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# Infrared photometry of giants in the globular cluster NGC 4833

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**Abstract.** Infrared broad band JHK photometry is presented for 21 red giants in the metal-poor globular cluster NGC 4833. The colour magnitude and colour-colour correlations are discussed. Bolometric luminosities are calculated from apparent K magnitudes by using bolometric corrections for giants. A comparison with Yale isochrones gives most likely age of this cluster to be about $12 \times 10^9$ yr.

*Key words* : globular cluster—infrared photometry—red giant stars

## 1. Introduction

NGC 4833 ($\alpha$ (1950) = $12^h\ 56^m.0$, $\delta$ (1950) = $-70°\ 36'$) is a metal poor globular cluster. The galactocentric distance and the distance from the sun for NGC 4833 are 7.6 kpc and 5.2 kpc respectively (Menzies 1972). Those for $\omega$ Cen are 7.1 kpc and 5.5 kpc respectively (Alcaino 1973). The radii ($r_h$) of NGC 4833 and $\omega$ Cen are 3.3 pc and 6.0 pc respectively (van den Bergh & Morbey 1984). van den Bergh & Morbey (1984) also have found that the correlation co-efficient between $\log R$ and $\log r_h$ is $0.62 \pm 0.07$ and between $\log R$ and metallicity [Fe/H] is $-0.57 \pm 0.07$.

Menzies (1972) studied the photoelectric and photographic photometry of 800 stars in this cluster. Broad-band infrared photometry of the 10 brightest and reddest stars in this cluster has also been studied by Frogel, Persson & Cohen (1983 $\equiv$ FPC). The infrared broad-band J (1.25 micron), H (1.65 micron) and K (2.2 micron) photometry of 21 red giants is presented in this paper.

## 2. Observations

Twentyone red giants, mostly from the outer zone C and a few from zone B, were observed. The observations were made with the 1.9 m telescope of Mount Stromlo Observatory during 1983 March–April. An InSb detector cooled to liquid nitrogen temperature was used for detection. We used a set of standard *JHK* filters. A 13

arcsec aperture was used except for a few occasions when the seeing was very poor. The beam separation was 54 arcsec in the east-west direction; stars which would have had another star in the reference beam were not observed. In most of the runs the photometric measurements were continued until the statistical error was less than 0.01 mag but for a few cases the error was up to 0.03 mag. The nearby standards BS 4773, BS 4802, *Y* 3992 and *Y* 3924C of spectral type *F* to *M* were observed several times. The broadband *J*, *H* and *K* magnitudes of 21 giants were determined.

## 3. Results and discussion

The observed JHK magnitudes were corrected for airmass and reddening effect. The reddening corrected *K* magnitudes ($K_0$) were corrected for distance modulus, and absolute *K* magnitudes ($M_K$) were obtained.

The $E_{B-V} = 0^m.36$ (FPC) and the distance modulus $(m - M) = 13.66$ corresponding to a distance of 5200 $\pm$ 450 pc (table 1) were adopted for the cluster. The absorptions in the infrared were calculated as $A_J = 0.29 \pm 0.01$, $A_H = 0.18 \pm 0.01$ and $A_K = 0.11 \pm .01$, considering the colour-excess ratios of the van de Hulst theoretical curve, as shown by Johnson (1968).

**Table 1.** Physical parameters of NGC 4833

| $E(B-V)$ | $(m-M)_V$ | $r_h^*$ | $R$ kpc | [Fe/H] | Rad. vel. km s$^{-1}$ | Notes |
|---|---|---|---|---|---|---|
| 0.34 | 14 | | 7.6 | −1.86 | +186 | a |
| 0.34 | 14.90 | | 7.6 | −1.37 | +216.6 | b |
| 0.36 | 13.70 | | | −1.91 | | c |
| | | 3.3 | 7.6 | −2.15 | | d |

*$r_h$ is the radius containing half of the cluster stars in projection.
[a]Zinn & West (1984).
[b]Pilachowski, Sneden & Wallerstein (1983).
[c]Frogel, Cohen & Persson (1983).
[d]van den Bergh & Morbey (1984).

As suggested by McGregor & Hyland (1981), $(J - K)_0$ could be used as an indicator of effective temperature for cool stars. So effective temperatures were determined following the calibration of Bessell, Wood & Lloyd Evans (1983), where they obtained an empirical relation between $T_e$ and $J - K$ which appears to hold equally well for carbon stars and oxygen-rich giants. The bolometric corrections were determined following Frogel, Persson & Cohen (1981) and bolometric luminosities were obtained. The star numbers (Menzies 1972), absolute *K* magnitudes $M_K$, corrected colours $(J - H)_0$ and $(H - K)_0$, bolometric luminosity ($M_{bol}$), and effective temperature ($T_{eff}$) are listed in table 2.

### 3.1. *The colour-magnitude diagram* [$K_0$ *vs* $(J - K)_0$]

The $K_0$ magnitude and $(J - K)_0$ colour of the giants in NGC 4833 are shown in figure 1, along with the transformed (Elias *et al.* 1983) colour and magnitude of

**Table 2.** Reddening corrected and derived data

| No. | $K_0$ | $M_K$ | $(J-H)_0$ | $(H-K)_0$ | $M_{bol}$ | $T_{eff}$ |
|---|---|---|---|---|---|---|
| Zone B | | | | | | |
| 150 | 10.54 | −3.12 | 0.56 | 0.07 | −1.16 | 4830 |
| 168 | 9.18 | −4.48 | 0.65 | 0.06 | −2.18 | 4220 |
| 181 | 12.26 | −1.40 | 0.55 | 0.00 | +0.42 | 5160 |
| 185 | 10.24 | −3.42 | 0.66 | 0.06 | −1.30 | 4520 |
| 199 | 12.14 | −1.52 | 0 54 | 0.05 | +0.34 | 5000 |
| 200 | 9.30 | −4.36 | 0.70 | 0.10 | −2.12 | 4350 |
| Zone C | | | | | | |
| 7 | 10.78 | −2.88 | 0.52 | 0.09 | −0.92 | 4800 |
| 26 | 10.91 | −2.75 | 0.55 | 0.06 | −0.82 | 4900 |
| 81 | 8.62 | −5.04 | 0.70 | 0.12 | −2.73 | 4200 |
| 129 | 9.68 | −3.98 | 0.64 | 0.08 | −1.86 | 4520 |
| 143 | 10.29 | −3.37 | 0.62 | 0.08 | −1.26 | 4590 |
| 144 | 9.97 | −3.69 | 0.62 | 0.10 | −1.52 | 4430 |
| 177 | 10.90 | −2.76 | 0.55 | 0.10 | −0.72 | 4650 |
| 288 | 11.19 | −2.47 | 0.35 | 0.12 | −0.81 | 5550 |
| 230 | 11.30 | −2.36 | 0.44 | 0.08 | −0.59 | 5300 |
| 233 | 11.11 | −2.55 | 0.42 | −0.10 | −1.20 | 6500 |
| 235 | 9.77 | −3.89 | 0.57 | 0.07 | −1.80 | 4550 |
| 257 | 10.73 | −2.93 | 0.55 | 0.09 | −0.96 | 4800 |
| 274 | 10.81 | −2.85 | 0.52 | 0.05 | −1.01 | 5080 |
| 290 | 11.50 | −2.16 | 0.42 | 0.04 | −0.51 | 5600 |
| 296 | 10.35 | −3.31 | 0.66 | 0.11 | −1.20 | 4500 |

the giants in the metal poor clusters M92 and M13 (Cohen, Frogel & Persson 1978) and the metal rich cluster 47 Tuc (Frogel, Persson & Cohen 1981). The colour and magnitude of NGC 4833 giants studied by FPC are also plotted.

The figure shows considerable scatter at lower luminosities, with $K_0 \simeq 11.0$ mag, at higher luminosities the dispersion in $(J-K)_0 \simeq 0.02$ mag which is within the limit of our statistical error. The spread at $(V-K)_0 \simeq 0.10$ mag is typical in all the cluster giants. Menzies (1972) has mentioned a large scatter of stars below the giant branch in the $C-m$ diagram at low luminosities $B \leqslant 17^m.4$. He also has suggested that this scatter is probably due to the effects on the fainter stars of undetected faint companions. The limit of our observation in $K \simeq 12$ mag. It has been shown by Da Costa, Frogel & Cohen (1981) for the case of NGC 3201 that reddening variation will have a larger effect on the width of the giant branch at higher luminosities than at lower luminosities. Since the scatter in the present case is more at lower luminosities so this is not due to the variation of reddening, but may be due to the unresolved background stars. Also since there is no such wide spread at all luminosities, as is found in $\omega$ Cen, so NGC 4833 is not like $\omega$ Cen in that respect.

Mean lines drawn through each cluster in figure 1 show that the giants of NGC 4833 are not as metal poor as M92 and not as metal rich as 47 Tuc. This agrees with Frogel, Cohen & Persson (1983), who derived for 47 Tuc [Fe/H] = −0.64, for NGC 4833 [Fe/H] = −1.91 and for M92 [Fe/H] = −2.19. It appears from the figure that NGC 4833 is more metal rich than M13. Recently Pilachowski, Sneden & Wallerstein (1983) has shown that for NGC 4833 [Fe/H] = −1.37 and for M13 [Fe/H] = −1.44.

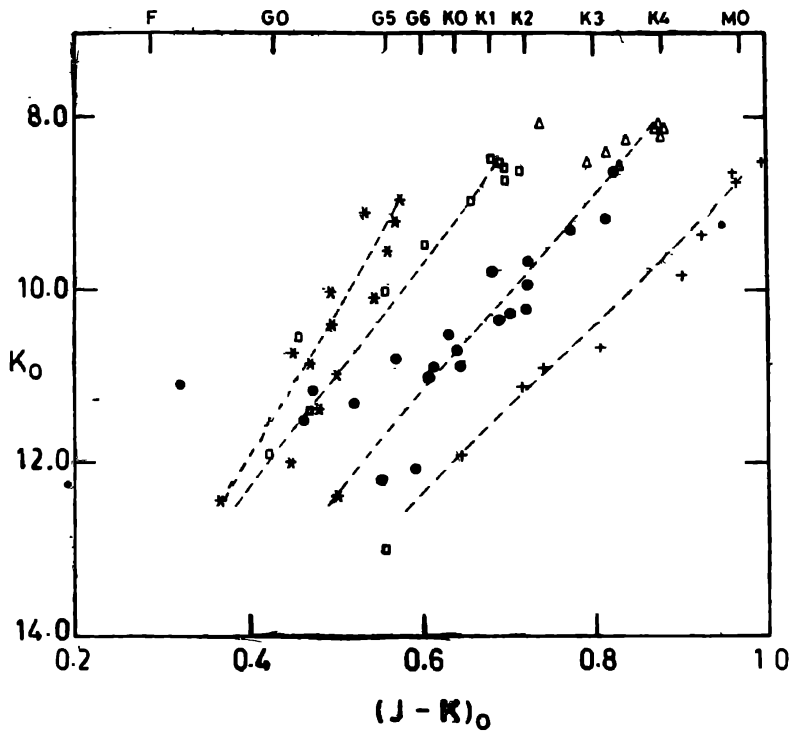


**Figure 1.** Colour-magnitude diagrams $[K_0, (J-K)_0]$ for zone B and zone C redgiants in NGC 4833 (●), M92 (*), 47 Tuc (+), M13 (□) and NGC 4833 (Δ) studied by FPC (1983).

### *3.2. Colour-colour diagram*

The $(J-H)_0$ and $(H-K)_0$ colours of NGC 4833 are plotted in figure 2 along with the mean field giant line (Cohen, Frogel & Persson 1978). The colours of M13 (Cohen, Frogel & Persson 1978) and NGC 4833 (FPC) are also transformed (Elias *et al.* 1983) to the AAO system and plotted in figure 2. The $(H-K)_0$ colour of of a few giants of NGC 4833 appears bluer than the field giants at the same $(J-H)_0$ colour. The giants in M13 (Cohen, Frogel & Persson 1978) have shown a similar scatter.

Frogel, Persson & Cohen (1981) have explained that $H_2O$ molecule formation in the extended atmosphere of the stars strongly modifies their energy distributions. The wing of the 1.9 $\mu$m $H_2O$ band overlaps both the $H$ and $K$ filter bands, when the $H_2O$ absorption is within the $K$ filter bandpass then the $K$ magnitude becomes fainter and $(H-K)$ colour bluer (FPC).

The displacement of the reddest stars from the field giants for $(J-H)_0 \simeq 0.80$ mag is also found in 47 Tuc (Frogel, Persson & Cohen 1981) and $\omega$ Cen (Persson *et al.* 1980). Frogel, Persson & Cohen (1981) again have suggested that the displacement from the field colours is well correlated with the $H_2O$ absorption. It needs further investigation to explain the reason of the scatter.

### *3.3. The* $[M_{bol}, \log T_{eff}]$ *diagram*

The bolometric luminosities ($M_{bol}$) are plotted against the logarithm of effective temperatures ($\log T_{eff}$) for the giants in NGC 4833 along with those of M92 and

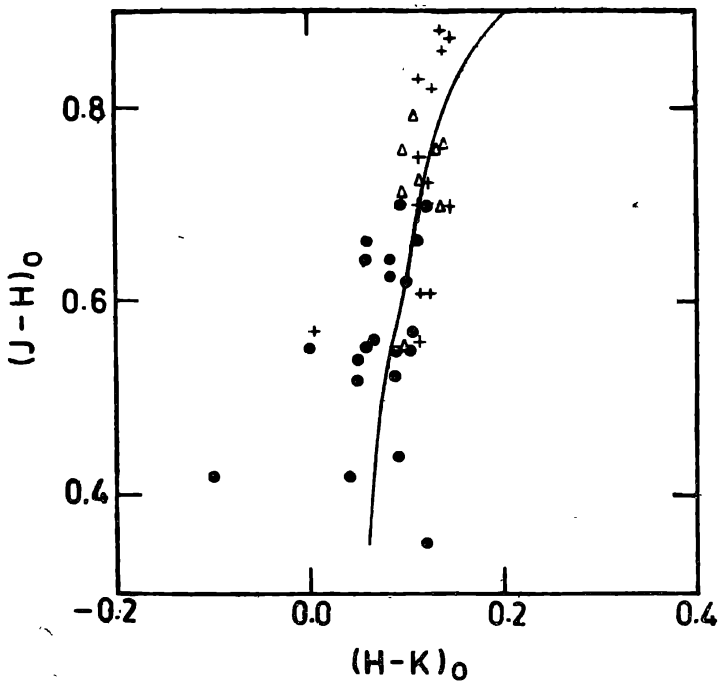


**Figure 2.** Two colour diagram $[(J - H)_0, (H - K)_0]$ for red giants in NGC 4833 (●), NGC 4833 giants (Δ) observed by FPC (1983) and giants in M13 (+) (Cohen, Frogel & Persson 1978). The line shows the mean relationship for field giants.

M13 giants (Cohen, Frogel & Persson 1978). Here also a significant spread is found at lower luminosities. A few stars are hotter than the others.

The $M_{bol}$ and log $T_{eff}$ values of the giants are compared with the theoretical tracks (shifted) obtained by Frogel, Persson & Cohen (1981). The tracks used for $M = 0.7\ M_\odot$ and $Y = 0.30$ model were shifted by $\Delta \log T_{eff} = 0.037$ by Frogel, Persson & Cohen (1981) in order to bring the tracks into agreement with the M92 and M13 giant tracks. It is found that a better agreement is obtained for the [Fe/H] = −1.7 track than for the [Fe/H] = −2.3 track. The metallicity recently found by Zinn & West (1984) is −1.86 and by Pilachowski, Sneden & Wallerstein (1983) is −1.37.

It is also possible to have an idea of the age of the cluster giants by comparing $M_{bol}$ and log $T_{eff}$ values with isochrones. Though this is not good to get the age in this way. Comparing with the Yale isochrones the probable age is $\simeq 12 \times 10^9$ yrs. The age and metallicity thus obtained agree fairly well when compared with the [[Fe/H], age] plot of Demarque (1979).

## 4. Conclusion

JHK photometry of 21 red giants in globular cluster NGC 4833 suggests that they are members of this cluster. JHK colours of these stars imply a metal deficiency of [Fe/H] $\simeq$ −1.7, which is in agreement with the earlier investigations.

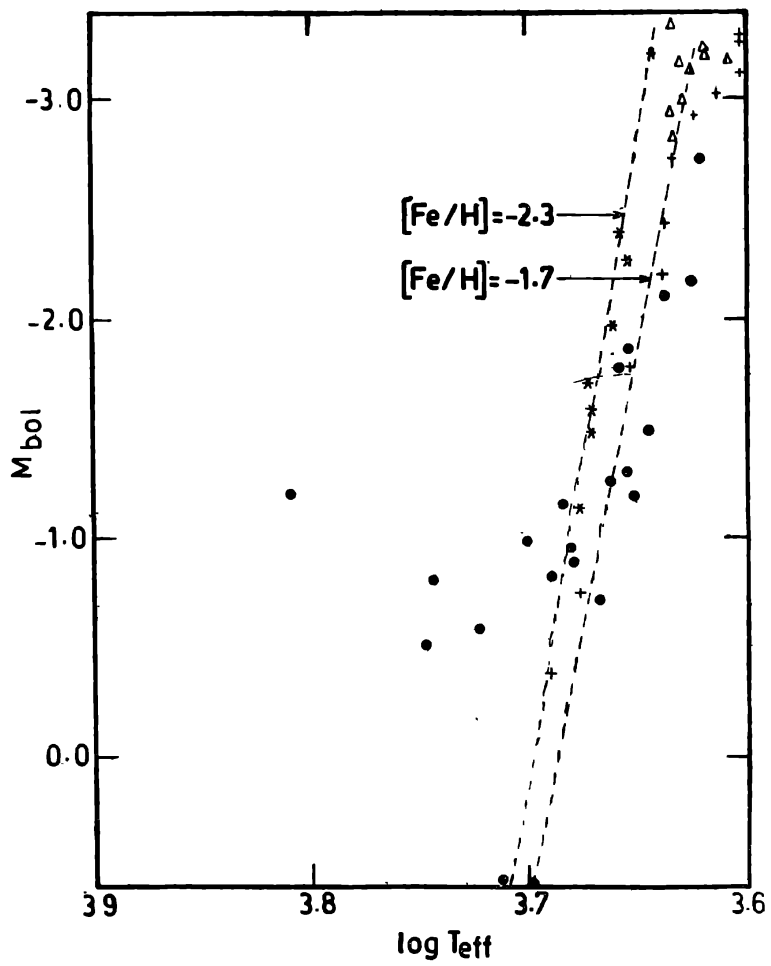


**Figure 3.** [$M_{bol}$ vs log $T_{eff}$] plot for red giants in NGC 4833 (●), giants in M92 (*), M13 (+) and NGC 4833 giants (△) observed by Frogel, Persson & Cohen (1983). The two dashed lines are the theoretical tracks shifted by + 0.037 dex, correspond to [Fe/H] = −2.3 and −1.7 (Frogel, Persson & Cohen 1981).

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