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Letter to the Editor

Metal-rich globular clusters: giant branch morphology as a metallicity criterion*

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Summary. We have obtained VI CCD photometry of the very metal-rich inner bulge globular clusters NGC 6528, NGC 6553 and Ter 1, and of 47 Tuc and NGC 6356, which are usually called metal-rich clusters.

We discuss the RGB morphology in the V vs. (V-I) and I vs. (V-I) diagrams for ranking the metallicities of these clusters. We used the arc-like structure present in their RGB, due to blanketing in the cooler giants, as a metallicity criterion, which is corroborated by line strengths in integrated spectra. We propose criteria of morphological parameters based on RGB inclination for increasing metallicities.

We conclude that Terzan 1 is the most metal-rich globular cluster of this sample.

Key words: Clusters: globular – Galaxy: bulge

1. Introduction

The metallicity scale of metal-rich globular clusters in the Galaxy still is a controversial issue. Different photometric calibration results are in conflict, and very few spectroscopic determinations of individual stars are available for bulge metal-rich clusters, because of their faintness.

The metallicities of the metal-poor clusters are relatively better established, the disagreements remaining for the clusters of metallicities above [M/H] $\approx$ -1.0.

Accurate colour-magnitude diagrams (CMDs) in colours such as V, R, I can provide additional information on the metallicities of globular clusters, as originally suggested by Lloyd Evans and Menzies (1977), Lloyd Evans (1983).

Recently, Da Costa and Armandroff (1990) have studied the RGB morphology of metal-poor to intermediate-metallicity clusters, in M_I vs. (V-I), for the range [M/H] $\approx$ -2.0 to $\approx$ -1.0, where a colour shift towards the red was studied as a metallicity effect, and used to calibrate the moderate metallicity clusters Pal 12 and Eridanus. No further peculiar RGB morphology was found in their metallicity range.

In the present work we study globular clusters of metallicities in the range [M/H] $\approx$ -0.8 to probably above solar (Zinn & West, 1984; Webbink, 1985 for a compilation). The observations are CCD BVRI CMDs for 47 Tuc, NGC 6356, NGC 6528, NGC 6553 and Terzan 1. NGC 6553 diagrams were discussed in detail by Ortolani et al. (1990, hereafter OBB90), whereas those for 47 Tuc (B and V) were studied by Aurière and Ortolani (1988). Now we have gathered a complete new set of data for 47 Tuc, NGC 6528, NGC 6356 and Terzan 1.

In this Letter we present CMD morphology parameters which appear to be suitable for ranking metal-rich clusters, as confirmed by integrated spectra. Detailed CMD analyses of the individual clusters which are not yet published, will be presented in forthcoming papers.

2. Observations

High quality VI CCD frames, using Johnson-Cousins system as defined by Landolt (1983) were obtained at the 1.5m Danish telescopes and at the 3.5m New Technology Telescope - NTT at the European Southern Observatory (ESO), La Silla, Chile, under excellent seeing conditions (FWHM from 0.65" to 1.0").

The reductions were made with the Daophot code adapted to the Midas package at ESO-Garching.

3. Results

3.1 CMD morphological parameters

The V vs. (V-I) and I vs. (V-I) colour combinations are used for the study of the red giant branch (RGB) morphology of the program clusters.

Our criterion is based on the strong V band blanketing due to the presence of TiO bands which become very deep in metal-rich cool giants, as well as other important absorbers such as MgH and C_2 molecular bands, as shown in model atmosphere calculations (e.g., Barbuy, 1989), whereas the I band (λ_e = 7900) Å contains relatively weaker molecular absorption.

In figures 1a and 1b we show the calibrated I vs. (V-I) diagram for NGC 6528 and Terzan 1, respectively. Notice the curved red giant branch (RGB) in Terzan 1, which is neither present in NGC 6528 nor in NGC 6553 (OBB90). In other CMDs such as V vs. (V-R), NGC 6528 (Ortolani, Bica & Barbuy, 1991) and NGC 6553 present curved RGB, which in turn are absent in clusters which are not so metal-rich. Compar-

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

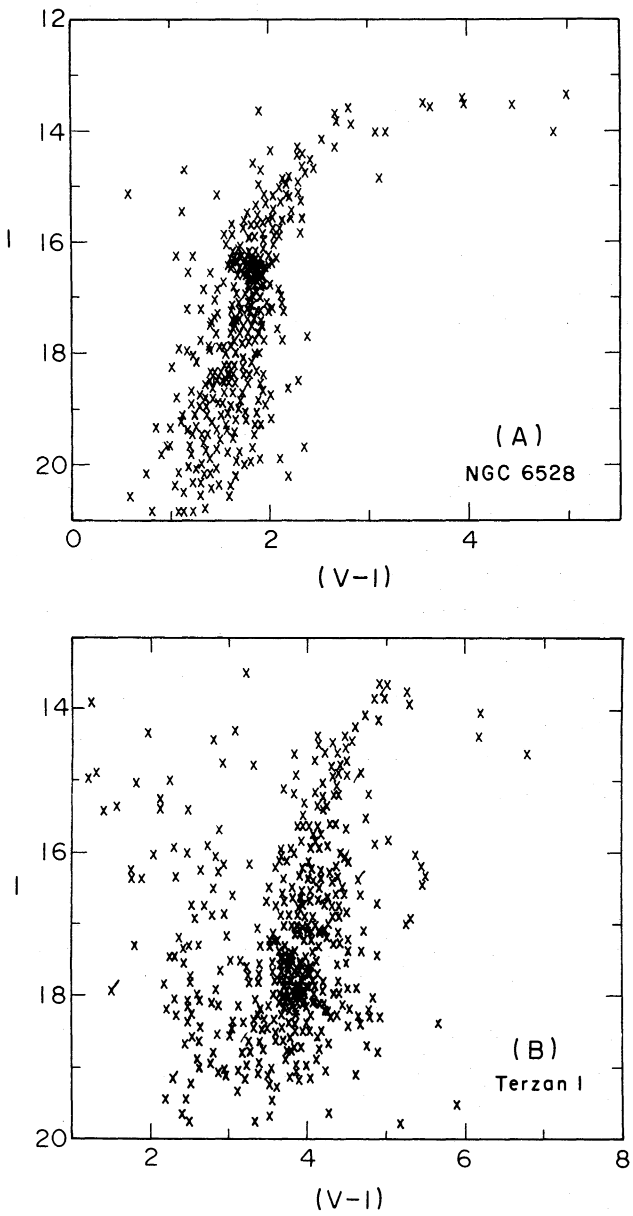

Figure 1 - Observed I vs. (V-I) diagram for (a) NGC 6528 and (b) Terzan 1. The points correspond to a circular extraction of 0.9 arcmin around the cluster center. Notice the different inclinations of the descending RGB. The strong concentration of stars in Terzan 1 corresponds to the horizontal branch.

Table 1 - Morphological parameters defined in the present paper, concerning the RGB morphology of metal-rich clusters

name or NGC	$\Delta V/\Delta(V-I)$	$\Delta I/\Delta(V-I)$	$W_{822-873\ nm}(\text{Å})$
47 Tuc	0.77 ± 0.07	-0.24 ± 0.07	13.2 ± 2.9
6356	0.80 ± 0.07	-0.16 ± 0.07	17.6 ± 1.5
6528	0.82 ± 0.07	-0.06 ± 0.07	36.5 ± 1.8
6553	0.92 ± 0.20	-0.02 ± 0.10	58.6 ± 2.9
Ter 1	1.47 ± 0.20	$+0.56 \pm 0.07$	– – –

isons of this kind suggest that metallicity differences might be detected according to the behaviour of the RGB morphology in different CMDs. Morphological parameters connected with blanketing, in a given metallicity range, may saturate in particular magnitude-colour combinations, but not in others.

Two main RGB characteristics are seen in Figures 1a and 1b for these metal-rich clusters: the inclination and the red extension of the RGB tip. The latter property appears to vary from cluster to cluster, and might be used also as morphological parameter, but it is dependent on stochastic effects from a few stars.

As morphological indicators we define the following inclination parameters:

(i) The inclination of the descending RGB (cooler giants) in the V vs. (V-I) diagram: $\Delta V/\Delta(V-I)$.

(ii) The inclination $\Delta I/\Delta(V-I)$ similarly to (i) (see also Figure 1).

The results are shown in Table 1. We point out the striking inclination derived for Terzan 1.

3.2 Integrated spectra

In recent years many metallicity estimate compilations using different methods, mainly from integrated photometry, have been published (e.g., Zinn & West, 1984; Webbink, 1985). These are very useful as a preliminary indication of metallicity, but sometimes their rankings are contradictory, in particular for highly reddened and metal rich clusters.

High quality spectra are required in order to establish more precise rankings. In the present work we use near infrared integrated CCD spectra of NGC 6356 and NGC 6528 (Bica & Alloin, 1987) and more recent ones for 47 Tuc and NGC 6553 taken at the ESO 1.52m telescope.

These spectra are presented in Figure 2 for the region $\lambda\lambda$ 8150 - 8750 Å, containing the CaII triplet and TiO + CN molecular absorptions. The line strength is clearly decreasing from top to bottom. Measured equivalent widths in the range $\lambda\lambda$ 8220 - 8730 Å, are shown in column 4 of Table 1. These equivalent widths are metallicity indicators (Alloin & Bica, 1989; Erdelyi-Mendes & Barbuy, 1991), and moreover they are reddening independent.

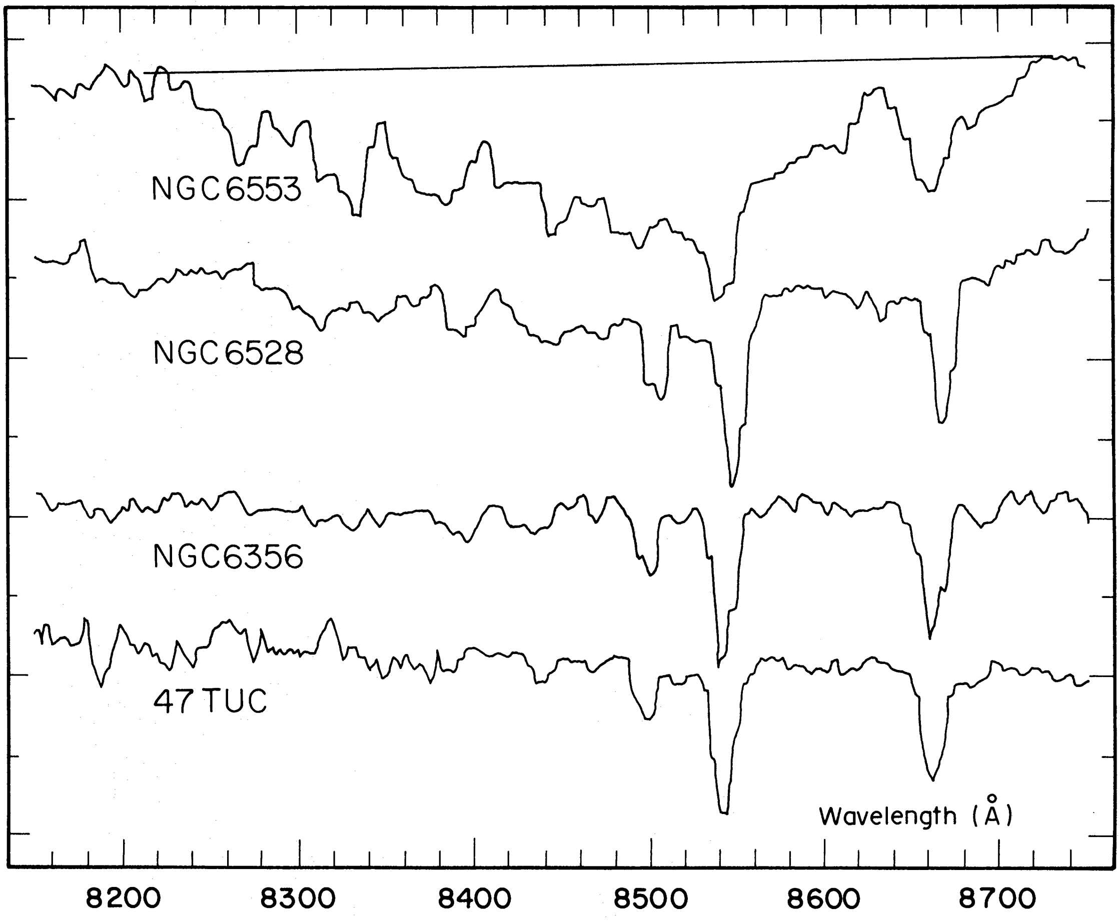

Figure 2 - Near infrared CCD spectra in the CaII triplet region for 47 Tuc, NGC 6356, NGC 6528 and NGC 6553. The continuum tracing adopted is indicated.

3.3 Discussion

The CMD morphological parameter and the equivalent widths point to the same metallicity ranking for the clusters: 47 Tuc, NGC 6356, NGC 6528 and NGC 6553 in order of increasing metallicity.

Based on the inclination parameters Terzan 1 is conclusively the most metal-rich cluster in the sample.

It should be noted that these criteria are very practical also for very reddened, faint and highly contaminated clusters. They are independent on the absolute calibration and almost insensitive to the reddening.

4. Conclusions

We have obtained a photometric CCD imaging method based on CMDs for ranking the metallicities of bulge globular clusters. This is a first step in the study of such generally very reddened clusters. A next step would be an accurate calibration of metallicities using high dispersion spectroscopy of individual stars belonging to these clusters.

We stress the importance of the arc-structure in the CMDs of metal-rich populations. In the future, this method may be the most suitable for studying bulges of external galaxies.

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