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Bright Stars and Metallicity Spread in the Globular Cluster ω Centauri

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Abstract. The globular cluster ω Centauri (NGC 5139) is the most massive and brightest cluster in our Galaxy. It has also a moderately high mass to light ratio (3.6) and an anomalous flattening (0.83) for a globular cluster. This cluster is also very interesting because it is one of a few examples of globular clusters with a measurable spread in the metal abundance (see Da Costa & Willumsen 1981, Norris et al. 1996, and Suntzeff and Kraft 1996 and references therein) and then it offers a unique, big sample of nearby stars having all the same distance and reddening but showing different metallicity (and age ?) effects. A recent paper by Norris et al. (1997) shows also an interesting correlation between kinematics and metal abundance.

1. Introduction

Most of the recent work has been based on spectroscopy, while little effort was done in analyzing the photometry. In this poster we present new, high accuracy photometry obtained at ESO La Silla with the New Technology Telescope (*NTT*) under good seeing conditions ($0.7''$ *FWHM*) in the inner regions of the cluster. In particular we will focus our analysis in the field located at $5'$ North of the cluster center, where the crowding is considerably lower than in the central region, but the field is still rich enough in stars to secure more than about 1000 objects between the Main Sequence (MS) Turnoff region (TO) and the Horizontal Branch (HB) in a 6 square arcminute field.

2. The Color-Magnitude Diagram

Fig. 1a shows the Color-Magnitude Diagram (CMD) obtained in this field. Overimposed are 15 *Gyr* isochrones for metallicities of $z = 0.0001, 0.0004$ and 0.004 (corresponding respectively to about $[Me/H] = -2.3, -1.7$ and -0.7), adopted

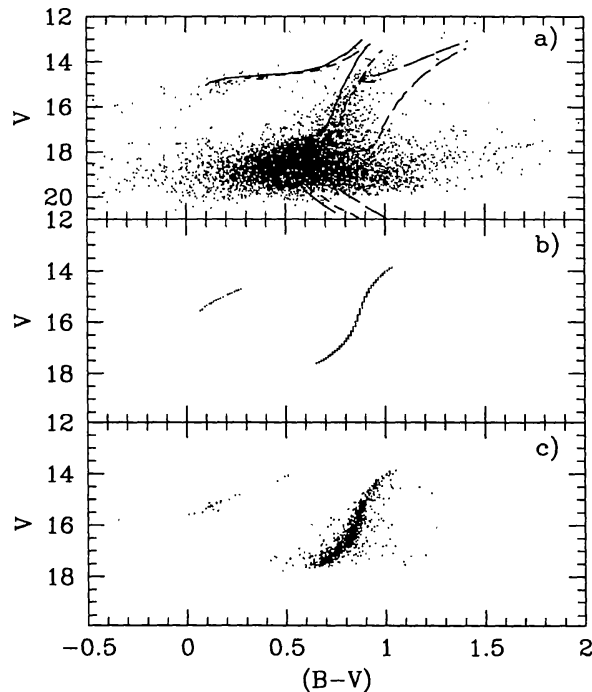


Figure 1. The bright portion of ω Centauri CMD. See text for details.

from Bertelli et al. (1994) and shifted by 0.12 *mag.* in $(B - V)$ and 14.1 *mag.* in V to get the best fit of the $z = 0.004$ isochrone with the data. The points follow quite well the two metal poor isochrones, from the HB to the TO, while the $z = 0.04$ isochrone clearly appears at the edge of the distribution, but still could explain the presence of a bump in the Sub Giant Branch (SGB) at about $V = 14.6 - 14.7$, due to metal rich HB stars superimposed. In order to evaluate the effects of instrumental errors on the CMD, we carried out several experiments with about 1000 artificial stars injected in the original frame, generated from the input CMD shown in Fig. 1b. The corresponding output is shown in fig. 1c. A close analysis of the results from the simulations indicate that the output diagram is systematically shifted upwards, compared to the input one, as a consequence of blending.

The resulting spread is also higher than that obtained simply combining the photometric errors in the two colors from single stars.

3. Comparison with Metallicity Data

Fig. 2a presents the histogram distribution in color of the observed data, Fig. 2b the histogram distribution from the artificial CMD and Fig. 2c the distribution of the SGB stars metallicities observed by SK without any compensation for radial and evolutionary effects. The shape of the two histograms is surprisingly similar in spite of the different samples used (SK sample is located at about $10'$ from the cluster center, while ours is at $5'$), with a tail toward the highest metallicities and redder colors.

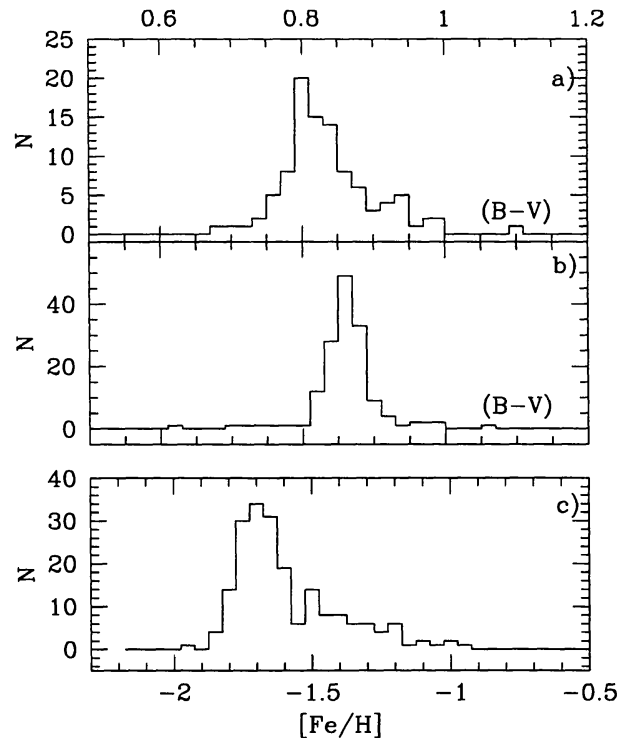


Figure 2. Comparison between metallicity and photometry.

The problem of the existence of a secondary peak due to a metal rich broad distribution discussed by Norris et al. (1997) cannot be confirmed by the present data but will be further investigated after the analysis of the full set of the available data.

Our comparison of the spectroscopic metallicities with the photometric ones is based mainly on the intrinsic width of the SGB compared with the width computed from the spectroscopically determined metallicity spread. We used Suntzeff and Kraft paper (1996) as a reference because they measured a wide and consistent sample in the SGB. Fig. 3a has been obtained from their original data (Tab. 3b). It shows the relation $[Fe/H]$ versus $(B - V)$ dereddened color (see also their fig. 9), where the high resolution metallicity scale was chosen. The solid line superimposed to the data is the theoretical relationship derived from Bertelli et al. (1994), for an age of 15 *Gyr*, at the level of 0.44 *mag.* below the HB, corresponding to SK sample of stars. The dashed line has been obtained using younger models (9 *Gyr*) for the $[Fe/H] = -0.7$ isochrone. Fig. 3b is the same as fig. 3a but for the sample of SK giant stars located within 6.2' from the cluster center. Two facts are evident from these figures:

- the spread in both metallicity and $(B - V)$ color is very wide. At a fixed metallicity the color range spans about 0.2 *mag.*, while at a given color the metallicity goes from $[Fe/H] = -1.8$ to -1.0 . This wide range is higher than the expected observational errors, even if it is not easy to get an estimate of the photometric errors in the colors published by SK (which are derived from Wolley, 1966);

- the $[Fe/H]$ versus $(B - V)$ relationships are roughly in agreement with the general trend of the data and they get steeper for a younger age of the metal rich component, as it is evident from the analysis of fig. 3c, where isochrones of 15 and 9 *Gyr* are shown, respectively.

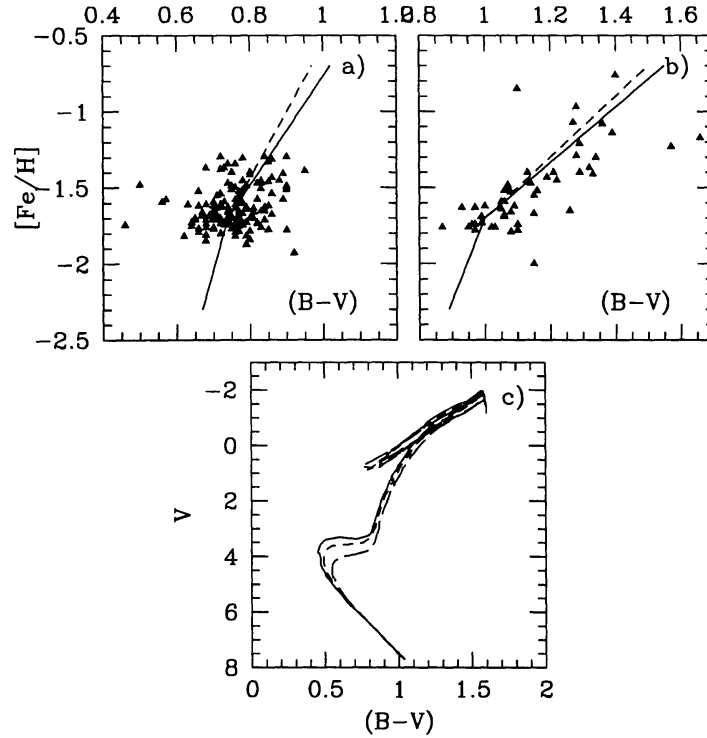


Figure 3. Metallicity vs dereddened colors. See text for details.

4. Discussion

This younger age is still compatible with the data. An analytical, approximate expression for the intrinsic width of the SGB can be given in the following simplified form

$$\begin{aligned} \Delta(B - V) &= \sqrt{\left(\left(\frac{d(B - V)}{d[Fe/H]}\right) \times \Delta[Fe/H]\right)^2 + \left(\frac{d(B - V)}{d\tau} \times \Delta\tau\right)^2} = \\ &= \sqrt{\left((0.23 \times \Delta[Fe/H])^2 + (0.01 \times \Delta\tau)^2\right)}. \end{aligned} \quad (1)$$

where τ is the age measured in billion years. The factor $\Delta\tau$ is negative for increasing age at a metallicity higher than the average, positive if lower. Using a metallicity spread $\sigma[Fe/H] = 0.2 \text{ dex}$ obtained by SK for the SGB sample, corrected for radial effects, we derive a theoretical $\sigma_{(B-V)} = 0.26 \times 0.23 = 0.06 \text{ mag.}$ when no age difference is assumed between the metallicity components. From our data in fig. 1 we measured a SGB, width at $V = 15.8$ in a half magnitude bin in our data obtaining $\sigma(B - V) = 0.064 \text{ mag.}$ From the artificial CMD in the same bin we get $\sigma(B - V) = 0.047 \text{ mag.}$, indicating that an important fraction of the color spread is coming from instrumental errors.

The deconvolution gives a final $\sigma(B - V) = 0.043 \text{ mag.}$, which is smaller than the predicted one. This is still an upper limit because binary stars, peculiar objects and field stars contributes in widening the intrinsic distribution. Similar results are obtained changing the bin width and the position along the SGB. Possible explanations to this relatively narrow photometric dispersion are the following:

- (1) individual element ratios are effective in reducing the global $[Me/H]$ spread, or
- (2) the metal rich component is some billion years younger than the metal poor one, as discussed by Norris et al. (1997).

The first hypothesis implies a trend of decreasing *CNO* or *s*-elements with increasing *Fe*, which is not supported by from Norris and Da Costa (1995) high resolution analysis. The age effect is an interesting possibility, with important consequences on the metal enrichment history of the cluster, but further work is still needed to check if the observed residual is due to some systematical effects in the color transformations or in other ingredients used in the theoretical models (Cayrel et al., 1997). A further test could be the measurement of the MS intrinsic width (see also Noble et al., 1991, Bell and Gustafsson, 1983). Unfortunately the color-metallicity relationship in the MS is expected to give a color spread about twice smaller than in the SGB. Our tests performed from the best photometry at about 1 *mag.* below the turnoff show that the intrinsic width is completely hidden by the binary star sequence.

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