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Blanketing effects in the very metal-rich bulge globular cluster Terzan 1*

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Abstract. We present *BVRI* and Gunn *z* CCD photometry for the bulge metal-rich globular cluster Terzan 1. The RGB shows an anomalous shape and the HB is extremely red. It is projected on a very metal-rich bulge population. We demonstrate that this cluster is strongly affected by blanketing in the *B* and *V* bands. From the *I* vs. $(V-I)$ photometry, we obtained a reddening $E(B-V)\approx 1.67$, in agreement with previous JHK photometry estimate.

We conclude that this cluster has a very high metallicity, as revealed by an anomalous RGB morphology, in particular in the *V* vs. $(B-V)$ diagram, and an excess blanketing of $\Delta(V-I)\sim 0.8$–0.9 relative to the Baade window population.

These results should be considered in the modelisation of metal-rich atmospheres and analyses of metal-rich composite spectra and photometric indices.

Key words: bulge globular clusters – *BVRI* CCD images – colour-magnitude diagrams

1. Introduction

Terzan (1966, 1967, 1968, 1971) discovered a dozen globular clusters near the direction of the Galactic center, which significantly increased the number of galactic globular clusters.

Terzan 1 (HP 2 = GCL 69 = GCL 1732-304 = ESO 455 SC 23) is located ($\alpha_{1950}=17^h32^m34^s$, $\delta_{1950}=-3°00'27''$; $l=357.^\circ5$, $b=1.^\circ0$) only $2.^\circ7$ from the direction of the Galactic center. An inspection of sky survey Schmidt plates shows a concentrated cluster, which is extremely faint in blue plates as compared to *R* and *I*, indicating strong obscuration by dust.

Little information is available for the cluster: reddening $E(B-V)=1.52$ and metallicity $[M/\mathrm{H}]=+0.10$ estimates are found in compilations (e.g. Zinn & West 1984; Webbink 1985). They are based on the integrated infrared photometry of Malkan (1982), which suggests that one is dealing with one of the most metallic globular clusters in the Milky Way. Terzan 1 is a very concentrated post-collapsed cluster, showing a central pulsar.

We have started a program to study in detail such bulge clusters, which are generally highly reddened, interested mostly in high metallicity effects [e.g., Ortolani et al. 1990 (Paper I); Ortolani et al. 1992 (Paper II)]. For such studies, it is necessary to observe under excellent seeing conditions because of crowded fields and to probe in particular with long-wavelength filters like *R*, *I* and Gunn *z* in order to minimize the reddening influence. The study of NGC 6553 revealed striking features in the CMD, like curved red giant branch with very faint tip due to strong blanketing effects in the cooler giants. These effects were further discussed in Ortolani et al. (1991) and Bica et al. (1991).

In the present study we provide deep CCD images in *BVRI* and Gunn *z* of Terzan 1 and surrounding field, taken with the Danish 1.54 m telescope. The colour-magnitude diagrams (CMDs) morphology is analysed in different filter combinations and we derive cluster parameters like reddening, metallicity and distance.

In Sect. 2 we present the observations. In Sect. 3 we show colour-magnitude diagrams. In Sect. 4 we analyze the field background. In Sect. 5 the cluster reddening and distance are derived, and the metallicity problem is addressed. The conclusions are given in Sect. 6.

2. Observations

The Johnson-Cousins *BVRI* and Gunn *z* images were taken at the 1.54 m Danish telescope at the *European Southern Observatory* (ESO), La Silla, Chile, in June 1990. The 512 × 320 pixel ESO CCD no. 5, an RCA 30 μm was used. The frame corresponds to $4' \times 2.'5$ on the sky. The background field was obtained 5′ northwest of the cluster. The log-book of the observations is reported in Table 1. A *V* image of the cluster is shown in Fig. 1. The cluster appears very concentrated, as many other bulge ones. We have placed it off-center in the image, to avoid some very bright field stars.

2.1. Reductions

The reductions were carried out in Padova Observatory and at ESO-Garching computer centers, using Midas and IHAP packages. The final individual stellar photometry was obtained with the Daophot code adapted to Midas environment. Standard flat-field procedures as described in Paper I have been followed.

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* Observations collected at the European Southern Observatory, La Silla, Chile

Table 1. Log-book of the observations

Filter	Date	UT	Exp. time (s)	Seeing
V	20.06.89	$1^h52^m20^s$	300	1″.2
V	20.06.89	$2^h00^m42^s$	300	1″.2
B	20.06.89	$2^h11^m39^s$	120	1″.3
B	20.06.89	$2^h17^m30^s$	1200	1″.2
B	20.06.89	$2^h44^m01^s$	1200	1″.2
R	20.06.89	$3^h08^m51^s$	300	1″.2
R	20.06.89	$3^h20^m31^s$	300	1″.2
I	20.06.89	$3^h33^m26^s$	180	1″.0
I	20.06.89	$3^h39^m10^s$	180	1″.0
Gunn *z*	20.06.89	$3^h45^m13^s$	120	1″.0
Gunn *z*	20.06.89	$3^h52^m41^s$	120	1″.0
V	20.06.89	$3^h57^m58^s$	300	1″.3
V	20.06.89	$4^h06^m06^s$	300	1″.3

2.2. Calibrations

The calibration of clusters located close to the Galactic center is not an easy task, for two main reasons: (a) The colour range covered by the stars present in the frame is very wide, containing extremely red stars. Furthermore no extremely red stars are available for calibrations. Since the filter passband combined with instrumental sensitivity do not perfectly match the Johnson-Cousins system, colour correction factors must be carefully investigated. (b) The crowding is severe and it is very difficult to identify isolated stars suitable for aperture photometry.

Intensive investigations on colour terms in wide colour ranges have been performed during several observing runs (Papers I and II), from March 1988 through June 1990, using the same CCDs and filters. We concluded that there is no evidence for a significant deviation from a linear interpolation in the colour equation in the range $-0.2<(B-V)<2.2$ in the *B* and *V* bands. In the *R* and *I* bands, the colour terms are very small, while no colour term is required for the *V* transformation. Up to now the near infrared Gunn *z* band ($\lambda_e = 0.89$ μm) has been little used because of the low sensitivity of the detectors in this wavelength region. In our case however it is very useful because we are dealing with very red stars. Moreover this band is relatively less affected by blanketing effects. Due to a lack of southern intermediate luminosity standard stars measured in this band, we could not obtain the absolute calibration during our observing run. Recent observations of some standard stars provided by Thompson (1991, private communication) showed that our filter plus CCD combination is not affected by a significant colour term. Using typically 5 Landolt (1983) standard stars per night, we derived the following transformation equations with CCD no. 5, for 1 s integration:

$$B = b + 0.13(B-V) + 21.2,$$
$$V = v + 21.78,$$
$$I = i - 0.015(V-I) + 20.76, \quad (1)$$

with the notation used in Paper I, where *B*, *V* and *I* are the calibrated magnitudes in the standard Johnson-Cousins system and *b*, *v* and *i* are the instrumental ones.

The stars were measured several times to check possible systematic sources of errors due to the CCD system, including shutter delays, focus, position on the CCD, seeing, linearity deviation and the sky stability. At the beginning of the night, the first star is monitored for about 1 h, measuring on line the instrumental magnitudes (about 15 to 20 measurements are typically obtained). Since the *B* and *V* bands are more sensitive to the extinction, the star is again measured several times, at the end of the monitoring period, in these bands. We begin the observations of the objects, only if the deviations of the standard star measurements (corrected, if the case, for shutter errors and colour terms) are within 0.01 mag. The same procedure is repeated at the middle and if necessary at the end of the night. Since the accuracy of Landolt stars is 5 to 10 times better than a single CCD measurement, the procedure outlined above improves the accuracy of the measurements as compared to methods which use

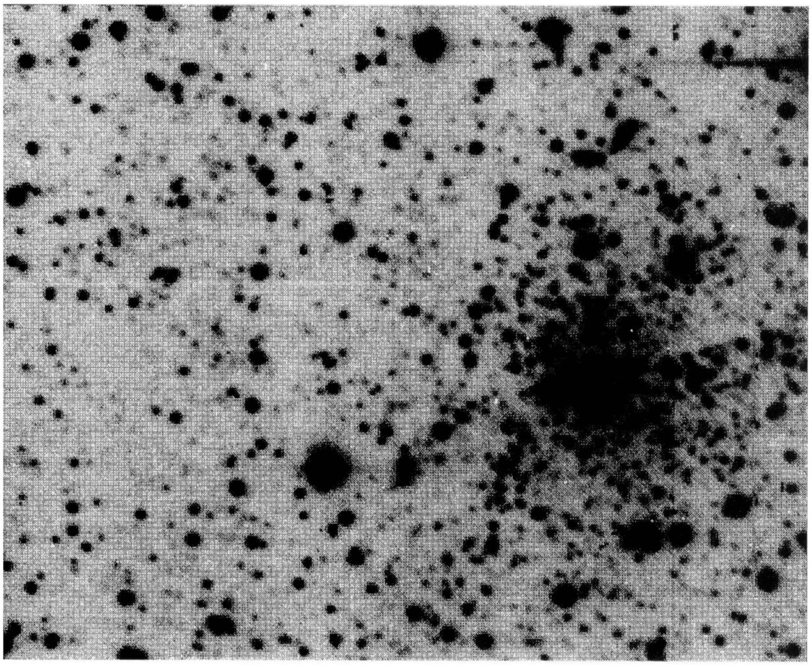


Fig. 1. *V* image of the cluster. The position of Terzan 1 is off-center in order to avoid the presence of a bright star nearby. The field is 3′ × 4′ with north to the top and east to the right

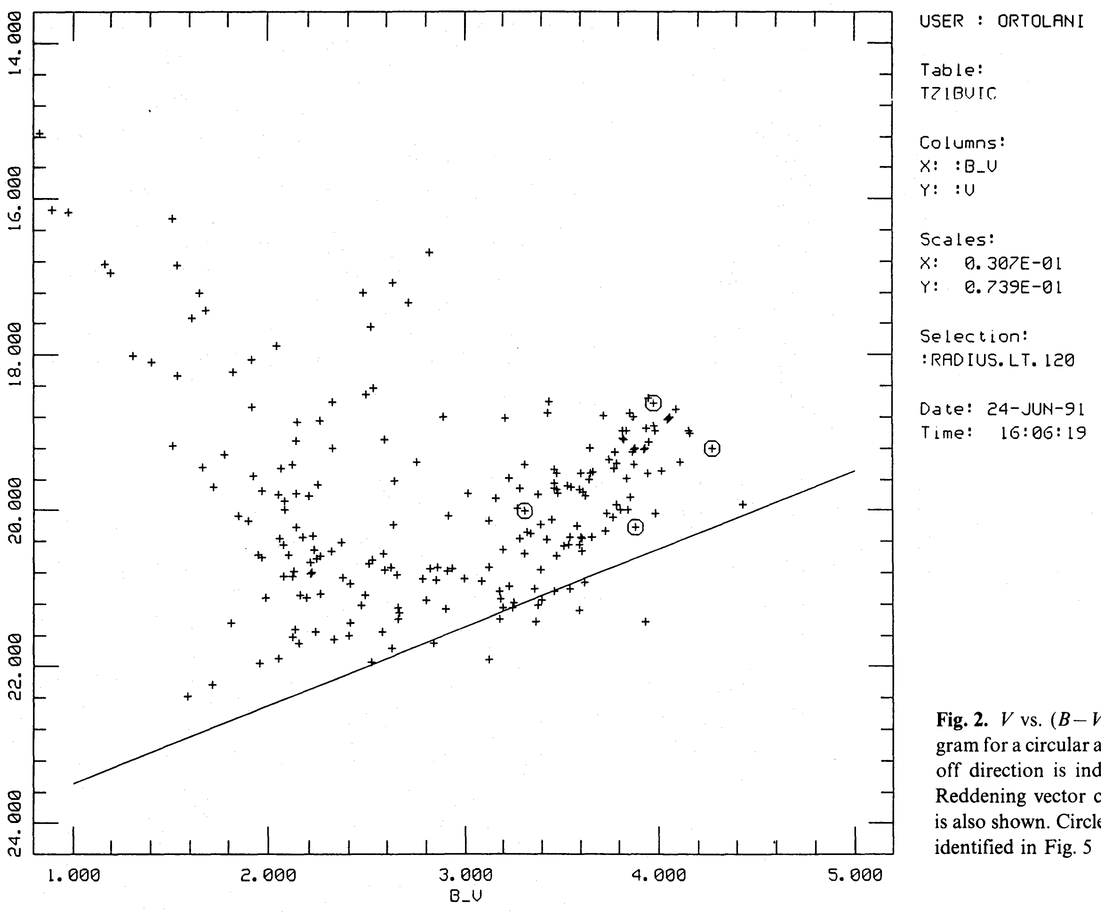


Fig. 2. V vs. $(B-V)$ colour-magnitude diagram for a circular area of $r<56''$. The B cut-off direction is indicated by the long line. Reddening vector corresponding to $A_V=1$ is also shown. Circled crosses are cool giants identified in Fig. 5

many stars as in photoelectric photometry (as well as CCD single observations of many stars). The method also allows one to control the different sources of error, because the many star methods introduce more free parameters.

In addition, standard stars are observed at similar airmasses as the clusters, minimizing errors (in the case of Terzan 1 we had 1.1, 1.15, and for the standards 1.15, 1.23 airmasses). Besides, we corrected the residual difference using the standard coefficient extinctions for La Silla (see also the procedure followed by Armandroff 1988). Any deviation is checked by examining the nightly evolution of extinction coefficients provided by the photometric telescope at La Silla (in particular the 0.5 m Danish telescope data were used for Terzan 1).

The calibration of Terzan 1 stars was done through aperture photometry. Due to the crowding effects, we used the procedure described in Paper II, based on growth-curves obtained from standard stars with the same seeing and then applying the transformations above using a small aperture ($r=2''$) and the aperture correction derived from the growth curve. The scatter of these aperture magnitudes compared to the instrumentally fitted ones are on average ≈ 0.02 for all colours.

The error in the constants of the transformation equations are of the order of ± 0.015. This means that our calibration error is dominated by the aperture photometry transfer. Our combined estimated error is then of about 0.03 mag. It should be noted that the calibration error for this cluster is much smaller than in Papers I and II, because less crowded stars can be found in the field.

The internal relative stellar photometry errors within the cluster CCD frame are dominated by crowding effects. Typically for stars of 15 to 18 V mag, the errors are in the range ≈ 0.04 to 0.06, as derived from frame to frame comparisons. Obviously the real errors must be larger because of blending effects, which are common in dense fields (for a discussion, see Papers I and II).

3. The colour-magnitude diagrams (CMDs)

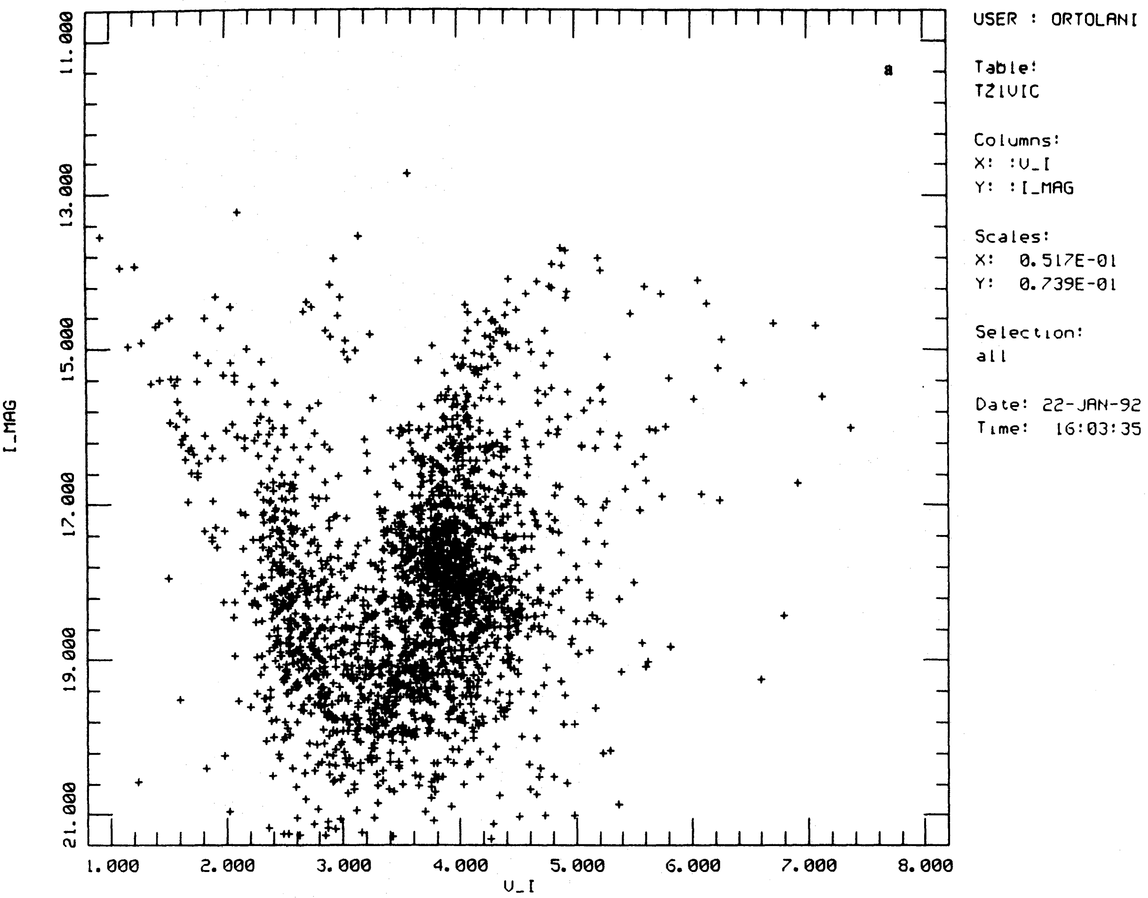
The B image of the cluster is very faint due to the strong reddening. In Fig. 2 we show the usual V vs. $(B-V)$ diagram with a circular extraction of $r<56''$. A young disk main sequence due to foreground field stars is present, as well as a cluster red giant branch. The effect of the B cut-off in the CMD is also indicated.

A deeper analysis can be obtained with redder filters. An example is shown in Fig. 3a in I vs. $(V-I)$ corresponding to the whole cluster frame.

3.1. *The horizontal branch (HB)*

The cluster is heavily contaminated by background population (Fig. 1). In order to evaluate the effects we show in Fig. 4 the I vs. $(V-I)$ diagram from a field frame centered at 5′ NW of the cluster. The general appearance is very similar to that of the cluster whole frame diagram (Fig. 3a). In particular, we recognize the blue disk main sequence (MS) and a clump at $I\approx 17.75$ and $(V-I)\approx 3.95$, which appears to be a red horizontal branch typical of metal-rich populations. These features indicate the importance of contamination effects. We point out that we were misled by this contamination regarding the HB location mentioned in Ortolani et al. (1991).

The cluster features can be separated from those of the field by comparing diagrams obtained in circular areas of different radii, centered on the cluster. Figs. 3a, b, and c show the diagrams for



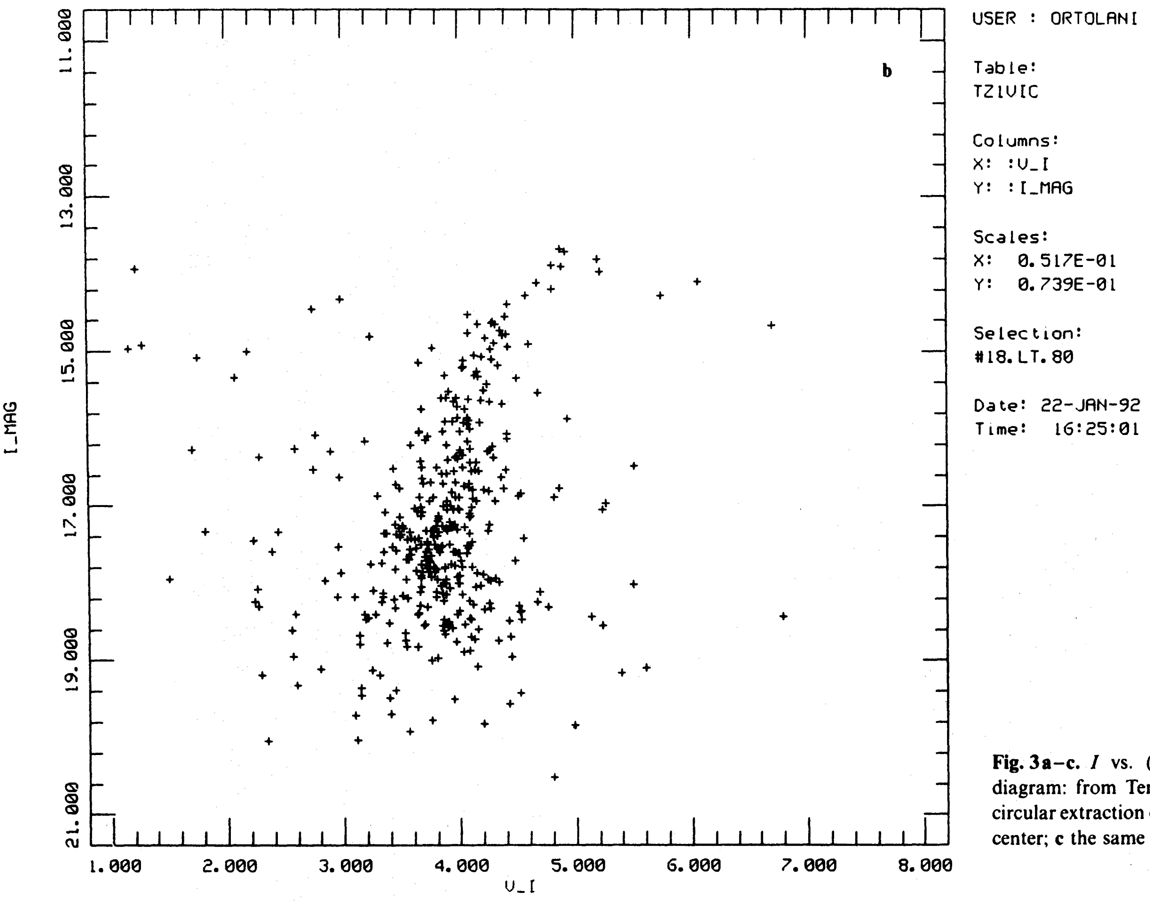


Fig. 3a–c. I vs. $(V-I)$ colour-magnitude diagram: from Terzan 1: **a** whole frame, **b** circular extraction of $r < 38''$ from the cluster center; **c** the same for $r < 12''$

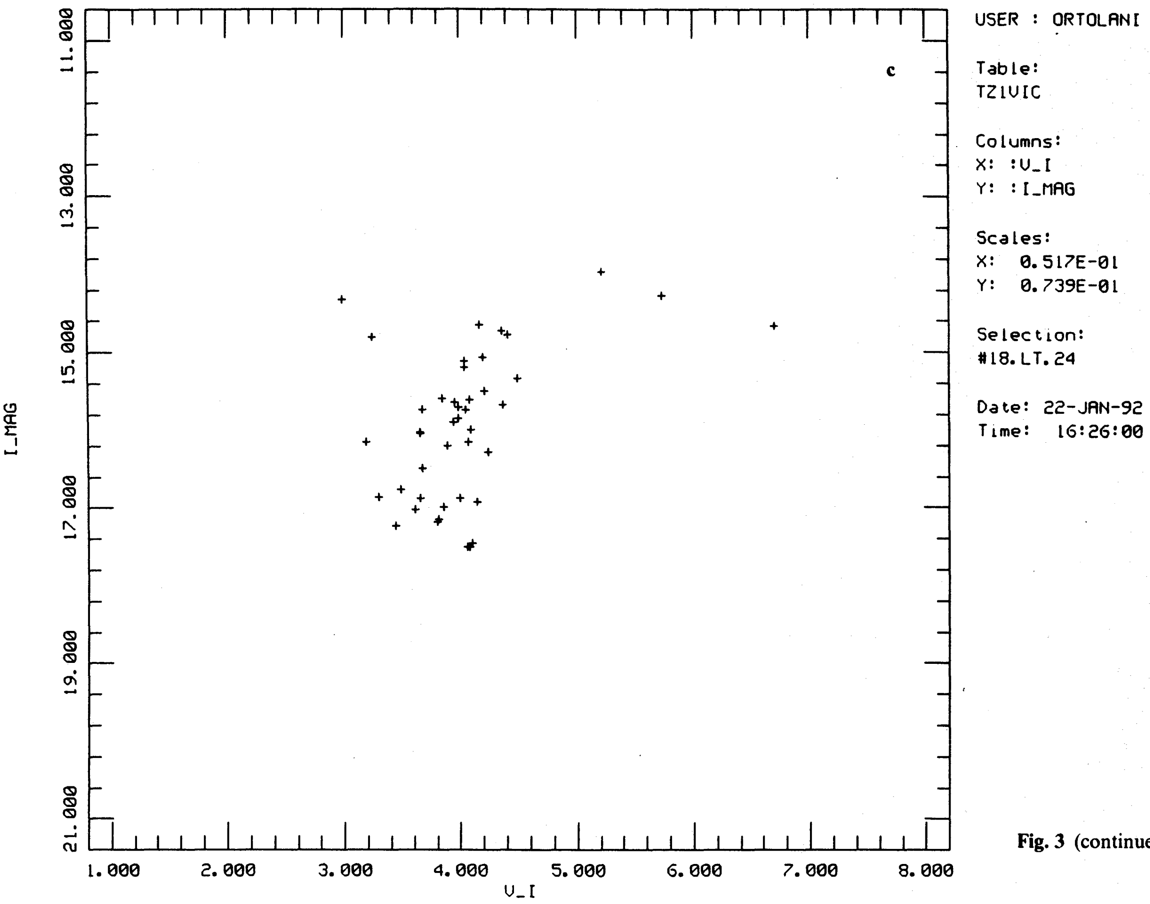


Fig. 3 (continued)

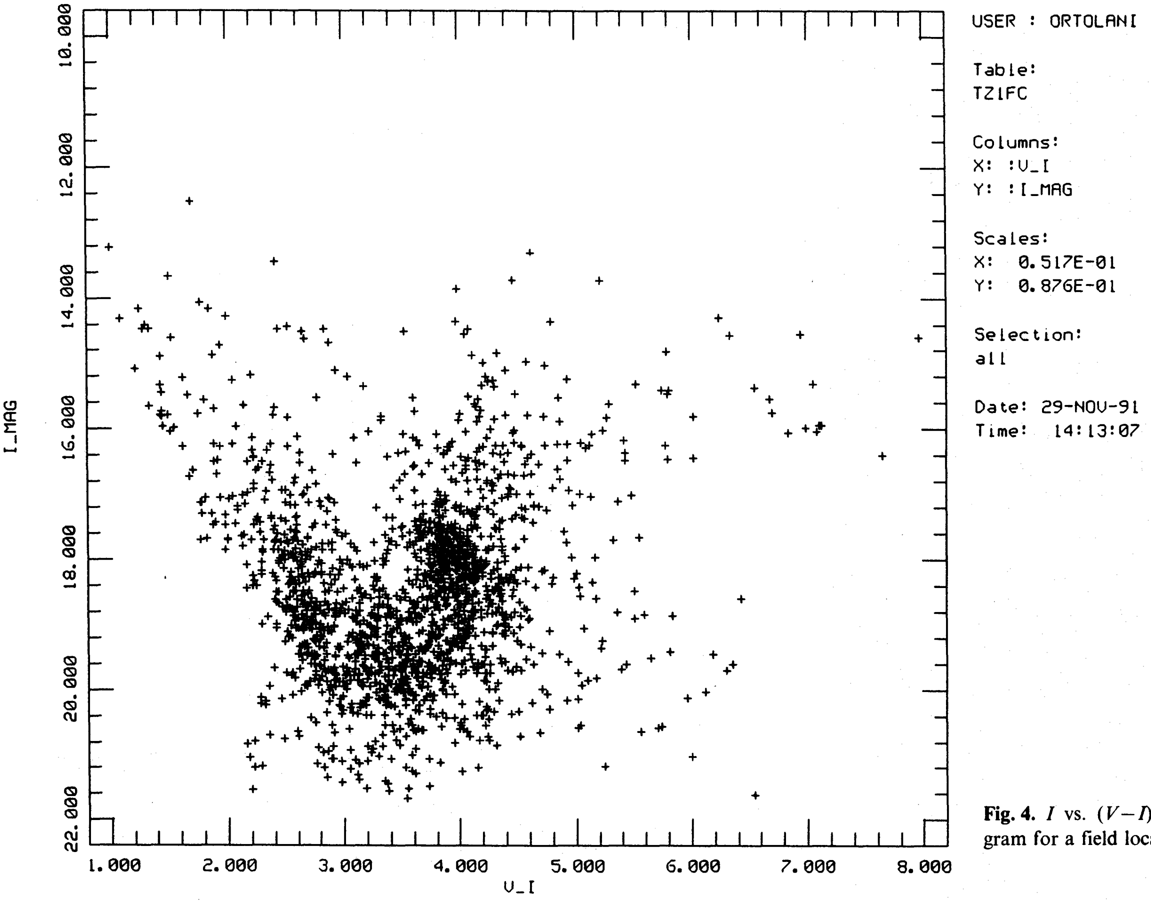


Fig. 4. I vs. $(V-I)$ colour-magnitude diagram for a field located 5′ NW of cluster

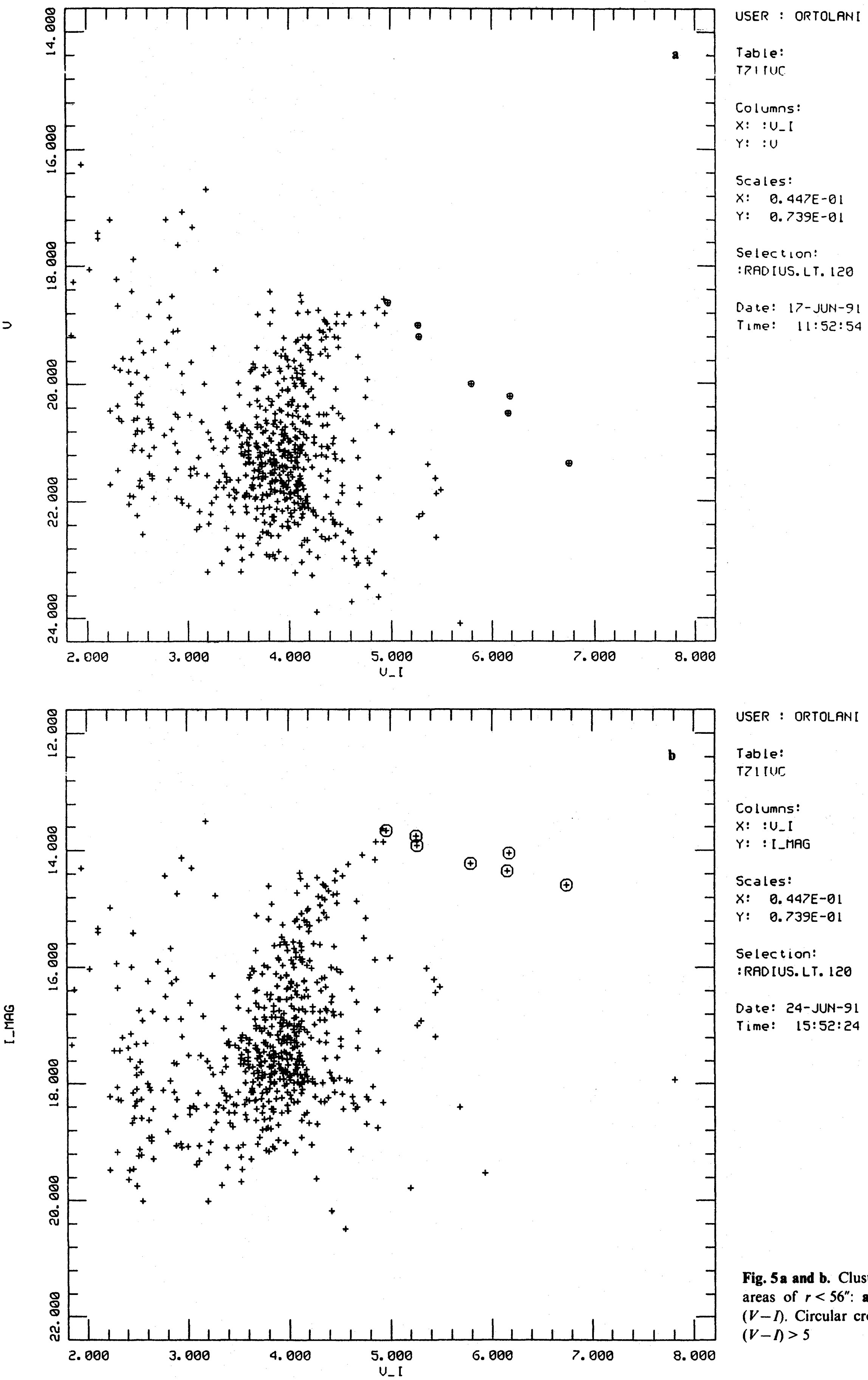


Fig. 5a and b. Cluster extraction in circular areas of $r < 56''$: **a** V vs. $(V-I)$; **b** I vs. $(V-I)$. Circular crosses are cool giants of $(V-I) > 5$

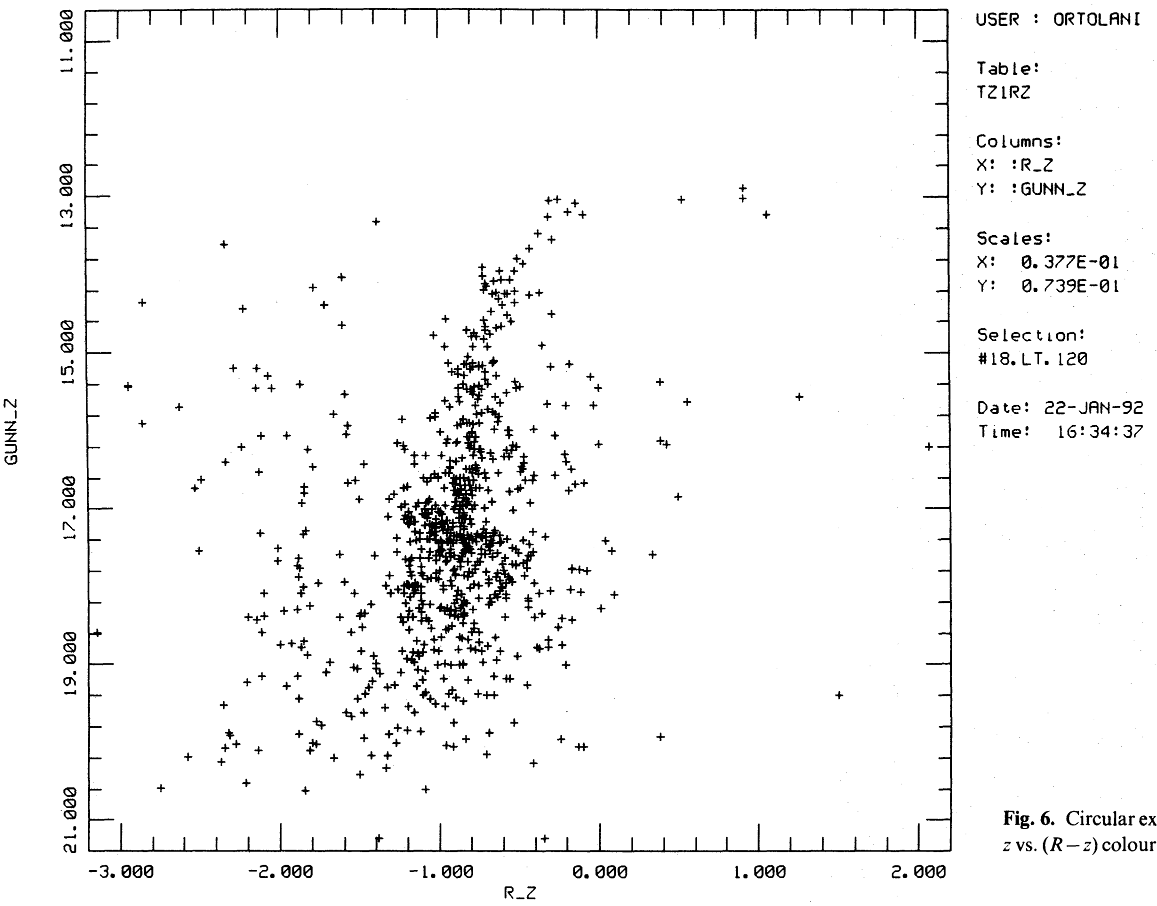


Fig. 6. Circular extraction of $r<56''$ for z vs. $(R-z)$ colour-magnitude diagram

the whole field, $r<38''$, and $r<12''$ respectively. This sequence shows how the blue disk MS gradually disappears while the cluster giant branch becomes clear, although the clump is close to the cutoff limit. The very prominent HB clump in the field and in Fig. 3a rapidly decreases in Figs. 3b and c, suggesting that it is indeed due to a field contamination. Another argument against the contamination of the faint feature as HB is the large magnitude difference relative to the brightest giants (Sect. 5.1). We interpret then as HB of the cluster the concentration of stars still present in Fig. 3c at $I\approx 15.9$ and $(V-I)\approx 4.0$.

3.2. *The red giant branch (RGB)*

The cluster RGB shows a pronounced arc structure, as already discussed in Ortolani et al. (1991). In V vs. $(V-I)$ (Fig. 5a), the RGB tip is possibly truncated by the V cutoff. This curved structure is more extreme than that in NGC 6553 and NGC 6528 (Papers I and II), as measured by the inclination of the descending RGB branch: $\Delta V/\Delta(V-I)\approx 1.47$ for Terzan 1 and ≈ 0.90 for the other two clusters. The cooler giants (those in the descending RGB) are identified in the plot with superimposed circles. The same stars are also identified in the I vs. $(V-I)$ diagram (Fig. 5b). Four of them are also indicated in the V vs $(B-V)$ diagram in Fig. 2, where the remaining ones are absent because they are too faint in B.

In the V vs. $(B-V)$ diagram the distribution of these stars completely superimposes with the ascending RGB. Unusually strong blanketing effects must play an important role in this peculiar morphology. These effects are minimized in the z band: we present in Fig. 6 the circular extraction for the instrumental z vs. $(R-z)$-diagram. The RGB curvature is less pronounced than in the previous figures, as expected, because of low opacity at these passbands.

4. The background field

Besides the I vs. $(V-I)$ diagram for the 5′ NW offset field we dispose also of a V vs. $(V-I)$ CMD. From a comparison with Terndrup's (1988), and our unpublished data on the Baade window (BW), the following remarks are worth:

(a) The blue disk main sequence in the Terzan 1 field is more prominent, as expected, because we are looking through a low latitude direction.

(b) The red HB is more elongated and tilted in Terzan 1's offset field (henceforth T1F), which suggests that reddening effects prevail over distance (depth) ones, whereas in the BW the two effects are comparable.

(c) The $(V-I)$ colour separation between the blue MS and the RGB measured at the HB level in the T1F's and BW's are respectively $\Delta(V-I)=1.2$ and 0.8. This reflects different distributions of dust clouds in the line of sight and/or different blanketing between the RGBs in the two fields.

(d) The cluster Terzan 1's CMD (as well as its offset field) presents a global shift in observed colour of $\Delta(V-I)>2.0$ mag with respect to that of the BW, which is mostly due to interstellar reddening.

4.1. *Comparison with the Baade window*

(e) The HB mean locus is at $V\approx 21.8$, $(V-I)=3.95$, and $V=17.0$, $(V-I)=1.65$ respectively for T1F's and BW's fields. Assuming that these bulge fields are on average at the same distance (that of the Galactic center), then we can calculate the relative amount of reddening and blanketing. If there is no relative blanketing effect, any colour difference should reflect only the reddening whereas the luminosity difference should be related to it by the reddening law. From total $\Delta(V-I)_T = 2.30$ we expect $\Delta A_V = 6.05$ against an observed difference between HBs of $\Delta V = 4.6$. This can be explained by a blanketing contribution. The observed ΔV quantity in fact corresponds to reddening $\Delta(V-I)_R = 1.75$, following Whitford's reddening law. This means that the blanketing effect in $(V-I)$ is not negligible, amounting at least to $\Delta(V-I) > 0.55$. A better estimate of the $(V-I)$ blanketing can be obtained from the longer wavelength passbands, because these are less affected by opacity. Using the I band, we derive $\Delta(V-I)_{\rm Redd} = 1.46$, which implies $\Delta(V-I)_{\rm Bl} > 0.85$. We recall that this is a lower limit, for two reasons: (a) we ignored the blanketing effects in the I band, at the HB level; (b) we ignored possible differences in the absolute luminosity of the HB's evolutionary models, due to metallicity.

T1F is projected closer to the Galactic center than the BW field. Our conclusion of higher average blanketing in the former might suggest a metallicity increase towards the center. However, it is clear that more fields are required for a conclusion about metallicity gradient. We note also that Tyson (1991), from Washington photometry CMDs found rather a "plateau" inside $b < 5°$.

4.2. *Comparison with models*

Another method to evaluate reddening and blanketing is through a comparison with the theoretical models for solar abundance by Alongi et al. (1992). The model predicts for the HB: $V = 1.25$, $I = 0.11$, $(V-I) = 1.11$, for $t = 15$ Gyr, helium content $Y = 0.28$ and overshooting parameter of 0.5. Applying this to the BW we derive $E(V-I) = 0.51$ or conversely $A_V = 1.34$ mag. This implies a distance modulus of $(m-M)_0 = 14.41$ corresponding to 7.6 kpc, in agreement with the literature (e.g., Terndrup 1988). For T1F we get $E(V-I) = 2.81$, $A_V = 7.4$, $(m-M)_0 = 13.05$ and $d = 4.0$ kpc. Such short distance for a metal rich bulge field seems unlikely. We conclude that T1F $(m-M)_0 = 14.72$ ($d = 8.8$ kpc for the Galactic center) and neglecting blanketing effects at the I band, then we can get a lower limit to the blanketing contribution at the HB $(V-I)$ colour. Using $I_{\rm HB} = 17.75$ (Fig. 4) then $A_I = 3.03$ and $E(V-I)_{\rm Redd} = 1.92$. This result compared with the observed value $E(V-I) = 2.81$ provides a blanketing component of $\Delta(V-I)_{\rm Bl} > 0.89$ in good agreement with the value obtained in Sect. 4.1.

We conclude that, if the two fields are at comparable distances, T1F's field stellar population is more metal-rich than that of the BW. If one assumes equal metallicity, the T1F's field should be located approximately at half way between the Sun and the Galactic Center, which appears unrealistic given the large fraction of old bulge component observed in this direction. The blanketing excess between T1F and BW should be at least $\Delta(V-I) > 0.85$.

5. Cluster parameters

5.1. *Reddening and distance*

A method currently used to derive the reddening from CMDs of globular clusters is the $(B-V)_0$ colour of the SGB at the level of the HB. Unfortunately, in our case this procedure cannot be followed because (a) there are no templates for high metallicities and (b) V vs. $(B-V)$ photometry is not deep enough.

5.1.1. HB model comparison

The cluster HB is detected in the I vs. $(V-I)$ diagram (Fig. 3c) at $I \approx 15.95$.

The distance modulus and reddening can be simultaneously obtained if the absolute magnitude of the HB is known, once the true distance (Sun–Galactic center 8.8 kpc, cf. Harris 1976) is used. Unfortunately the HB absolute magnitude level depends on the (unknown) metallicity. Theoretical models show, however, that around solar metallicity the dependence on the $M_I^{\rm HB}$ on the metal abundance is quite low and the conservative value for a solar abundance $M_{I0} = 0.11$ can be adopted. Using this value, a distance modulus $(I-M_I) = 15.84$ is obtained. Since the HB colour predicted by the model is $(V-I) \approx 1.14$, and the observed value is $(V-I) \approx 4.0$, then a colour difference $E(V-I) = 2.86$ is obtained. This implies $A_I = 4.51$ (or $A_V = 7.52$), giving $(m-M)_0 = 11.33$ or $R = 1.8$ kpc.

The distance so derived appears to be too small for this cluster, which shows:

(a) very high absorption $A_V = 7.38$ for such a short distance

(b) such a high metallicity cluster would be expected to be close to the Galactic center.

Clearly this reddening determination is affected by blanketing effects, which were not as severe in the models.

Adopting the blanketing corrected reddening $E(V-I) = 1.92$ (or $A_I = 3.03$), already derived from the field (Sect. 4.2), we get $(m-M)_0 = 12.77$ and $s = 3.7$ kpc. An analogous calculation from the V band provides $d = 5.5$ kpc. This discrepancy could be due to a deviation from the standard Whitford reddening law and/or inadequacy of solar models applied to more metal-rich populations.

5.1.2. Comparison with the field

The CMDs of the field background, and the cluster, show that the $(V-I)$ colours of the HBs are approximately the same $(V-I) \approx 4.0$ (Figs. 3 and 4). This suggests that reddening is comparable, given that the metallicities appear not to be very different. There is a magnitude difference $\Delta V = 21.7-19.95 = 1.75$ mag (cluster HB is brighter).

A high metallicity for the cluster is as well supported by the descending RGB also in I and Gunn z bands (see Sect. 3.2). From $\Delta V_{\rm HB} = 1.75$ found above, we get a distance for Terzan 1, from the Sun, of at least $d = 4$ kpc, if a distance of 8.8 kpc is adopted for the field (Sect. 4.3), comparable to the distance of NGC 6553. The reddening $E(V-I) = 1.92$ (Sect. 5.1.1) corresponds to $E(B-V) = 1.67$, which is slightly larger than the value $E(B-V) = 1.52$ derived by Malkan (1982) from integrated infrared photometry.

5.1.3. RGB method

An independent way to estimate the reddening and distance is by using the luminosity of the brightest giants and the colour of the SGB + hot RGB. In order to minimize blanketing effects, we use the I magnitude and the $(V-I)$ colour. We use reference 47 Tuc with $M_{I0} = -4.0$ and $(V-I)_0 = 1.00$ (da Costa & Armandroff 1990). For Terzan 1 we obtain $I = 13.85$ and $(V-I) = 3.90$ which provides a distance from the Sun $d = 3.6$ kpc. This distance is comparable to those derived from the HB (Sect. 5.1.1, 5.1.2). Applying the same method to NGC 6553 (Paper I), we get $I = 11.6$, $(V-I) = 2.05$ and $d = 5.5$ kpc. This value is in agreement with the value $d = 4.9$ kpc given in Paper I.

This RGB method is of course blanketing dependent, since even in I the brightest giants in such a metallic cluster as Terzan 1 are blanketed. However the blanketing effects on the distance modulus caused by the magnitude and the colour are opposite, and basically cancel out.

This simple method shows that the identification of the Terzan 1 HB at $I=15.95$ appears to be correct.

5.2. *Metallicity and blanketing*

Some clusters of the Galactic bulge are already known to have high metal content. Armandroff & Zinn (1988) presented an integrated spectrum of Terzan 1 in the near-infrared Ca II region which appeared to be of a metallicity similar to that of 47 Tuc. This is in contradiction with our CMDs and also with Malkan's infrared photometry. There is reasonable agreement between Malkan and Armandroff & Zinn for the other clusters, except Terzan 1. In a careful check of the Terzan 1 images, we realized that superimposed to the cluster we find at least two field stars, considerably brighter and bluer than cluster giants, located at 2″.5 and 10″ from the cluster center. They of course affect much more the integrated observations at shorter wavelengths (Bica 1991).

The RGB morphology of Terzan 1 indicates that it is more blanketed than any other cluster so far studied with CMDs, including the solar metallicity cluster NGC 6553 (Barbuy et al. 1992). Non-linear behaviour of blanketing indicators as a function of $\approx Z/Z_{\odot}]$ have been found (Burstein 1979; Bica & Alloin 1986; Barbuy et al. 1992). A preliminary derivation of the metallicity could be obtained from V blanketing estimate for Terzan 1 and magnesium triplet feature blanketings obtained from the models in the latter reference, resulting $[M/H]>0.5$.

From our analyses in Sects. 4 and 5, the cluster Terzan 1 and its field appear to be significantly more blanketed than the BW and the solar model. We have estimated about $\Delta(V-I)_{\rm B}>0.8$–0.9 (see Sect. 5.13).

By superimposing I vs. $(V-I)$ and z vs. $(R-z)$ diagrams we can estimate the blanketing in the I band taking as reference the Gunn z photometry which is located in an almost line-free region. Assuming that the hottest main sequence stars are not blanketed in I and z, we get $\Delta(I-z)=0.65$ for the HB stars. This is the upper limit for the blanketing, since reddening effects may be present. A similar calculation for NGC 6553 leads to no differential blanketing at the HB $[(V-I)_0=1.03]$ between the I and z passbands. However, NGC 6553 also provides a blanketing $\Delta(I-z)_{\rm B}\approx 0.6$ when the RGB at the same intrinsic colour $(V-I)_0\approx 2.1$ is considered, which basically shows that a temperature decrease can mimic a blanketing effect caused by high metallicity. In Barbury et al. (1992) a more detailed discussion is presented showing that the colour shift is due to metallicity.

6. Conclusions

From the analysis of the peculiar *BVRIz* CMDs of Terzan 1, we found:

(a) The cluster is heavily contaminated by the field population.

(b) The cluster horizontal branch is located at equal $(V-I)$ colour as that of the field, but at $\Delta V=1.75$ mag brighter.

(c) The cluster and its field are clearly more metal-rich than the Baade window and the solar metallicity models.

(d) Using the HB as reference, we derived a reddening of $E(B-V)=1.67$, and a distance of 4–5 kpc from the Sun, if the bulge field population is located essentially at the Galactic center. A similar distance is obtained for Terzan 1 using the RGB as distance indicator.

(e) We estimate the excess blanketing with respect to the Baade window population and solar metallicity models of $\Delta(V-I)>0.8$–0.9 and $\Delta I_{\rm B}\approx 0.6$.

(f) The blanketing appears to be more extreme than in any globular cluster so far studied in detail, including the previously analysed metal-rich bulge clusters NGC 6553 (Paper I) and NGC 6528 (Paper II).

These results are of major importance for the interpretation of data on metal-rich stellar populations and should be taken into account for the computation of metal-rich stellar evolutionary tracks.

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