into account, the turnoff region will necessarily be the dominant component.

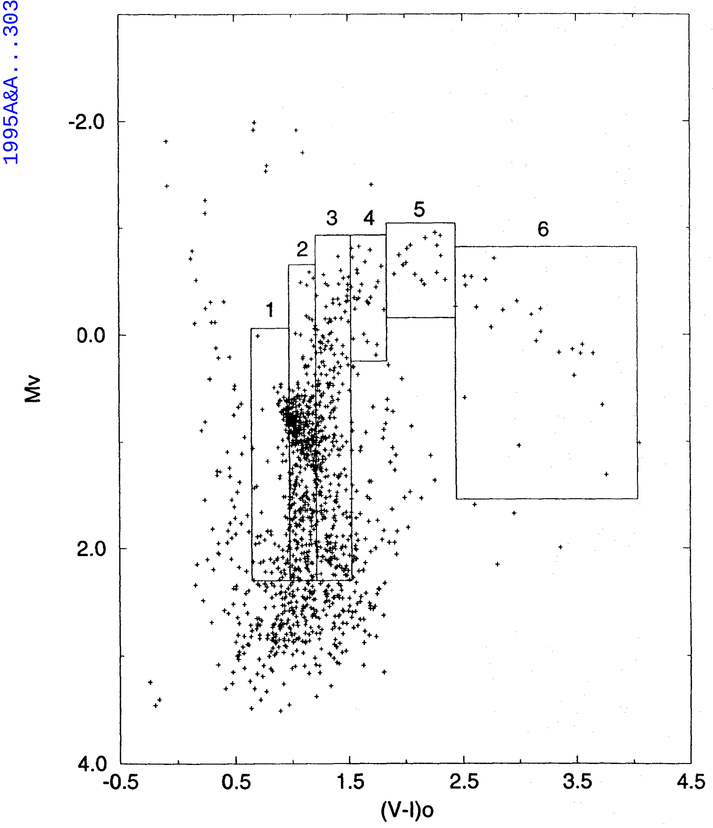

Fig. 2. Distribution of stars in the $V\times(V-I)$ colour–magnitude diagram of NGC 6553. The boxes indicate stars which are associated to spectral types in the stellar library

Table 2. CMD synthesis

Group	n	$< M_v >$	C
G8K0III	144	1.17	6.09
K13III	417	1.00	22.19
K45III	259	0.72	18.83
K67III	22	-0.39	4.87
M3III	17	-0.69	5.33
M5III	24	-0.04	4.65

Table 3. Synthesis for intermediate groups

Group	n	$< M_v >$	C
G8K0III	996	2.74	9.87
G5IV	1635	3.72	5.99
F7G6V *	5097	4.53	8.94

Table Note. * Average of the groups F7G0V, G23V and G46V.

4.2. Synthesis of the fainter sequences

In order to synthesize the Main Sequence (MS) and the evolved sequences below the boxes in Fig. 2, and to tie them to the spectral synthesis of the observed parts of the CMD from Sect. 4.1, we assume the proportions of stars in the CMD of 47 Tuc by Hesser et al. (1987), which includes a considerable part of the MS. The CMDs of NGC 6553 and 47 Tuc have in common the well–sampled ranges $-0.1 < M_v < 1.1$ (Horizontal Branch, HB), and $1.1 < M_v < 2.3$ (Red Giant Branch, RGB, below the HB). For NGC 6553 the numbers of stars in these regions are respectively 384 and 350, whereas in 47 Tuc they are 277 and 230. The ratio of stars in these CMD areas are similar for the two clusters, which reinforces our assumption that they are comparable clusters in terms of relative number of stars in well–sampled CMD regions. As a check on the possible influence of age and metallicity variations on this ratio, we estimate comparable theoretical ratios from the simple stellar populations (SSP) computed by Buzzoni (1989). Taking his SSPs with a red HB, a Salpeter IMF, Z=0.001, Y=0.23, 12.5 Gyr and Z=0.01, Y=0.25, 10 Gyr (cluster parameters which basically encompass possible differences between 47 Tuc and NGC6553), we obtain bolometric luminosity ratios L(RGB)/L(HB)=4.1 and 3.9, respectively. Assuming that L(RGB)/L(HB) scales with the star number ratio in the considered parameter ranges, we conclude that age and metallicity differences are not affecting much the observed ratios. On the other hand, these two SSP models differ in $\Delta(U-V)$=0.28 and $\Delta(B-V)$=0.11, showing that the spectral energy distributions are strongly dependent on the assumed parameters, as expected.

Combining the two CMD regions, the number ratio between the two clusters will be adopted as scaling factor to infer on the amounts of stars in the fainter areas for NGC 6553. The results of counting stars in the CMD of 47 Tuc in the regions $2.3 < M_v < 3.5$ (Subgiants), $3.5 < M_v < 4.0$ (Turnoff) and $4.0 < M_v < 5.6$ (brightest part of the MS) are respectively 688, 1128 and 3516. The scaled numbers for NGC 6553 in these CMD regions result respectively 996, 1635 and 5097. Associating spectral types from Table 1 to these numbers in NGC 6553 we derived their proportions as shown in Table 3.

The MS below the group F7G6V requires the assumption of a mass function

$$\Phi(M) = AM^{-(1+x)}$$

being A a normalization constant and x the slope. We used Miller & Scalo's (1979) mass–luminosity relation and M_v values for the groups from Table 1 for the determination of the V flux proportions for the MS spectra. Not many globular clusters have been studied in detail for the determination of the mass function slope; the first results suggested a dependence on metallicity (McClure et al. 1986; Pryor et al. 1986), but more recently Capaccioli et al. (1991), with a large sample of clusters, found evidence that the cluster position in the Galaxy correlates well with x. Based on these studies one would infer that NGC 6553, NGC 6528 and NGC 6440 should have flat slopes ($x \approx 0$), as metal–rich bulge clusters. In any case, we tested the values x= -0.5, 1.35 (Salpeter) and 2.5. Using the number of stars in the group F7G6V (Table 3) in the determination of the mass function normalization constant A, we derived the number of stars for the MS groups as shown in Table 4 for the different x values.

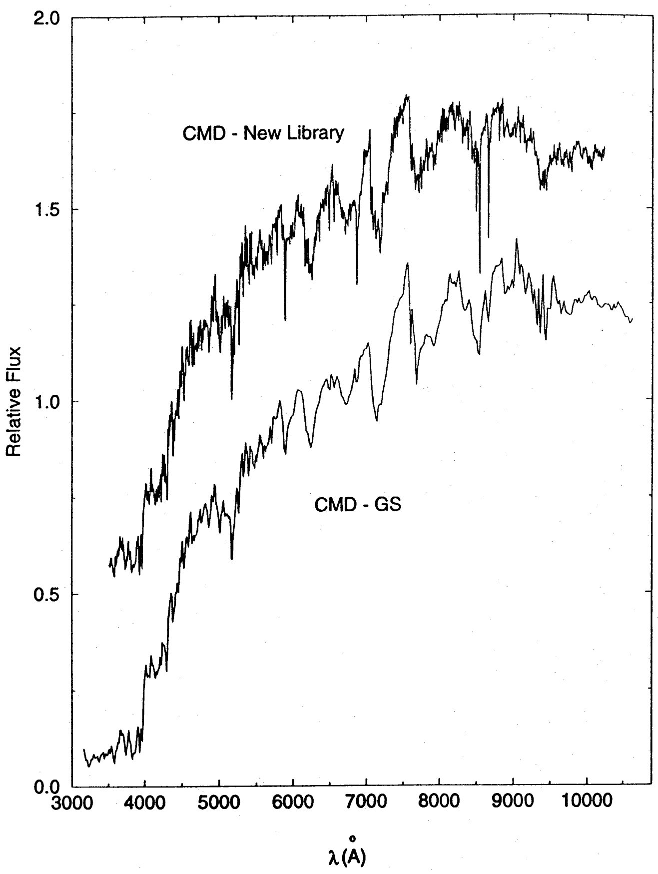

Fig. 3. The synthetic spectra resulting from the statistically complete parts of the CMD: using the higher resolution stellar library (top) and using Gunn & Stryker's (1983) library (bottom). Fluxes as in Fig. 1

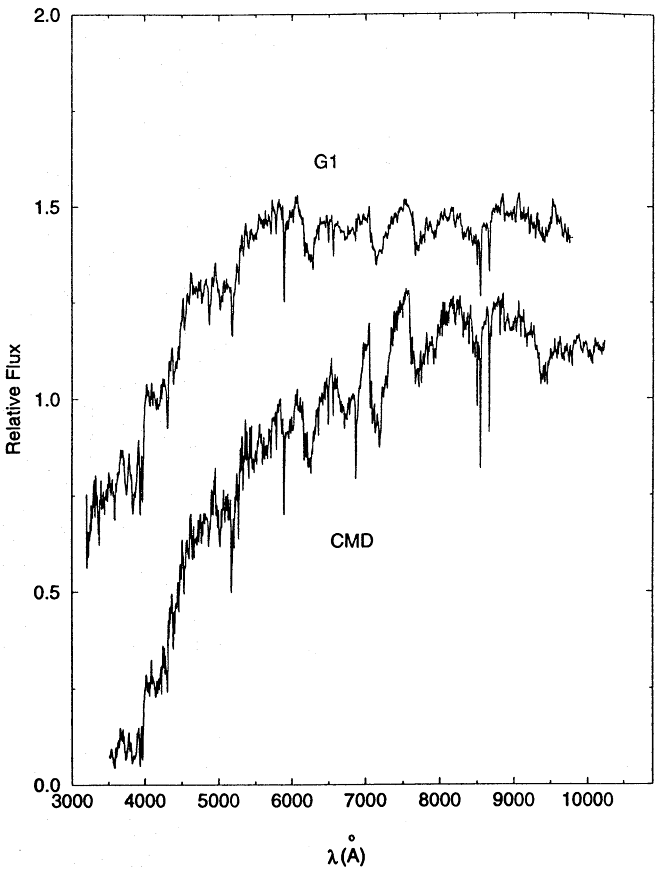

Fig. 4. Top: The G1 template (average spectrum of NGC 6528, NGC 6553 and NGC 6440). Bottom: the synthetic spectrum resulting from the statistically complete parts of the CMD using the higher resolution stellar library. Fluxes as in Fig. 1

Finally, we show in Table 5 the percentage flux contributions at 5870Å of the CMD down to M_v = 4.0 (Table 2 and 3), the intermediate luminosity group F7G6V (Table 3) and the fainter groups (Table 4).

The results indicate that the MS groups amount to ≈15%, and owing to this minor contribution, the influence of the tested mass function slope values is not significant on the integrated light, in the observed wavelength range. This is in agreement with the results of Covino et al. (1994) concerning the IMF slope influence on globular cluster SSPs by Buzzoni (1989). They tested x= 0.35 and 1.35 and concluded that the $(U-B)$ and $(B-V)$ colours are little affected; only in the infrared (K band) significant differences appear. We compare in Fig. 5 the synthetic spectrum for x=1.35, together with its components shown to scale, with the G1 template. The solar library synthetic spectrum and the G1 template are similarly strong–lined, confirming indications from other studies based on different approaches (Sect. 1), that NGC 6553, NGC 6528 and NGC 6440 have indeed a nearly solar metallicity. The Red Giant Branch and the Horizontal Branch stars are the main contributors to the integrated light with respectively ≈60% and ≈20% of the flux at 5870Å. The synthetic spectrum and its components in Fig. 5 are degraded to the same resolution as that of the G1 template. The SSPs computed by Buzzoni (1989) for metal rich globular clusters predict contributions around 5870Å of ≈40% for the MS, ≈30% for the RGB+AGB, and ≈12% for the HB, which

Table 4. Star numbers for three mass functions

Group	M_v range	x		
		-0.5	1.35	2.5
K01V	5.6 – 6.5	2449	3535	4410
K34V	6.5 – 8.2	4488	9606	15442
M01V	8.2 – 9.3	2584	8486	17679

Table 5. Final syntheses

Group	x		
	-0.5	1.35	2.5
DCM	87.3	85.4	83.3
F7G6V	10.0	9.8	9.6
K01V	1.4	2.0	2.5
K34V	1.1	2.3	3.6
M01V	0.2	0.5	1.1

differ significantly from our results. As pointed out by Covino et al. (1994), these SSPs failed to describe NGC 6553, which they attributed to a possible poor determination of the reddening for this cluster. Another possibility is the fact that the SSPs employed theoretical spectral energy distributions which lack molecular lines. The match we obtained with the observational stellar library from the near–UV to the near–IR suggests that the latter possibility cannot be neglected in metal rich populations, and that the derived ratios for each evolutionary sequence might be reasonable approximations. Deeper CMDs will certainly further clarify these issues.

The relative spectral residuals calculated as

(G1-Model)/G1

are shown in Fig. 6. Positive values are thus in the sense of a metallicity deficiency of G1 with respect to the synthesis model. For $\lambda < 4500$Å, a flux excess can be identified with the overall blue–violet blanketing caused mostly by weak iron lines, which suggest that G1 is slightly underabundant in iron. Some metallic line residuals are labeled in the figure. The residual of the strong Fe line at 5270Å points to the same conclusion as the blue–violet excess. Also the lines CaII H and K and Mg I 5175Å have residuals in the sense of G1 being somewhat subsolar. On the other hand the NaI D line is stronger in G1, but this is certainly caused by a significant interstellar gas component in the globular cluster spectra, since they are much more reddened than the stars in the libraries.

Molecular bands involving the CNO elements like CN (3883, 4200Å), CH (G band, 4300Å) and TiO (6300, 7200Å) have local residuals which are basically null, or negative in some cases, which suggest that [CNO/Fe] is larger than solar. These results are similar to those obtained in the high dispersion study of a giant in NGC 6553 by Barbuy et al. (1992), for which [M/H]=-0.2 and [N/Fe]=+0.4 were obtained, but [C/Fe] and [O/Fe] resulted solar. Interestingly, CNO enhanced isochrones were necessary to match observations of the metal–rich globular cluster NGC 6637 (Buzzoni et al. 1994). The blue–violet (3500–4500Å) residual between the solar model and G1 is a factor 2.4 smaller than that between the solar model and the G2 template. G2 is an average of globular cluster spectra which are less strong–lined than those in the G1 group, and which include 47 Tuc as the least strong–lined member (Bica 1988, BA86). Assuming that the metallicity scale for the global content of metals is basically established to the level of G2 ($[Z/Z_{\odot}]$=-0.50), a linear interpolation with the solar model leads to $[Z/Z_{\odot}]$=-0.10 for G1. This result agrees well with the combined Fe and CNO abundances by Barbuy et al. (1992) for NGC 6553.

More spectral studies of giants at high and medium resolution are important to further explore and clarify the abundance properties in NGC 6553, NGC 6528 and NGC 6440, as well as of other bulge globular clusters which might be even more metallic.

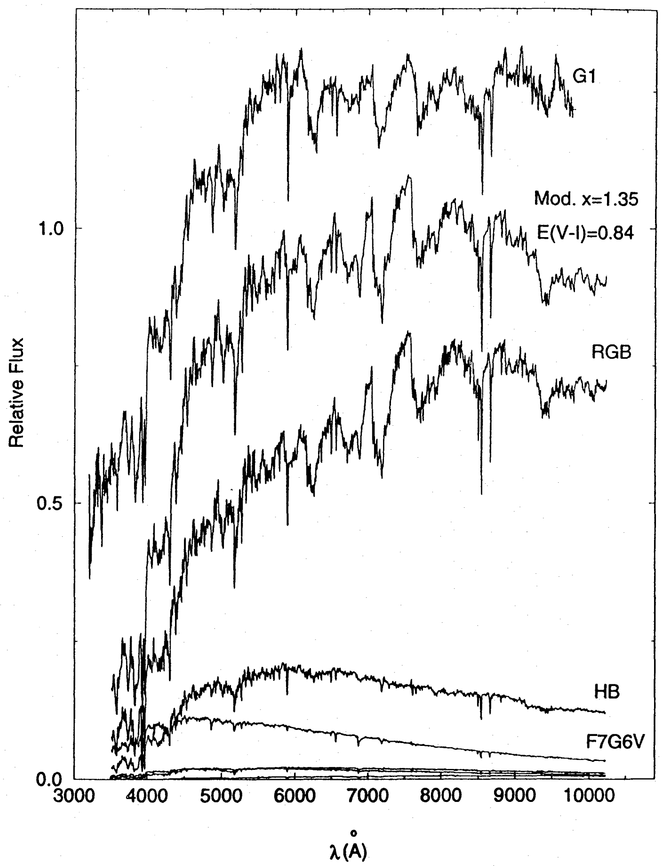

Fig. 5. Comparison of the G1 spectrum (top) to the synthetic spectrum combining the observed parts of the CMD and an IMF slope x =1.35 for the Main Sequence (2nd from top). Components are shown to scale, the dominant ones, i.e. Red Giant Branch, Horizontal Branch and upper Main Sequence (F7 to G6) are labeled. Fluxes as in Fig. 1

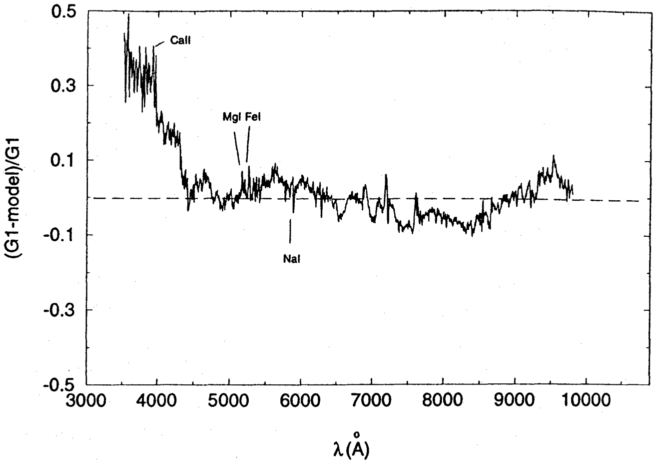

Fig. 6. Residuals calculated as (G1–Model)/G1. Labels indicate the residuals of some important spectral lines

5. Concluding remarks

An average integrated spectrum of the very metal–rich globular clusters NGC 6528, NGC 6553 and NGC 6440 was analyzed with the SBD90 spectral synthesis method which uses as constraint flux proportions of stars from the statistically complete parts of the colour–magnitude diagram. The remaining parts of the CMD were simulated according to different mass function slopes. The library of stellar spectral types used in the synthesis arised from the connection of visible (Jacoby et al. 1984) and near–infrared spectra (Alloin & Bica 1989). The spectral resolution is greatly increased with respect to Gunn & Stryker's (1983) library, allowing one to analyse in more detail residuals of absorption features. The dominant stellar components in the integrated light of the clusters are the RGB and the HB with respectively ≈60% and ≈20% of the flux at λ5870Å. The MS contributes with ≈15% of the flux at 5870Å, and values of mass function slopes x = -0.5, 1.35 and 2.5 do not affect significantly the integrated light. The spectral model based on the solar neighbourhood stars clearly shows that the metallicity, as inferred from the observed molecular and atomic features in the integrated spectrum of NGC 6553, NGC 6528 and NGC 6440, cannot differ much from that of the Sun. In detail, the residuals of the observed integrated spectrum with respect to the model suggest that [Fe/H] is slightly subsolar in these globular clusters, whereas [CNO/Fe] is slightly above the solar ratio. High and medium resolution spectroscopic data of individual cluster giants are important to further investigate the abundance ratios in these bulge globular clusters, which in turn have fundamental implications on the chemical enrichment history of the Galaxy.

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