J. Astron. Space Sci. 15(1), 39–48 (1998)

ON THE VARIABILITY OF BLUE STRAGGLER STARS IN THE GLOBULAR CLUSTER M53

Soo-Chang Rey, Young-Wook Lee, and Yong-Ik Byun
Center for Space Astrophysics & Department of Astronomy,
Yonsei University, Shinchon 134, Seoul 120-749, Korea
e-mail: screy@csa.yonsei.ac.kr, ywlee@csa.yonsei.ac.kr, byun@csa.yonsei.ac.kr

Mun-Suk Chun
Department of Astronomy, Yonsei University, Shinchon 134, Seoul 120-749, Korea
e-mail: mschun@galaxy.yonsei.ac.kr

(Received May 9, 1998; Accepted May 25, 1998)

ABSTRACT

We present the results of a search for photometric variable blue straggler stars (BSSs) in the globular cluster M53. Six of the 151 probable BSSs are identified as variable candidates based on the robust variable star detection technique of Welch & Stetson (1993). Most variable BSS candidates appear to occupy the instability strip in the color-magnitude diagram, and they appear to have visual light amplitudes of 0.2 mag - 0.3 mag. Further observations are required, however, to resolve the nature of variability between pulsating stars and eclipsing binaries for these variable BSS candidates.

1. INTRODUCTION

Searches for photomertic variability among globular cluster stars have led to the conclusion that a significant fraction of blue straggler stars (BSSs) are variable (Mateo 1993). Some of these are eclipsing contact binaries such as W UMa type while others have light curve characteristics of SX Phe stars in the instability strip (Nemec *et al.* 1995, Sarajedini 1996 and references therein). The variable nature of BSSs provides valuable clues towards understanding their nature and origin, and important information about stellar evolution in globular clusters and the link between stellar evolution and stellar dynamics (Nemec *et al.* 1995). Especially, considering the observational evidence for the existence of binaries among BSSs in low-central-density clusters, primordial binary mergers is considered to be, most likely, the origin for some BSSs (it cf. Nemec & Mateo 1990, Mateo *et al.* 1990, Stryker 1993, Mateo 1996). In denser systems, stellar collisions may also play a role (Bailyn & Pinnsoneault 1995 and references therein)

In their recent observations, Rey *et al.* (1998) found 114 new BSSs in the field of M53 and showed that the bright ($V < 19.39$) BSSs have bimodal radial distribution. In this paper, we have investigated whether there are evidences of light variation among these BSSs based on the powerful variable star detection technique of Welch & Stetson (1993).

2. OBSERVATIONS AND DATA REDUCTION

The observations were carried out on the nights of 1995 March 30/31 and March 31/April 1 at Mauna Kea using the University of Hawaii 2.2 m telescope with the $f/10$ secondary and the Tektronix 2048 × 2048 pixel CCD. Ten to 11 frames were taken in the B and V passbands, respectively. All of the light outputs of BSSs were obtained using the point-spread-function (PSF) fitting packages of DAOPHOT II and ALLSTAR (Stetson 1987, 1992a), as well as DAOMATCH/DAOMASTER routines (Stetson 1992b). For each frame, the magnitude offsets with respect to the master frames in B and V were calculated, and photometry for all 10 or 11 frames was shifted to common instrumental zero points. Finally, robust, intensity-weighted mean magnitudes and rms scatters of magnitudes were obtained for all stars. The reader is referred to Rey *et al.* (1998) for the observation log of the program fields and full description of our reduction procedures.

3. VARIABLE BLUE STRAGGLER STAR CANDIDATES

To search for variable BSS candidates, we investigated variability index returned by DAOMASTER for 151 stars in the BSS region, in addition to the magnitude variation from frame-to-frame reported in Rey *et al.* (1998). Variability index of each bandpass is defined to be the ratio of the magnitude scatter observed to that expected from the individual standard errors (*i.e.*, external standard error of one measurement based on frame-to-frame repeatability to internal error of the mean magnitude). Figure 1 shows variability index (I_B, I_V) of B and V bandpasses as a function of the mean magnitude. An arbitrary threshold of variability is selected at $I_B = 5.0$ and $I_V = 3.5$, respectively. We found six variable BSS candidates (closed circles) with relatively higher variablity index than that of threshold in both bandpasses, while some stars show higher index at only one bandpass.

Another variability index (I_{WS}) devised by Welch & Stetson (1993) was used to distinguish, more clearly, between intrinsically variable BSSs and stars with spuriously large variances, which show uncorrelated light variation in different bandpasses, caused by photometric errors such as single poor measurements, cosmic ray events, and/or crowding effect. The technique looks for correlated brightness changes simultaneously in two colors, and is strongly discriminant against "bad" data points. For the n epochs of photometry in two bandpasses (b and v), the variability index of Welch & Stetson (1993) is defined to be

$$I_{WS} = \sqrt{1/n(n-1)} \sum_{i=1}^{n} (\delta b_i \delta v_i), \qquad (1)$$

where δb_i and δv_i denote normalized magnitude residuals for each bandpass. For pulsating variables the residuals δb_i and δv_i will be correlated, since an increase in surface temperature or radius will result in an increase in brightness in both the b and v bandpasses. Therefore, large positive variability index implies true variability. This search method makes no assumptions as to the shape of the light curve, and requires only varibility, rather than periodicity (Rubenstein & Bailyn 1996). Figure 2

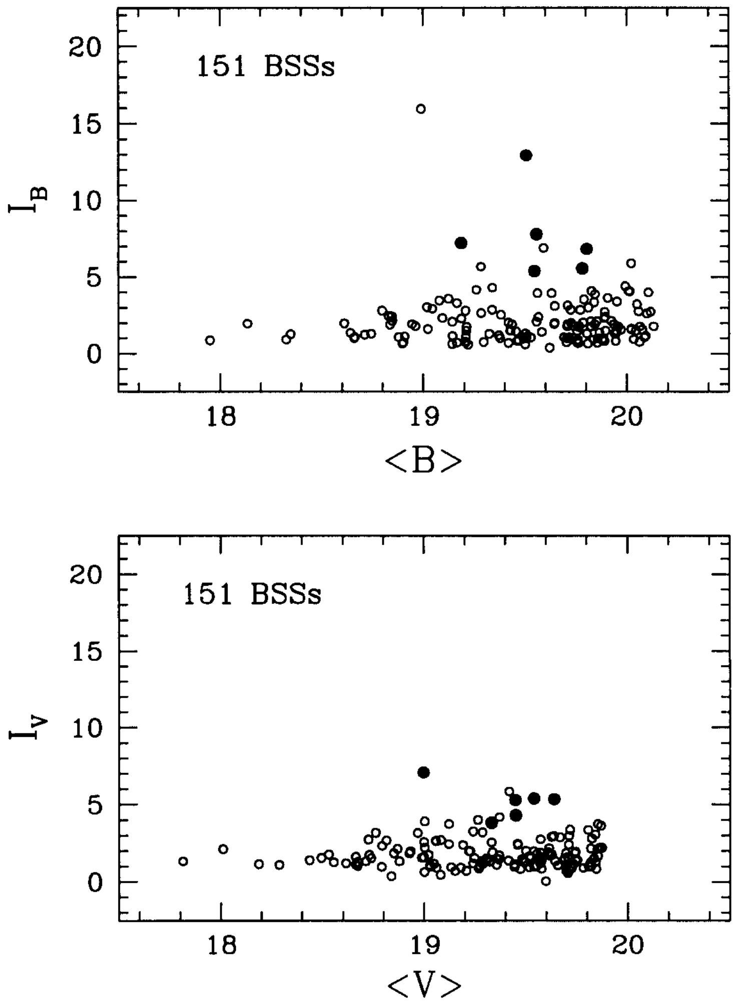


Figure. 1. The variability index (I_B, I_V), returned by DAOMASTER (Stetson 1992b), of B and V bandpass as a function of the mean magnitude. Six variable BSS candidates (closed circles), which have higher variablity index for both bandpasses, were selected.

Table 1. Variable blue straggler star candidates.

Star	x(pix)	y(pix)	r(′)	V	$B-V$	I_{WS}	I_B	I_V
BSS-V1	-138.1	-96.2	0.6	19.00	0.19	17.05	7.21	7.09
BSS-V2*	1520.5	936.6	6.5	19.33	0.22	30.87	5.38	3.82
BSS-V3	892.0	121.8	3.3	19.45	0.06	38.77	12.93	5.29
BSS-V4	-456.7	-38.9	1.7	19.45	0.11	17.06	7.78	4.31
BSS-V5	605.7	415.1	2.7	19.54	0.26	53.44	6.82	5.39
BSS-V6	-457.4	-888.3	3.7	19.64	0.14	19.86	5.55	5.35

* No.56 of blue straggler stars listed by Rey *et al.* (1998)

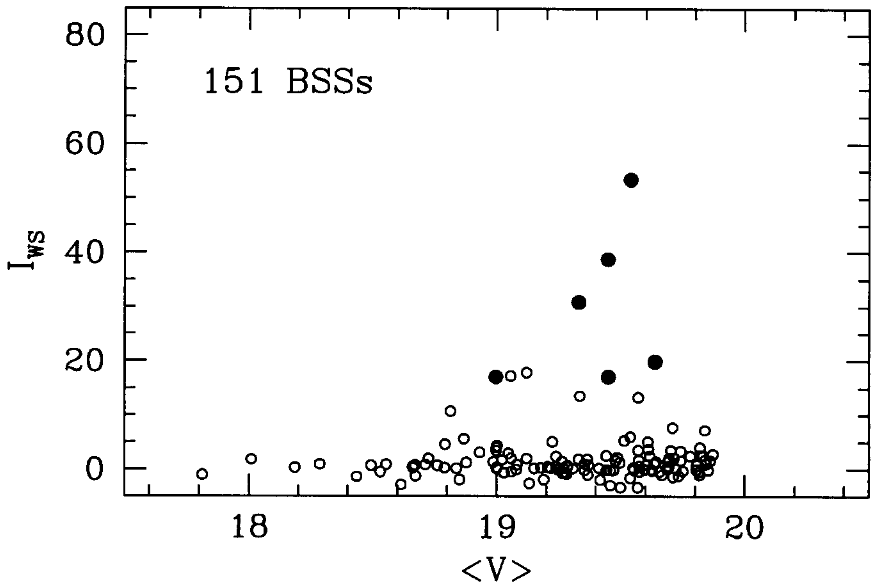
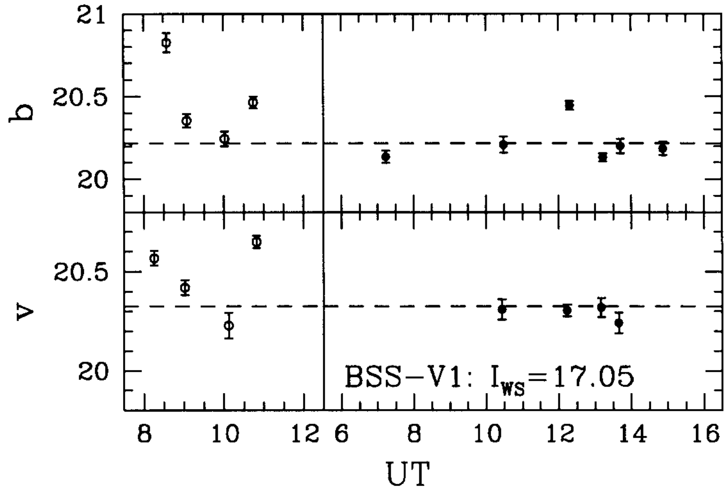


Figure 2. The variability index, I_{WS}, of Welch & Stetson (1993) as a function of the mean V magnitude for all BSSs. Six variable BSS candidates (closed circles) are, clearly, discriminated from other BSSs with relatively low I_{WS} (see text).

contains variability index, I_{WS}, as a function of the mean V magnitude for all BSSs. Six variable BSS candidates (closed circles) are, clearly, discriminated from other BSSs. Table 1 lists six variable BSS candidates in M53.

Figure 3 shows individual light curves for six variable BSS candidates in instrumental b and v magnitudes, which were shifted to common zero points. The open and closed circles represent data of different two successive nights. The horizontal line marks the derived intensity weighted mean magnitude of the star, and error bars shown are photometric errors returned by ALLSTAR. Their light curves indicate that all of them are likely to be photometric variables since the variability appear to be periodic, while more observations will be needed for the clarifying the accurate variability. Figure 4 shows light curve for the control sample of one reference star, which is nonvariable BSS.



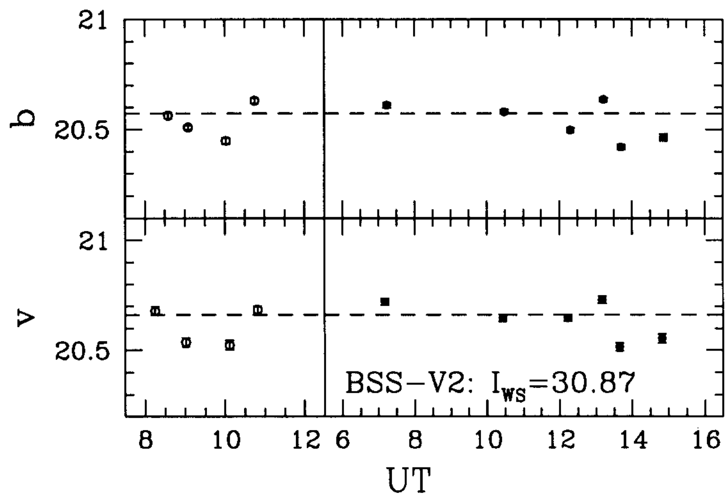


Figure 3. Individual light curves for six variable BSS candidates in instrumental b and v magnitudes. The open and closed circles represent data of different two successive nights. The horizontal line marks the derived intensity weighted mean magnitude, and error bars indicate photometric errors returned by ALLSTAR.

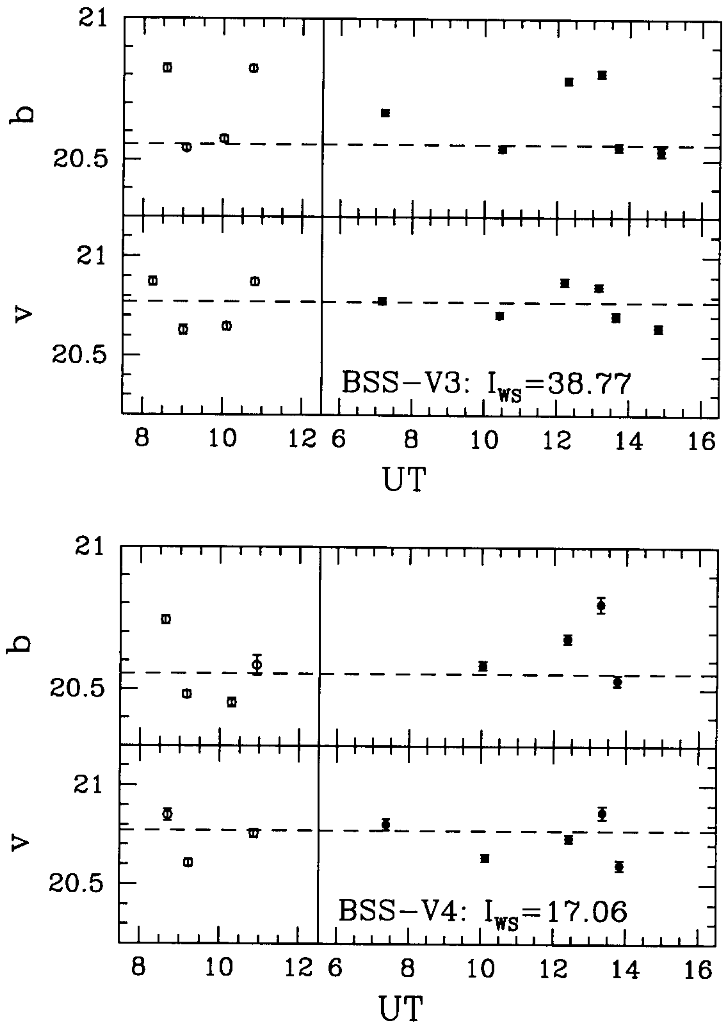


Figure 3. (continued)

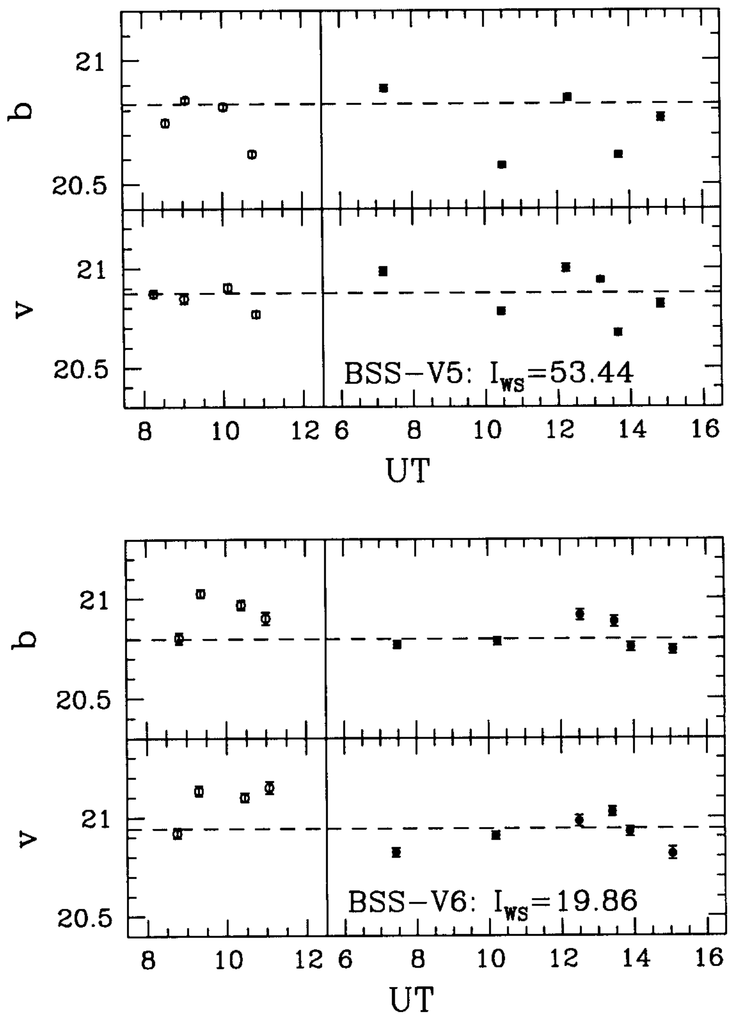


Figure 3. (continued)

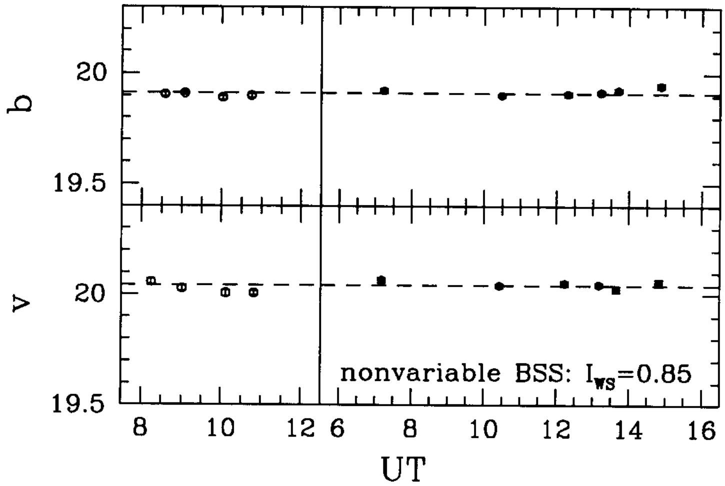


Figure. 4. The light curve for the control sample of one reference star, which is nonvariable BSS.

The 22 well-studied SX Phe stars show period and visual amplitude ranges of 0.03 d - 0.08 d and 0.1 mag - 0.9 mag, respectively (Nemec *et al.* 1995 and references therein). Six variable BSS candidates of M53 appear to have longer periods (0.08 d - 0.13 d), however, short periods similar to those of SX Phe stars can not be ruled out from the present data. If our variable BSS candidates can be considered as SX Phe stars, with amplitudes ranging from 0.2 mag to 0.3 mag, they would be among the intermediate amplitude SX Phe stars that are currently known. In comparison, the eclipsing binary BSSs discovered in the globular cluster NGC 5466 by Mateo *et al.* (1990) have light curve amplitudes of 0.3 mag - 0.4 mag in V, which is also compatible with those of six variable BSS candidates found in this study. If they are eclipsing binaries, however, periods of these stars (0.16 d - 0.26 d) would represent the lower boundary of the period range among binary BSSs found in globular clusters or, be out of the period range of contact binaries (Mateo 1996 and references therein).

The location of BSSs in the color-magnitude diagram of M53 are shown in Figure 5, along with six variable BSS candidates (closed circles) and 27 RR Lyrae stars (closed triangles). Schematic blue and red edges for the cepheid instability strip (long dashed lines), which was estimated from the observed mean magnitudes and colors of the SX Phe stars in NGC 5053, are also shown (Nemec *et al.* 1995, see also Figure 1 of Mateo 1993). It is remarkable that most variable BSS candidates appear to occupy the instability strip and the low lumninosity region of BSS. This is consistent with the result of Nemec *et al.* (1995), who found in NGC 5053, that no BSSs brighter than their five SX Phe stars shows any sign of variability (see their Figure 5). Future observations of BSS, especially with large ground-based telescopes at the site with superb seeing condition, will undoubtedly help to resolve the nature of variability of BSS.

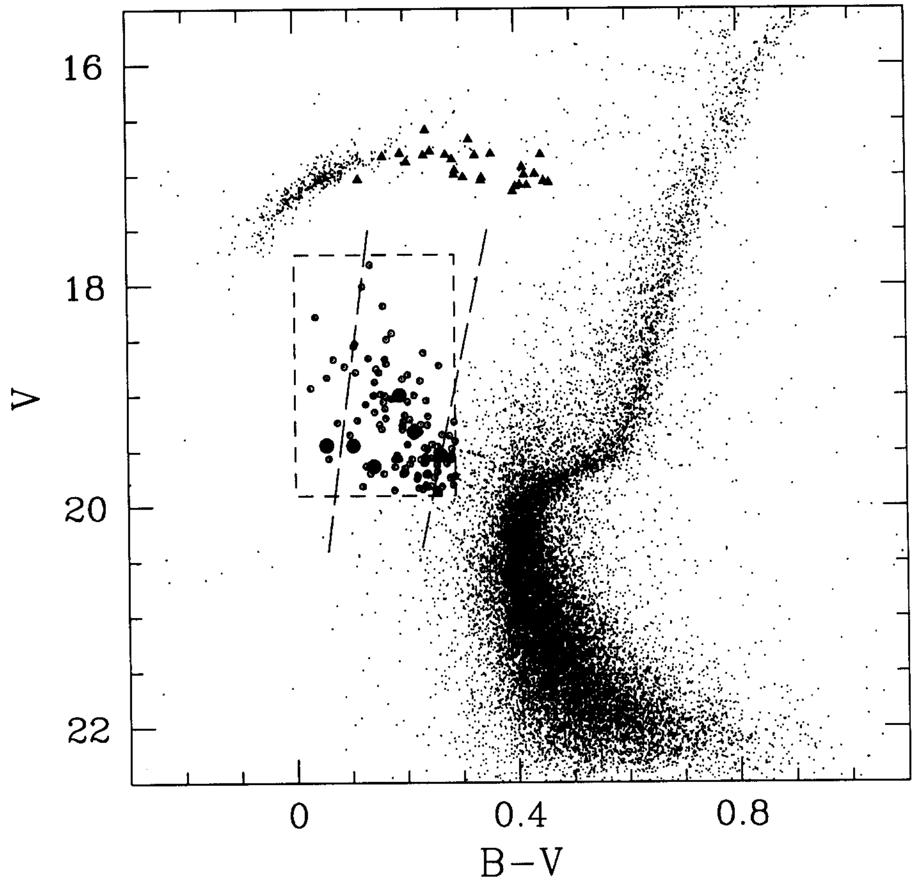


Figure 5. Color-magnitude diagram for M53, formed from the V and $B - V$ photometry of Rey *et al.* (1998). The BSS region is outlined by the box and the six variable BSS candidates (closed circles) and 27 RR Lyrae stars (closed triangles) are shown. Schematic blue and red edges for the cepheid instability strip (long dashed lines) for NGC 5053 are also shown (Nemec *et al.* 1995).

ACKNOWLEDGEMENTS: Support for this work was provided by the Creative Research Initiatives Program of the Korean Ministry of Science & Technology, and in part by the Korean Science & Engineering Foundation through grant 95-0702-01-01-3.

REFERENCES

Bailyn, C. D. & Pinnsoneault, M. 1995, ApJ, 347, 705

Mateo, M. 1993, in ASP Conference Series vol.53, Blue Stragglers, ed. R. Saffer (Astronomical Society of Pacific: San Francisco), p.74

Mateo, M. 1996, in ASP Conference Series vol.90, The Origins, Evolution, and Destinies of Binary Stars in Clusters, ed. E. F. Milone & J.-C. Mermilliod (Astronomical Society of Pacific: San Francisco), p.346

Mateo, M., Harris, H. C., Nemec, J. M. & Olszewski, E. W. 1990, AJ, 100, 469

Nemec, J. M. & Mateo, M. 1990, in ASP Conference Series vol.11, Confrontation Between Stellar Pulsation and Evolution, ed. C. Cacciari & G. Clementini (Astronomical Society of Pacific: San Francisco), p.64

Nemec, J. M., Mateo, M., Burke, M. & Olszewski, E. W. 1995, AJ, 110, 1186

Rey, S.-C., Lee, Y.-W., Byun, Y.-I. & Chun, M.-S. 1998, AJ submitted

Rubenstein, E. P. & Bailyn, C. D. 1996, AJ, 111, 260

Sarajedini, A. 1996, preprint

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

Stetson, P. B. 1992a, in ASP Conference Series vol.25, Astronomical Data Analysis Software and Systems I, ed. D. M. Worrall, C. Biemesderfer, & J. Barnes (Astronomical Society of Pacific: San Francisco), p.297

Stetson, P. B. 1992b, in IAU Colloquium 136, Stellar Photometry-Current Techniques and Future Developments, ed. C. J. Butler & I. Elliot (Cambridge University Press: Cambridge), p.291

Stryker, L. L. 1993, PASP, 105, 1081

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