J. Astron. Space Sci. 18(1), 7–14 (2001)

METALLICITY OF GLOBULAR CLUSTER NGC 5053 FROM *VI* CCD PHOTOMETRY

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(Received Feburary 28, 2001; Accepted April 25, 2001)

ABSTRACT

Red giant branch shape and the luminosity of horizontal branch on the $(V-I)-V$ CMD are used to derive the metallicity of the globular cluster NGC 5053. The metallicities of NGC 5053 derived by SMR method ([Fe/H]= -2.62 ± 0.07) and the relation between [Fe/H] and $(V-I)_{o,g}$ ([Fe/H]= -2.50) are in good agreement with previously determined values. This result confirms that the morphologies of RGB and HB on the $(V-I)-V$ CMDs can be good indirect photometric metallicity indicators of galactic globular clusters.

Key words: photometry, globular clusters, metallicity

1. INTRODUCTION

This is the third in a series of papers studying morphologies of red giant branch (RGB) and horizontal branch (HB) on the $(V-I)-V$ color magnitude diagrams (CMDs) and thier use of an indirect photometric metallicity indicator of galactic globular clusters. In the papers of Sohn & Lee (2000, Paper I) and Sohn (2000, Paper II), we derived metallicities, reddenings, and other physical parameters such as the HB magnitudes of M3, M5, and M13 applying Sarajedini (1994)'s simultaneous metallicity and reddening (SMR) method on the $(V-I)-V$ CMDs, and suggested that the morphologies of RGB and HB on the $(V-I)-V$ CMDs can be good indirect photometric metallicity indicators of galactic globular clusters. The SMR method in the $(V-I)-V$ CMD plane use the $(V-I)_o$ value of RGB measured at the level of HB, and the difference in V between the HB and RGB at $(V-I)_o = 1.2$. Note that the calibration of metallicity for the SMR method was based on the Zinn & West (1984)'s scale. Recently, Carretta & Bragaglia (1998) gave new accurate metallicity scale tied to the Carretta & Gratton (1997) abundance scale to employ the SMR method.

In the present paper, we analyze $(V-I)-V$ CMD of the most metal poor galactic globular cluster NGC 5053. Applying the SMR method with the photometric parameters, which are derived on the CMD, we determine the metallicity and reddening $E\ (V-I)$ of NGC 5053. NGC 5053 ($\alpha_{2000} = 13^h 14^m 00^s.2, \delta_{2000} = +17^o 57' 41'', l = 335^o.691, b = 78^o.944$) is of particular interest globular cluster in many cases. It has a low degree of central concentration, $c = \log\ (r_t/r_c) = 0.82$ and $r_c = 2'.25$ (Trager et al. 1993), placing NGC 5053 among the most open of the Galactic globular clusters. With an age $\sim 15-18$Gyr, it is one of the oldest known globular clusters (Sandage

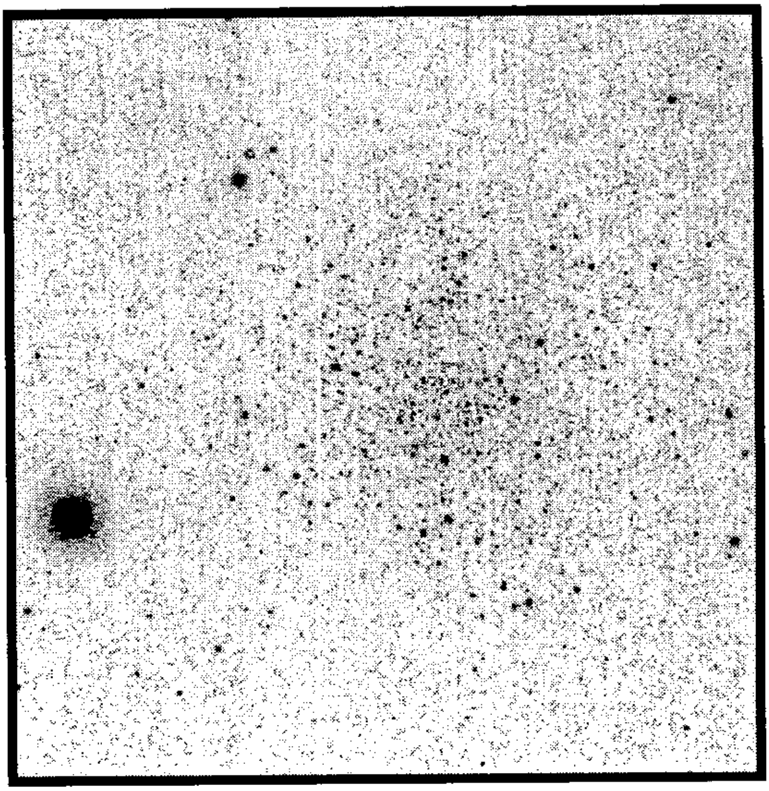

Figure 1. *V* image of NGC 5053.

et al. 1977, Nemec & Cohen 1989, Fahlman et al. 1991, Heasley & Christian 1991). From a dynamical point of view, however, NGC 5053 is young, because the large core radius leads to a long dynamical time scale, i.e., Djorgovski (1993) calculated the central relaxation time to be 7.4×10^9 yrs. NGC 5053 has a very low absolute luminosity, $M_V = -6.1$ (Webbink 1985), with relatively small number of giant stars. NGC 5053 is a remote cluster; its galactocentric distance of $\sim$ 17kpc (Djorgovski 1993), so its properties are of interest for studying galactic halo and early history of the Galaxy formation. A further point of interest is the fact that NGC 5053 is very metal poor. In the Zinn & West (1984) compilation, it is the most metal poor cluster with [Fe/H]= -2.58. Therefore, NGC 5053 offers the opportunity to extend the calibration of indirect photometric metallicity determination from morphologies of RGB and HB on the $(V - I) - V$ CMDs of globular clusters to the most metal poor region.

The observation and data reduction are described in Sec. 2. We show the $(V - I) - V$ CMD of NGC 5053 in Sec. 3, and analyze the morphology of the CMD and determine the photometric parameters such as the mean V magnitude of HB. Also, applying SMR method we determine the metallicity and reddening of NGC 5053 and compare them with the previously determined ones in Sec. 3.

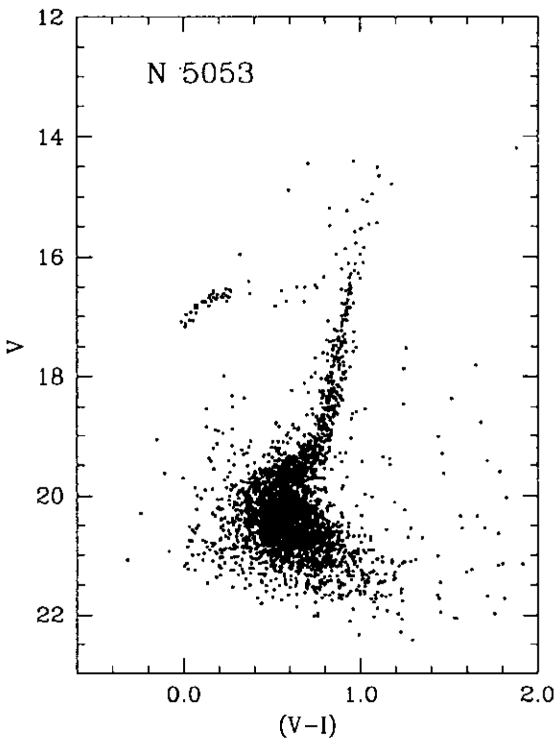

Figure 2. $(V - I) - V$ CMD of stars in NGC 5053.

2. OBSERVATION AND DATA REDUCTION

V and I images of a globular cluster NGC 5053 were obtained over the night in UT 1999 March 23 using the 1.8m telescope at BOAO. A single exposure centered on the cluster center was taken in each V and I filter with the exposure times of 600 and 300 seconds, respectively. The detector was SITe CCD chip of 2048 × 2048 format. At the f/8 Cassegrain focus, the image scale is 0.34 arcsec pixel^{-1}, which gives the sky coverage of 11.8×11.8 arcmin^2. The seeing measured from the reduced images is ~ 1.5 arcsec FWHM. Figure 1 shows the V image of NGC 5053. Observations were also obtained for the number of standard stars on the Landolt (1992).

The data reduction, including bias subtraction and flatfield, followed standard processing lines. Details of the photometric calibrations by observations of standard stars were given in the Paper I. V and I magnitudes of individual stars in NGC 5053 were measured using the PSF-fitting photometry package DAOPHOTII/ALLSTAR (Stetson 1987, Stetson & Harris 1988). The positional transformation solution for the VI pairs of the cluster has been derived by applying the DAOMATCH and DAOMASTER (Stetson 1992) packages. Also, details of the our stellar photometry in a globular cluster could be found in Paper I and Paper II. Finally, a total of 2,863 stars were detected in both V and I images of NGC 5053.

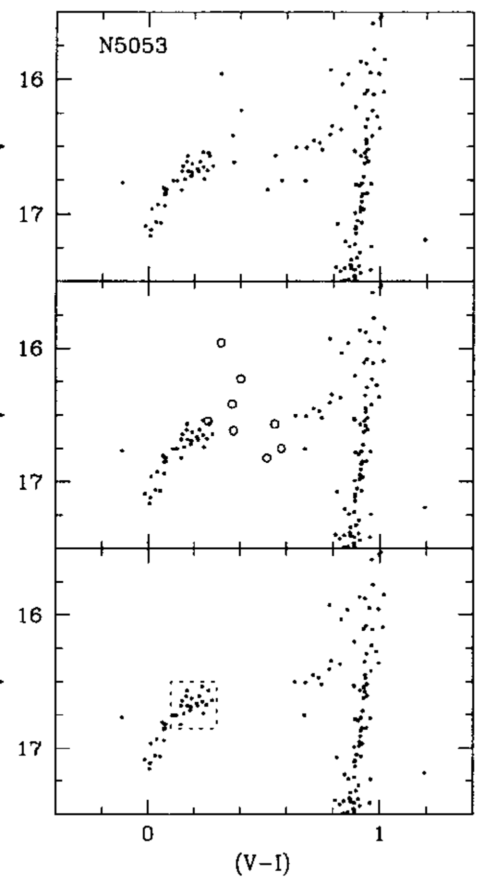

Figure 3. The HB of NGC 5053 showing 8 identified RR Lyraes plotted as open circles. Non-variable stars in the dashed box are used in computing the mean magnitude of HB.

3. COLOR-MAGNITUDE DIAGRAM AND METALLICITY

Figure 2 shows the final $(V-I)-V$ CMD of stars in NGC 5053 field having $\chi \leq 1.5$, which quantifies how well the empirically derived PSF for a frame matched a star's actual profile. Because the central concentration of stars is among the lowest of the globular clusters, it is feasible to make photometric measurements of stars even in the central region of the cluster NGC 5053.

The CMD of NGC 5053 reveals the HB predominantly populated on the blue side of the RR Lyrae instability strip and a relatively steep RGB shape. These are characteristic of a metal poor globular cluster. Blue stragglers are also located above and to the blue of the main sequence turnoff on the CMD (cf. Nemec & Cohen 1989).

Among 10 RR Lyrae variables in NGC 5053 listed in compilation of Sawyer-Hogg (1973), we identified 8 RR Lyrae stars on the NGC 5053 field. Figure 3 shows the HB of NGC 5053 (top) with 8 RR Lyraes plotted as open circles (middle). The magnitude of the HB is estimated by computing the mean V of the non-variable stars in the dashed box on Figure 3 (bottom). This yield V (HB)=

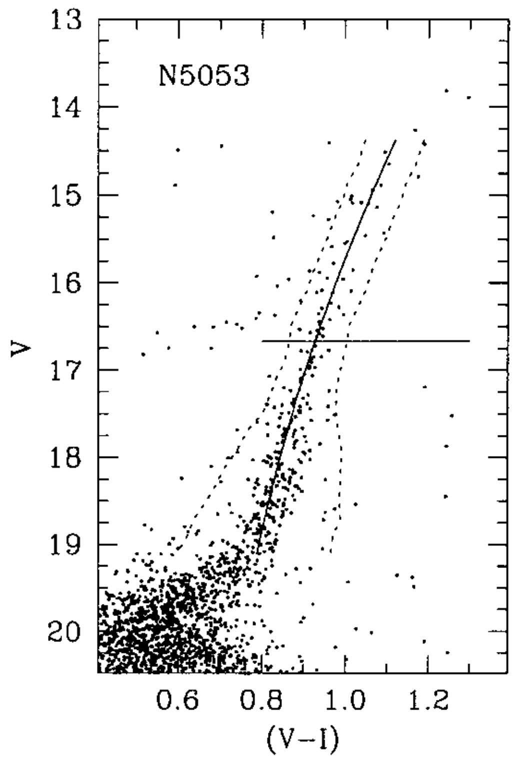

Figure 4. The RGB of NGC 5053 in $(V - I) - V$ CMD. Quadratic fit of RGB shape and the level of HB are plotted as solid lines.

16.67 ± 0.07 for NGC 5053, which is in an excellent agreement with V (HB)= 16.65 ± 0.03 derived by Sarajedini & Milone (1995) and V (HB)= 16.63 derived by Sandage et al. (1977). The quoted error is composed of standard errors of the means and estimated uncertainty in the photometric zero point. Using the HB morphology index of Lee (1990), we found $(B - R)/(B + V + R) = 0.53$, which is similar to the value of 0.51 estimated by Sarajedini & Milone (1995) and close to the value of 0.61 ± 0.18 tabulated by Lee et al. (1994).

RGB shape on the CMD of NGC 5053 has been determined using a quadratic relation of the form $V - I = a_0 + a_1 V + a_2 V^2$. The appropriate coefficients have been derived from fitting the relation on the RGB area plotted as dashed lines in Figure 4. RGB regions were defined from the eye-fitting of RGB fiducial line and its widths on $V - I$ color. The derived values of each coefficient are $a_0 = 3.685076$, $a_1 = -0.259813$, and $a_2 = 0.005665$, and the derived quadratic formulae for RGB stars of NGC 5053 is plotted on Figure 4 as solid line. The horizontal line in Figure 4 indicates the level of V (HB). At V (HB)= 16.67 ± 0.07 of NGC 5053, quadratic fit to the RGB stars give $(V - I)_g = 0.928 \pm 0.005$.

Sarajedini (1994) suggested a technique by which the metal abundance and reddening of a globular cluster can be derived simultaneously using the shape of the RGB and observed value of the HB magnitude [i.e., V (HB)] and the $V - I$ color of the RGB at the level of the HB [i.e., $(V - I)_g$]. Here, we apply this method to derive the metallicity and reddening of NGC 5053. Applying Eq.(1)

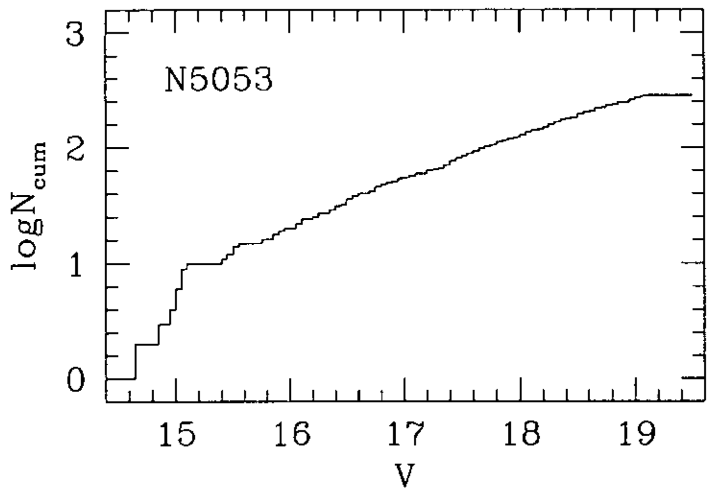

Figure 5. The cumulative luminosity function of RGB stars in NGC 5053. No RGB bump appear.

of Paper I to the Eq.(6) and Eq.(7) of Sarajedini (1994), we estimate the reddening $E\ (V - I)$ and metal abundance [Fe/H] of NGC 5053 simultaneously. As input parameters, we use $\Delta V_{1.2}$, which is the difference in V between the HB and the RGB at $V - I = 1.2$, and $(V - I)_g$ at the level of HB. Consequently, we obtained metal abundances of [Fe/H]= -2.62 ± 0.07. The reddening $E(V - I)$ was estimated as 0.09, which is very close to the value 0.08 estimated by Sarajedini & Milone (1995).

Note that Sarajedini (1994)'s calibration was based on Zinn & West (1984) metallicity scale. We therefore also applied Carretta & Bragaglia (1998)'s new relations, tied to the Carretta & Gratton (1997) abundance scale, to estimate metallicity of NGC 5053. From the relation between [Fe/H] and $\Delta V_{1.2}$, we derived [Fe/H]= -2.94. Also, metallicities are derived to be [Fe/H]= -2.50 from the relation between [Fe/H] and $(V - I)_{o.g}$.

In Paper I and Paper II, we used the RGB bumps of M3, M5, and M13 to estimate the metallicities of the globular clusters. Indeed, Sarajedini & Forrester (1995) derived the relation between metallicity and the RGB bump luminosity, i.e., [Fe/H] = $-1.33 + 1.43\Delta V^{HB}_{Bump}$. Usually, the luminosities of RGB bumps have been estimated on the cumulative luminosity functions of RGB stars of the clusters. Figure 5 presents the cumulative LF for RGB stars in NGC 5053 with a binning size of 0.05 mag. As shown in Figure 5, however, we could not find a clear RGB bump on the cumulative luminosity function of RGB stars in NGC 5053.

Table 1 gives the photometric parameters and metallicities of the NGC 5053 derived by applying the SMR method. Sandage et al. (1977) summarized the pre-determinations of [Fe/H] for stars in NGC 5053, and concluded that [Fe/H]= -2.2. Bell & Gustafsson (1983) derived [Fe/H]= -2.58 from a comparison of synthetic spectra with Searl & Zinn's (1978) spectra of red giants. Suntzeff et al. (1988) derived [Fe/H]= -2.2 from the spectroscopiy of 6 giant stars. Zinn & West (1984) returned [Fe/H]= -2.58 for NGC 5053 in their compilation. The metallicities of NGC 5053 derived in this paper by applying SMR method ([Fe/H]= -2.62 ± 0.07) and the relation between [Fe/H] and $(V - I)_{o.g}$ of Carretta & Bragaglia (1998) ([Fe/H]= -2.50) are in good agreement with previously

Table 1. Photometric parameters and the estimated metallicities of the NGC 5053.

cluster	V (HB)	$(V-I)_g$	$\Delta V_{1.2}$	$E(V-I)$	$[Fe/H]_{S94}$	$[Fe/H]^1_{CB98}$	$[Fe/H]^2_{CB98}$
NGC 5053	16.67	0.928	3.07	0.09	-2.62	-2.94	-2.50
	±0.07	±0.005	±0.07		±0.07		

$[Fe/H]_{S94}$: based on Sarajedini (1994)
$[Fe/H]^1_{CB98}$: based on the relation between [Fe/H] and $\Delta V_{1.2}$ of Carretta & Bragaglia (1998)
$[Fe/H]^2_{CB98}$: based on the relation between [Fe/H] and $(V-I)_{0,g}$ of Carretta & Bragaglia (1998)

determined values. Note, however, the metallicity determined by $\Delta V_{1.2}$ ([Fe/H]$= -2.94$) seems to be much smaller than the metallicities estimated by other methods. This may cause the steep shape of RGB on the CMD of NGC 5053.

With the results of this paper, and Paper I and II, we finally conclude that the morphologies of RGB and HB on the $(V-I)-V$ CMDs can be good indirect photometric metallicity indicators of galactic globular clusters. We emphasize here that a large and homogeneous CCD photometry data based on V and I band is still neccessary to take advantage of it.

ACKNOWLEDGEMENTS: This paper is supported by Creative Research Initiatives of the Korean Ministry of Science and Technology.

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