Metallicities and Reddenings For Young Globular Clusters

Ata Sarajedini[1]

Kitt Peak National Observatory, National Optical Astronomy Observatories[2], Tucson, AZ 85726, Email: ata@noao.edu

Andrew Layden

McMaster University, Hamilton, ON, L8S 4M1, Canada, Email: layden@physics.mcmaster.ca

Abstract. We have obtained VI CCD photometry for the young globular clusters Ruprecht 106, Terzan 7, and Arp 2 using the 0.9m and 1.5m telescopes at Cerro Tololo Inter-American Observatory. The resulting $V \sim (V-I)$ color-magnitude diagrams extend from the tip of the red giant branch to approximately 3 magnitudes below the horizontal branch. We have applied the SRM method of Sarajedini (1994) to the RGBs of these clusters in order to measure their reddenings and metallicities. Furthermore, we have formulated the SRM method in the $V \sim (B-V)$ color-magnitude plane and applied it to published BV photometry for these young globular clusters. The implications of these derived parameters will be discussed.

1. Introduction

Over the past several years, it has become increasingly clear that there are a number of exceptionally young globular clusters located in the Galactic halo. In each case, the derived relative age of each cluster depends sensitively on the adopted metal abundance, and the cluster distance is dependent on the metal abundance and the reddening. Furthermore, the interpretation of the age and abundance of each cluster in the context of the formation and evolution of the Galactic halo is affected by our knowledge of the cluster horizontal branch (HB) morphology. As such, it is vitally important to improve our knowledge of these quantities. With this is mind, we began a program to obtain high-precision CCD photometry in the V and I filters for three of these clusters - Ruprecht 106, Terzan 7, and Arp 2. The latter two clusters are believed to be members of the Sagittarius dwarf spheroidal galaxy (Da Costa & Armandroff 1995). We will apply the simultaneous reddening and metallicity (SRM) method of Sarajedini

---

[1]Hubble Fellow

[2]NOAO is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

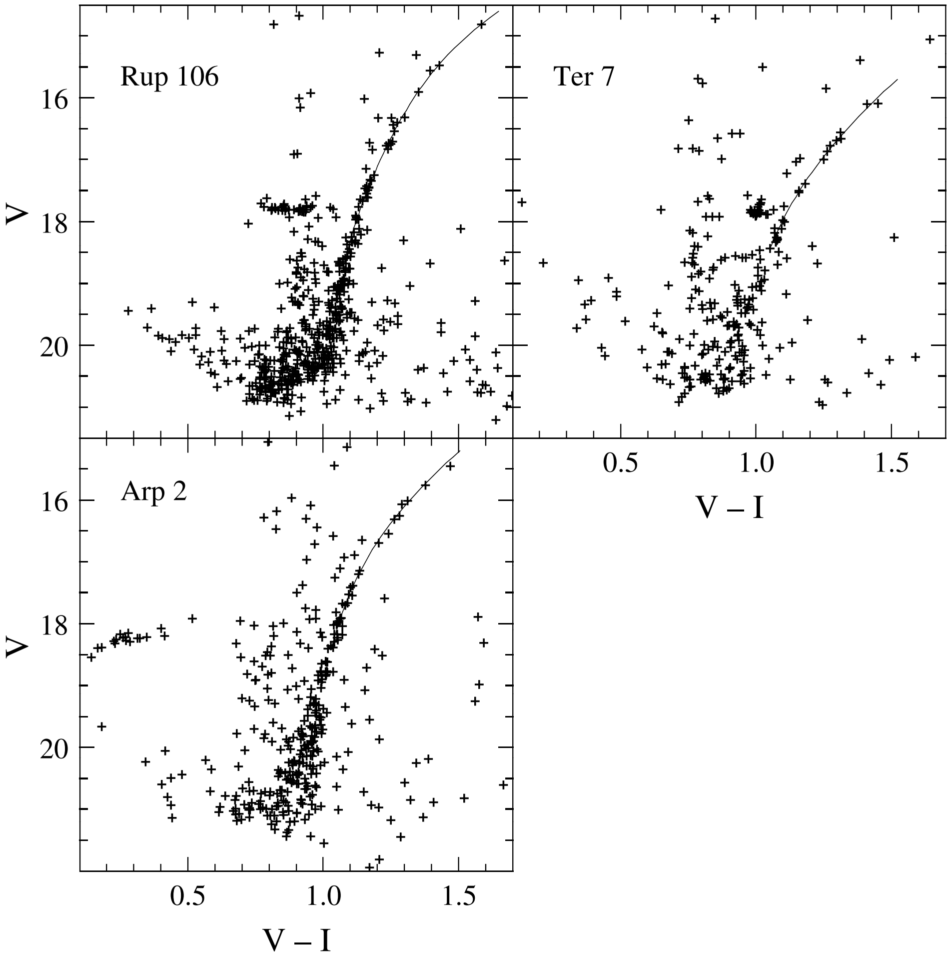

Figure 1. Color-magnitude diagrams for the program clusters. The solid lines show the polynomial fits to the red giant branches (see text).

(1994) to our $V - I$ photometry and formulate the method in $B - V$ so that it can be applied to photometry from the literature.

2. Observations and Reductions

The observations of Rup 106, Ter 7, and Arp 2 were obtained with the 0.9-m and 1.5-m telescopes at Cerro Tololo Inter-American Observatory. Twenty to thirty standard stars from the list of Landolt (1992) were observed on each night over a large range in color and airmass. The Rup 106 observations are based on three photometric nights while the Ter 7 and Arp 2 observations are based on two photometric nights. Each cluster CCD frame was reduced independently with the multiple PSF-fitting photometry package DAOPHOT II (Stetson 1987). The reduction procedure is similar to that used by Sarajedini & Milone (1995).

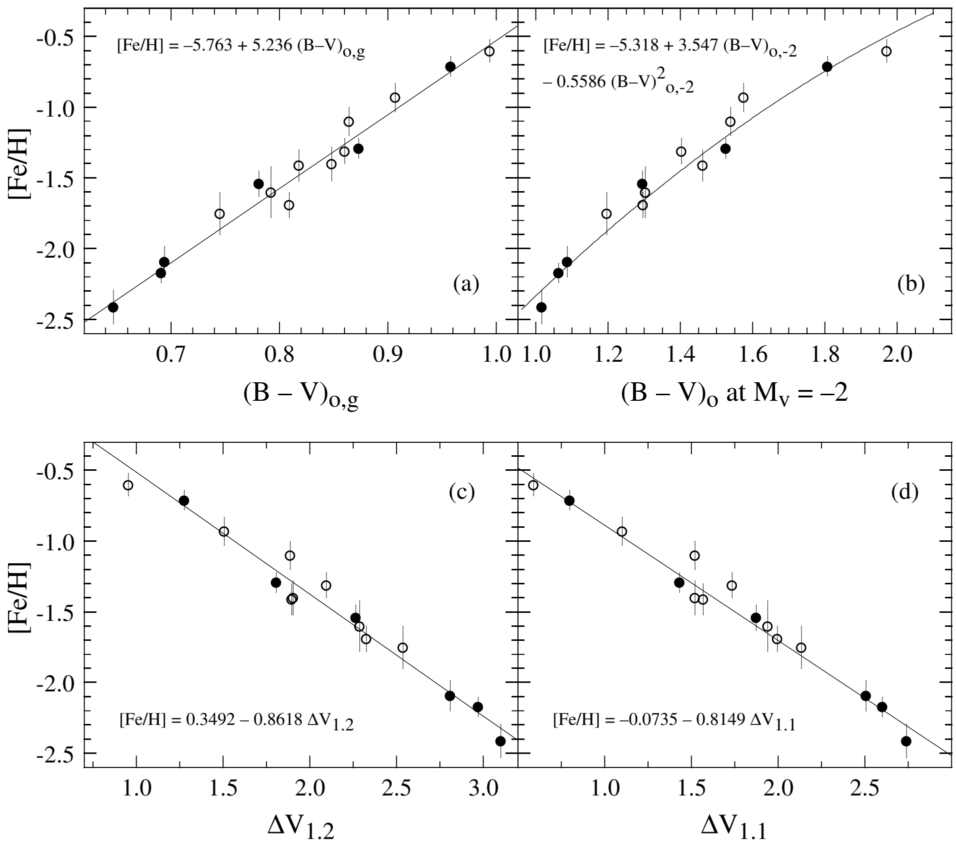

Figure 2. Calibration of the $B-V$ simultaneous reddening and metallicity (SRM) method using CCD photometry taken from the literature. The lines are fitted to the filled circles, which are the primary calibrating clusters - NGC 5053 ($[Fe/H]=-2.41$), M15 (−2.17), M68 (−2.09), NGC 6752 (−1.54), NGC 1851 (−1.29), and 47 Tuc (−0.71). The open circles are the secondary calibrators and are plotted to corroborate the primary fit.

3. Results

Figure 1 shows the CMDs for the program clusters. These include all stars with at least 3 detections, $\sigma_V \leq 0.050$ mag, $\sigma_{V-I} \leq 0.071$ mag, and located inside 2 arcmin of the cluster center. Comparison of our photometry with the most recent studies for each of the program clusters reveals the following offsets in the sense (others − us): $<\Delta V>= 0.003 \pm 0.004$ (Kaluzny et al. 1995) for Rup 106, $<\Delta V>= 0.035 \pm 0.011$ (Buonanno et al. 1995a) in the case of Ter 7, and $<\Delta V>= 0.074 \pm 0.002$ (Buonanno et al. 1995b) for Arp 2. All of these data are in $B-V$.

Using the Welch & Stetson (1993) variability index, we have identified 5 RR Lyrae variables in Arp 2. Their mean magnitude is $<V>= 18.15 \pm 0.048$. Along with 24 stars located blueward of the RR Lyrae instability strip and the assumption that no stars are located redward of the strip, we find $(B-R)/(B+V+R) = 0.83$ for Arp 2.

The solid lines in Fig. 1 are polynomial fits to the red giant branches performed using the $2-\sigma$ rejection algorithm described in Sarajedini & Norris (1994). These are used along with the V mag of the HB and the color of the red giant branch (RGB) at the level of the HB as inputs into the SRM method. Furthermore, we have formulated the SRM method in $B-V$ (see Fig. 2) and applied it to photometry of these clusters from the literature sources cited above. The primary calibrators plotted in Fig. 2 are also used in the calibration of the $V-I$ SRM method (see Sarajedini & Milone 1995). The SRM method uses the fits in (a), (c), and (d). The fit shown in (b) can be used to find the metallicity in cases where the HB is beyond the limit of the photometry.

We find general agreement in the derived $[Fe/H]$ and $E(B-V)$ between these two formulations. The mean metallicities and reddenings are $[Fe/H] = -1.89 \pm 0.10, E(B-V) = 0.18 \pm 0.02$ for Rup 106, $[Fe/H] = -0.82 \pm 0.15, E(B-V) = 0.07 \pm 0.03$ for Ter 7, and $[Fe/H] = -1.91 \pm 0.06, E(B-V) = 0.11 \pm 0.02$ for Arp 2. These [Fe/H] values are between ≈0.2 to ≈0.4 dex more metal-poor as compared with the Calcium triplet metallicity determinations for these clusters (Da Costa et al. 1992; Suntzeff et al. 1995; Da Costa & Armandroff 1995). This is also true of the young globular cluster Pal 12 (Da Costa & Armandroff 1990; Sarajedini 1994). This difference is of the same order as the errors in the abundances, but it is unlikely that random errors could cause all four clusters to behave in the same manner. One might speculate that this discrepancy in the abundances of these young clusters may be due to a difference in their chemical enrichment history within the 'Searle-Zinn' fragment or fragments in which they formed.

Acknowledgments. We are grateful to R. Phelps for obtaining some of the observations used in this study.

References

Buonanno, R. et al. 1995a, AJ, 109, 663

Buonanno, R. et al. 1995b, AJ, 109, 650

Da Costa, G. & Armandroff, T. 1990, AJ, 100, 162

Da Costa, G. & Armandroff, T. 1995, AJ, 109, 2533

Da Costa, G. Armandroff, T., & Norris, J. E. 1992, AJ, 104, 154

Kaluzny, J., Krzeminski, W., & Mazur, B. 1995, AJ, in press

Landolt, A. U. 1992, AJ, 104, 340

Sarajedini, A. 1994, AJ, 107, 618

Sarajedini, A. & Milone, A. A. E. 1995, AJ, 109, 269

Sarajedini, A. & Norris, J. E. 1994, ApJS, 93, 161

Stetson, P. B. 1987, PASP, 99, 191

Suntzeff, N. et al. 1995, in preparation

Welch, D. & Stetson, P. B. 1993, AJ, 105, 1813